A Fresh Perspective for Marine Fisheries: Ecosystem Based Fisheries Management in the Laurentian Great Lakes

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Abstract

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Abstract: Both freshwater and saltwater fisheries are complex socio-ecological systems that are integral to the lives of those who live in them. However, there is little effort or attention being paid to the differences and similarities between the management of freshwater and saltwater fisheries. If there are similarities between the systems as a whole then how do the management regimes between freshwater and saltwater fisheries compare? Ecosystem Based Fisheries Management (EBFM) is one form of management that we can use to gain insight into the progress of fisheries management in freshwater systems in comparison to management in saltwater systems. Because the Great Lakes management bodies have been considering and working with an EBFM style of management for longer than saltwater institutions they can provide insight in developing the EBFM approach being taken by federal fisheries. Likewise federal fisheries can advance the Great Lakes management bodies in terms of habitat protection and stock status assessments and management.

Table of Contents

Keywords: Ecosystem Based Fishery Management, EBFM, Great Lakes, Sustainable, Fisheries, Ecosystems, Federal Fisheries

1. Introduction:

Globally, there has been a growing call for a more extensive form of fisheries management called ecosystem-based fisheries management (EBFM) (Garcia et al. 2003, Marasco et al. 2007). This form of management looks at fisheries as having multiple components including the ecosystem with both its biotic and abiotic factors, the interaction between fisheries, as well as socio-economic aspects (Garcia et al. 2003, Layzer 2008, Pikitch et al. 2004). To answer this call, fishery management in a number of countries is responding (Patrick and Link 2015, Worm et al. 2009). The U.S is one, among several countries, in which EBFM is expanding and becoming more widely used (Ecosystem Sciences and Management Working Group 2014). The National Marine Fisheries Service (NMFS) along with the Regional Fishery Management Councils (RFMCs), the regional governance bodies established by the Magnuson-Stevens Fishery Conservation and Management Act, in charge of managing the U.S federal marine fisheries have recognized the importance broadening their management approach to include aspects of EBFM within their policy (Ecosystem Sciences and Management Working Group 2014, National Marine Fisheries Service 2015).

While marine fisheries have dominated the EBFM discourse, freshwater systems and their managers have also embraced this approach. In the U.S the size and commercial and recreational value of the Great Lakes makes them of particular interest. Indeed the Great Lakes are considered by the U.S government to be equivalent to an inland "sea". This can be seen in the lakes being treated similarly in national policy documents such as the Coastal Zone Management Act as well as in the National Ocean Policy Implementation Plan(National Ocean Council 2013; United States Congress 1972). Additionally, during the establishment of the regional fishery management councils in the mid- 1970's there was consideration to implement a fishery council in the Great Lakes (Taylor, Lynch, and Leonard 2012). However, the major actors in the Great Lakes region came together to develop A Joint Strategic Plan for Management of Great Lakes Fisheries (Taylor, Lynch, and Leonard 2012). This management plan filled in the gaps of the previous management regime and in theory eliminated the need for a formal federal council (Taylor, Lynch, and Leonard 2012). As such the Great Lakes region offers a

comprehensive case study of natural resource management working with an ecosystem approach (Taylor, Lynch, and Leonard 2012).

This is not to say though that saltwater and freshwater fisheries are exactly the same. Federal fisheries occur miles off the coast in a different physical ecosystem in size and chemical composition. While the same laws of physics and chemistry govern both systems, there are differences in the composition and makeup of the relationships that play roles in each. In particular, nutrient flow in the ocean is driven primarily by currents but within the Great Lakes because of temperature changes and lake freezing events turnover also provides an important source of nutrient movement(Dodds and Whiles 2010, Garrison 2012). Additionally, freshwater systems even as large as the Great Lakes are still affected more by the input of rivers and changes to the terrestrial ecosystem than saltwater ecosystems that occur miles off the coast. There is also a significant difference in the complexity and level of biodiversity between the systems with saltwater fisheries boasting a more diverse foodweb than those of the Great Lakes. Overall the Great Lakes can be seen as a more enclosed ecosystem that can be impacted more readily from changes including, seasonality, pollution, and other human activities than federal fisheries in oceanic waters.

Even with some differences in the physical and chemical aspects of the two systems there are many analogous parts between freshwater and saltwater. In both, fisheries represent a complex socio-ecological system that requires management actions to optimize the utilization of the resources (Ostrom 2009). Both federal fisheries and Great Lakes fisheries are composed of a diversity of actors ranging from states, to tribal nations, to multiple countries being involved in the management process. The Great Lakes for example, are surrounded by eight states, one province, and are co-managed between U.S, Canadian and Tribal authorities matching the complexity of actors involved in federal fisheries, eg. U.S., Canada, Mexico, Cuba, Russia plus Tribes and multiple State governments. See Table 1 for a comparison of the Social Ecological Systems of the Great Lakes and Federal Fisheries.

Little comparison has occurred between the management policy and actions used by the federal fishery managers and the Great Lakes region fishery managers and with the number of similarities and shared goals of the different sectors there is an opportunity to

obtain perspective and lessons for fisheries management. The question is how do freshwater and saltwater EBFM compare?

Table 1. Comparison of Social Ecological Systems of federal fisheries and Great Lakes fisheries.

Comparison of Social Ecological Systems	Federal Fisheries	Great Lakes Fisheries
Governance		
Guiding Document	Fisheries Conservation and Management Act	A Joint Strategic Plan for the Management of Great Lakes Fisheries
Guiding Document can be revised and reviewed	Yes	Yes
Overarching Body of Governance	NOAA Fisheries/National Marine Fisheries Service	Great Lakes Fishery Commission
Management Split into Regions, # of Regions	Yes, eight regions	Yes, five Great Lakes
Regional Management Bodies	Regional Fishery Management Councils	Lake Committees
Scientific Inputs	Science and Statistical Committee (Peer Review) Plan Development Teams	Lake Technical Committee
Additional subcommittees capable of being formed to guide and inform management?	Yes, Advisory Panels	Yes, Task Groups/Subcommittees
Enforcement	NOAA Law Enforcement	Department of Natural Resources for States
Social Components		
Recreational Fisheries Present	Yes	Yes
Commercial Fisheries Present	Yes	Yes
International Boarders	In some regions	Yes
Multiple States Involved	Yes, ranges from 1-7	Yes, 8 states
Tribal Involvement in Management	In some regions	Yes
Ecological Components		
Ecosystem Size	Unbounded, Ecosystems generally occur on ranges larger than overall	Bounded by terrestrial components, entirety of system within jurisdiction

	management jurisdictions	of management
Terrestrial Input Significance	Limited	Significant
Important factors in nutrient cycling	Upwelling Currents	Seasonal Turnover Currents
Seasonality	Intermediate Effects of Seasonality	Large Seasonality Effects
Number of Species involved in Fisheries	>200	<200
Foodwebs	More complex due to larger number of species and size of ecosystem	Less complex due to limited number of species in the lakes

1.1 Approach:

This thesis approaches this question of comparing fresh and saltwater fisheries management through the lens of a common framework to assess the RFMC's progress in implementing EBFM and the Great Lakes Fishery Commission's progress in EBFM as well. To do this EBFM will be defined and then the framework used for comparison of these two systems will be outlined. The results showing the status of EBFM in federal fisheries and the Great Lakes are presented. Finally, the strengths and shortcomings of each system will be identified and recommendations will be made in order to inform management.

1.2 Ecosystem Based Fisheries Management

Ecosystem-based management (EBM) is a framework, which entails a natural resource being a component of an overall larger matrix, creating a complex ecosystem(Layzer 2008, Patrick and Link 2015). This means that when managing a fishery it should be looked at for its full range of interactions in the ecosystem and at all of the impacts that may possibly occur from within or from outside of the ecosystem(Layzer 2008). NOAA defines EBM as "an integrated and multi-sectored approach to protecting and sustaining diverse and productive marine ecosystems and the services they provide"(National Marine Fisheries Service 2015). This definition is adopted for the purposes of this thesis.

EBM has become a prevalent topic in fisheries management around the U.S. Congress requested a report from NMFS to provide a report on the use of ecosystem principles in U.S Fisheries Management in its reauthorization of the Sustainable Fisheries act (United States Congress 1996). These principles and policies for implementing then were proposed in the Ecosystem Principles Advisory Panel's (EPAP) report to congress (Ecosystem Principles Advisory Panel 1999). When applied to fisheries directly EBM takes on the form and name of EBFM. It is seen as additional actions to take beyond the traditional management approach that focuses on single species fishery management in order to include habitat, predators and non-target species in fisheries waters(Pikitch et al. 2004). NMFS outlines EBFM as the following definition first developed by the Pacific States Marine Fisheries Commission:

"Ecosystem-based fishery management recognizes the physical, biological, economic and social interactions among the affected components of the ecosystem and attempts to manage fisheries to achieve a stipulated spectrum of societal goals, some of which may be in competition." (Marasco et al. 2005)

While fishery councils are interested in implementing more robust policies there is no clear definition or metrics to determine if a management organization is conducting EBFM. There have been attempts at eliciting a clearer understanding of the status of EBFM in the U.S, such as the recent report from the Ecosystem Sciences and Management Working Group (ESMWG) as well as the ongoing work by Lenfest to describe a blueprint of EBFM within the U.S. (Ecosystem Sciences and Management Working Group 2014, Fishery Ecosystem Task Force 2014). However, current research in this field has focused on assessing the RFMC's success in managing the oceans and seas around the U.S but have not taken into account the inland "sea" of the United States, the Laurentian Great Lakes.

2. Framework for Comparison of Freshwater EBFM with Marine EBFM:

In 2014, the ESMWG of the National Oceanic and Atmospheric Administration's (NOAA) Science Advisory Board was tasked with assessing the progress of implementing EBFM within federally managed marine fisheries. The ESMWG assessed the progress though three major categories of information. First, they assessed the science

available for management to use in implementing EBFM(Ecosystem Sciences and Management Working Group 2014). Second the ESMWG determined whether or not this science was actually being used during the management process to make decisions(Ecosystem Sciences and Management Working Group 2014). Finally the ESMWG identified what EBFM actions were currently being implemented by the federal fisheries of the U.S(Ecosystem Sciences and Management Working Group 2014).

In order to assess these three topics the working group delineated a set of fifteen actions that best represent the current understanding and working definition of EBFM(Ecosystem Sciences and Management Working Group 2014). These actions take into account the wide breadth of topics that fall within fisheries management and EBFM. Each action either addresses a component of management that is related to biological/ecological components of the ecosystem or to the human dimensions of the ecosystem (Ecosystem Sciences and Management Working Group 2014). Additionally, they are categorized to indicate whether they are a conceptual ideal or an action that can be taken by management(Ecosystem Sciences and Management Working Group 2014).

For the purposes of this paper, these actions are used to assess the current progress and framework of EBFM within the Laurentian Great Lakes management regime. While the majority of the actions are directly applicable to the Great Lakes system there are several adjustments that had to be made in order to make the indicator relevant to the Great Lakes system. The primary reason for these adjustments is because some of the actions include language that is required by the MSFMCA for all federal fisheries but is not required within the Great Lakes management. The actions, which were used for the assessment of EBFM within the Great Lakes, can be seen in Table 2 and then again in Section 4 where they are applied to the Great Lakes. A simple quantitative ranking system was then used to compare directly the results the Great Lakes management bodies have with the actions and the results obtained by the ESMWG in their assessment of federal fisheries. In order to create the quantitative assessment a number was assigned 1-4 for each of the actions based upon the qualitative ranking system the ESMWG developed in their report (see Appendix A). This ranking was performed by the author and may be subjective. Alternative Delphi techniques, etc. were explored but not adopted because of the exploratory nature of the research.

Table 2. List of 15 indicators taken from the Ecosystem Working Group's report to NOAA. Source:(Ecosystem Sciences and Management Working Group 2014). Modification included in this thesis analysis are emphasized with bold print.

Indicators used to assess management of federal and Great Lakes fisheries
• Cease overfishing and develop rebuilding plans for overfished species.
• Delineate extent of ecosystem/interactions.
• Develop a conceptual model of the foodweb
• Describe habitat needs of different life history stages of animals and plants in the "significant foodweb" and develop conservation measures
• Calculate total removals – including incidental mortality and relate them to standing biomass, production, optimum yields, natural mortality and trophic structure
• Assess how uncertainty is characterized and define what buffers against uncertainty are included in management actions
• A. Set ecosystem goal[s] B. Developed indices of ecosystem health as targets for management?
• Describe long term monitoring data and how they are used.
• Assess the ecological, human and institutional elements of the ecosystem, which most significantly affect fisheries, and are outside Council/NMFS**/Lake Management** jurisdiction and define a strategy to address those influences.
• Is there a Fishery Ecosystem Plan/ Fishery Management Plan**/Lakewide Management Plan** employing EBFM?
• Does the Council/**Lake Committees/Great Lakes Fishery Commission** have a lead entity designated to advance EBFM in the Council process?
• Are ecosystem models developed and available for use in the Council**/Great Lakes Fishery Commission** process?

• Are decision support tools for EBFM / trade-off analysis employed [e.g., management strategy evaluation, risk assessments, ecosystem indicators, and scenarios]?
• To what extent are spatial management tools applied (besides Essential Fish Habitat measures above) to accomplish EBFM? **Or in the case of the Great Lakes to what extent are spatial management tools applied including any Essential Fish Habitat measures to accomplish EBFM**
• Other – Unique actions furthering EBFM

The actions as modified were then assessed using information obtained from the management bodies involved in the Great Lakes fisheries. The primary sources of information for this assessment were obtained through a literature review of key documents and progress reports from the Great Lakes region management bodies. Additionally, beyond key policy documents, peer reviewed scientific literature on EBM ensures that concepts were up-to-date and using the best science available. Key differences between the applications in freshwater and saltwater systems were then identified and evaluated with respect to the potential to improve the management in both systems.

3. Fishery Management

3.1 Federal Fishery Management

Federal fisheries management in the U.S is governed under the Magnuson Stevens Fishery Conservation and Management Act and through the overarching guidance of NMFS. This act establishes eight Regional Fishery Management Councils to divide the management responsibilities of the many fisheries in federal waters. These eight councils establish Fishery Management Plans (FMPs) in order to manage the fishery stocks in each region. These councils are advised by Plan Teams that are in charge of assessing fish stocks, along with Science and Statistical Committees (SSC) and Advisory Panels in order to assure that the best available science is being used. For a general structure of the governance of federal fisheries see figure 1.

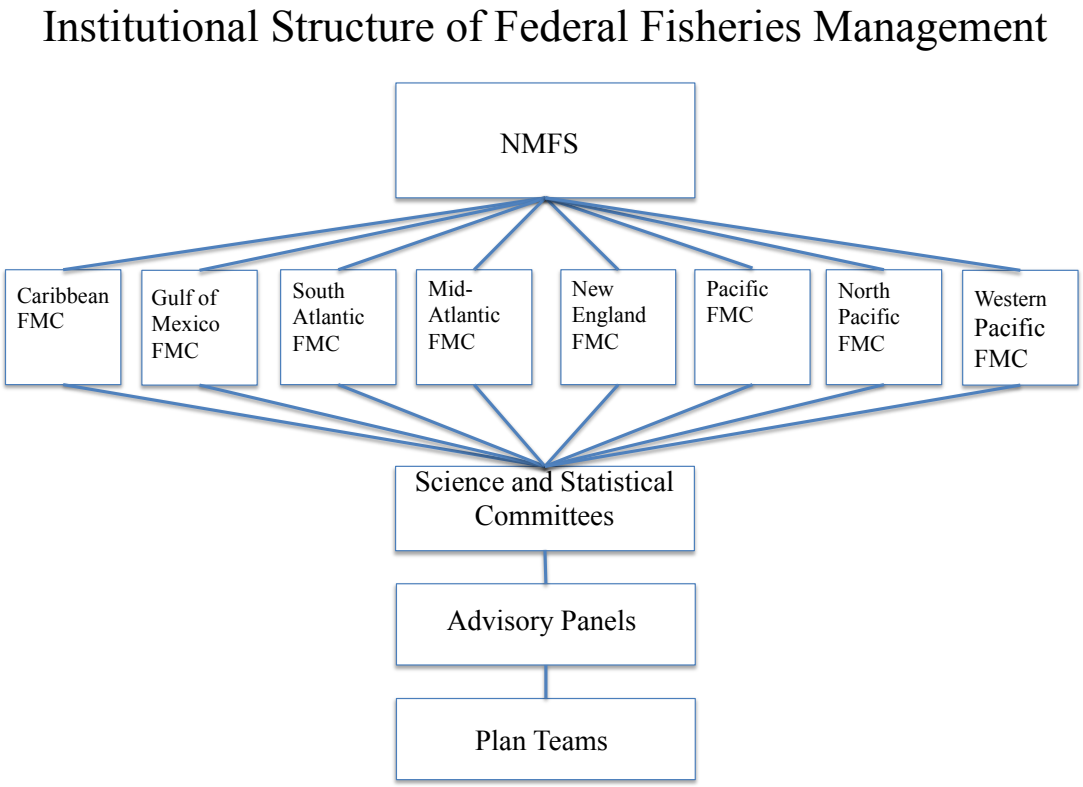

Figure 1. Institutional structure of federal fisheries management within the United States. NMFS acts as the overarching governance body and then fisheries are managed under eight regional councils that are advised by their own SSC and Advisory Panels to use the best available science to ensure fisheries meet the national standards set by 50 C.F.R. 600.310 et seq..

In recent years the U.S has made considerable improvements in managing stocks by reducing the number of fisheries that are overfished as well as those experiencing overfishing(National Marine Fisheries Service 2015). In the most recent Status of Stocks report the U.S federally managed fisheries have hit all time lows of the number of stocks at risk (National Marine Fisheries Service 2015). With these decreasing numbers of problematic fisheries the RFMC's are increasing their resolve to improve fisheries management. This has led to a growing emphasis on EBFM. In the Status of Stocks report released by NMFS there is a small section dedicated to EBFM(National Marine Fisheries Service 2015). According to NMFS and the ESMWG report every RFMC is

conducting some element of EBFM on some level (Ecosystem Sciences and Management Working Group 2014, National Marine Fisheries Service 2015).

3.2 Current Status of EBFM in Federal Fisheries

The current status of EBFM in federal fisheries is variable among the councils but there has been progress (Ecosystem Sciences and Management Working Group 2014). The RFMC's have worked to implement many of the different components of EBFM but the path and individual components used vary by council. The first area in which councils have made progress is through the implementation of MSA requirements such as Essential Fish Habitat (EFH). Many of the councils even go beyond the minimum requirements of EFH, which solely apply to targeted species and extend their habitat management to take other considerations into account. Another growing tool becoming more widespread within the councils is the Fishery Ecosystem Plan (FEP) document (Ecosystem Sciences and Management Working Group 2014). Currently, four out of the eight councils have FEPs and others are in the process of developing them ("Fishery-Ecosystem-Plan" 2015). These documents work to expand the comprehensiveness of management occurring within the federal fishery and include aspects of EBFM by creating goals and indicators of ecosystem status. The current FEPs while including goals and indicators have not established specific targets for management to achieve. In addition many of the RFMCs have developed committees to further the implementation of EBFM and to develop additional approaches to broadening management.

Overall, NOAA has stated that EBFM is a central theme to improving management within the federal councils particularly to improve the progress of stopping overfishing (National Marine Fisheries Service 2015). Recognizing the growing call for including ecosystem aspects into natural resource management from the U.S Oceans Commission, NOAA has developed a tool called Integrated Ecosystem Assessments(Levin et al. 2008). These management tools take a regional approach to creating comprehensive quantitative information relating to the social ecological system in order to inform fisheries management. So far these assessments have been started for five regions, Alaska Complex, California Current, the Gulf of Mexico, Pacific Islands, Northeast Shelf and another two regions including the Caribbean Sea and the Great Lakes

are being developed. Integrated Ecosystem Assessments are seen as important supporting tools for the implementation of fishery ecosystem goals developed by RFMCs in their FEPs' and Fishery Management Plans.

While not all of the councils are as far along in developing the science and policy needed for EBFM, there is discussion in all eight Councils continue developing and implementing what is needed to have more comprehensive management. The qualitative assessment for federal fisheries based on the actions conducted by the ESMWG is provided in Appendix B. For a full assessment of EBFM in federal fisheries consult the 2014 ESMWG report to NOAA Science Advisory Board "Exploration of Ecosystem Based Fishery Management in the United States". (http://www.sab.noaa.gov/Reports/SAB%20EBFM%20Report%20to%20NOAA_July%202014_Final.pdf)

3.3 Current Status of EBFM Within the Laurentian Great Lakes

The Great Lakes have a long-standing tradition of fishing and the management there was one of the first to consider the "ecosystem approach" which has evolved to be EBFM(Taylor, Lynch, and Leonard 2012). Just like the oceanic fisheries around the U.S, Great Lakes fisheries encompass a diverse social, economic and ecological system(Taylor, Lynch, and Leonard 2012). The current paradigm of management in the Great Lakes began in 1981 when the guiding policy document and treaty, A Joint Strategic Plan for the Management of Great Lakes Fisheries (Joint Strategic Plan), was enacted(Great Lakes Fishery Commission 2007). This document brought together all of the various management bodies and governments involved with the lakes into a cooperative management system. The key signatories to this document include the federal governments of Canada and the U.S, eight states, the province of Ontario, Chippewa-Ottawa Resource Authority and the pre-existing binational Great Lakes Fishery Commission (GLFC)(Great Lakes Fishery Commission 2007).

The Great Lakes fisheries are managed through the GLFC (Taylor, Lynch, and Leonard 2012). Established in 1955 the GLFC's role is to coordinate and facilitate management actions within the Great Lakes in areas such as fishery management, invasive species control, and fisheries research. The Joint Strategic Plan created Lake

Committees, which act as the regional bodies of the GLFC for each lake. These Lake Committees are made up of representatives from the state, federal, and agencies responsible for the management of natural resources. Lake Committees are then responsible for recommending the management actions and base decisions off of science provided through the use of their own Technical Committees and other sources such as NOAA, USGS, or universities. Technical Committees are responsible for collecting data and producing the science to be used by the Lake Committees in their management actions. The Lake Committees are responsible for ensuring that fishery management actions take into account the strategies set forth by the Joint Strategic Plan(Great Lakes Fishery Commission 2007). Similar to federal fisheries the Lake Committees also have option of setting up sub-committees to address specific issues or stocks in their lake(Great Lakes Fishery Commission 2007). The Technical Committees responsibilities however, while similar to "Plan Teams" do not include the peer review process that is contained within federal fishery SSCs to assure Best Available Science and Information. The actual day-to-day management of the lakes is left up to the agencies whose members make up the Lake Committees such as state departments of natural resources or environmental quality departments. Figure 2. demonstrates the general institutional structure of Great Lakes fisheries management under the Joint Strategic Plan.

Overall the actions taken by the management bodies are guided by four strategies outlined through the Joint Strategic Plan. These four strategies are: Consensus, Accountability, Ecosystem-Management, and Management-Information(Great Lakes Fishery Commission 2007). Specifically, the Ecosystem Management strategy then has an additional five procedures for Lake Committees to follow, which can be seen in Table 3. It is important to note that participation in the Joint Strategic Plan is completely voluntary of the state governments who conduct most of the day-to-day management of the lakes. This contrasts with most federal actions which are legal and binding on states.

Institutional Structure of Great Lakes Fisheries Management

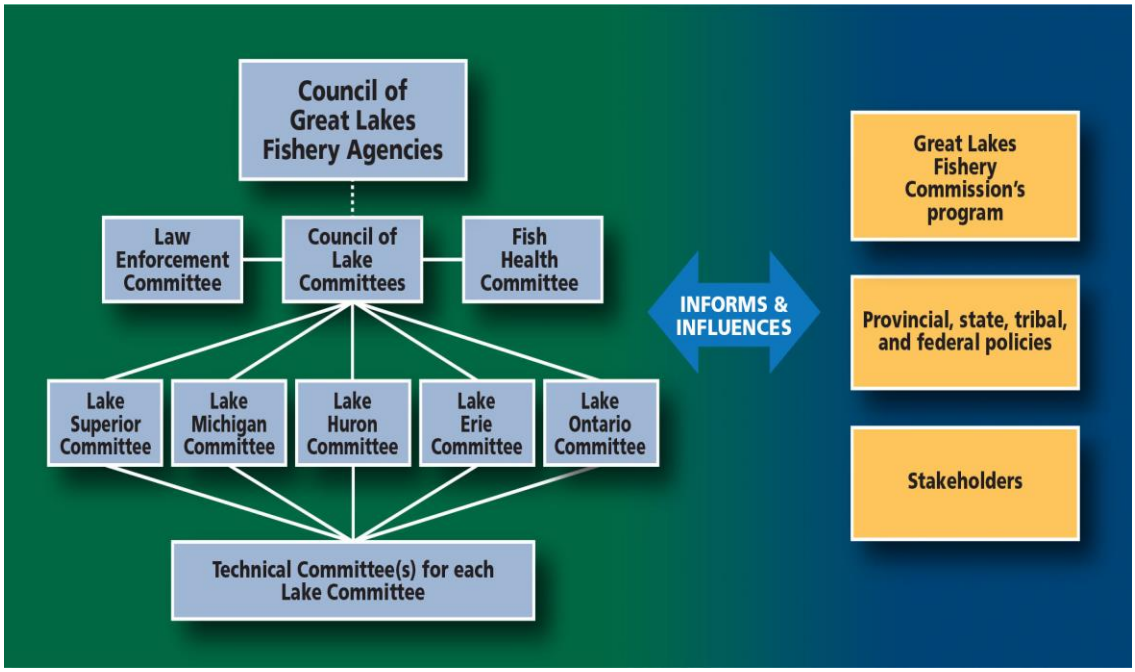

Figure 2. Institutional structure of Great Lakes fisheries management. Fisheries are managed through the regional Lake Committees who are advised by Technical Committees. The Council of Lake Committees is made up of individuals from all of the individual Lake Committees and they coordinate with the Council of Great Lakes Fishery Agencies which contain the federal agencies in the Great Lakes region to ensure the Great Lakes Fishery Commission's Joint Strategic Plan is being followed. Source of graphic (http://www.glfc.org/lakecom/).

Table 3: Ecosystem strategies used by the Great Lakes as taken from A Joint Strategic Plan for Management of Great Lakes Fisheries

Ecosystem Related Goals from A Joint Strategic Plan for Management of Great Lakes Fisheries	
Ecosystem Management Strategy	The Parties must exercise their full authority and influence in every available arena to meet the biological, chemical and physical needs of desired fish communities
Environmental Issues	Lake committees will identify environmental issues that may ipede achievement of their fish-community objectives and will work within

	governmental initiatives such as LaMPs, that provide opportunities for achieving refining, and assessing progress on environmental and fish-community objectives
Coordination with GLWQA/LaMPs	When participating in the LaMP process lake committees will develop joint proposals, which focus on identifying environmental needs relative to their fish-community objetives for submission to the fishery commission and other granting organizations
Environmental Issue Resolution	Unresolved or emerging environmental issues may be referred by lake committees to the parties, the Council of Great Lakes Fishery Agencies or the fishery commission, asking them to represent their interests before the appropriate controlling authority.
Habitat Advisory Board	The fishery commission will maintain an expert Habitat Advisory Board to assist the lake committees, the fishery commission, and the parties in developing ecosystem objectives and in identifying critical habitats essential for achieving fish-community objectives
Exotic Species	Fishery agencies will collectively identify and promote implementation of procedures that prevent unauthorized introductions of non-native species.

Source: (Great Lakes Fishery Commission 2007).

4. Implementation of Actions of EBFM for Laurentian Great Lakes

This section contains the summaries of the current actions being taken by the Great Lakes region management. The region is assessed as a whole and results are presented from the perspectives of the Great Lakes as a single entity. Where information or management practices vary between lake the section will note what differences there may be. At the end of the section the Great Lakes are assessed quantitatively in their progress for each of the actions and are then compared to the rankings each of the RFMCs received as well as federal fisheries as a whole. For additional comparison consult the qualitative assessment of federal fisheries provided in Appendix B.

Cease overfishing and develop rebuilding plans for overfished species.

Unlike the federal councils, which are governed by the definitions set forth by the MSA and the National Standard 1 regulations, the management of the Great Lakes is not governed by terms such as overfishing and overfished (50 C.F.R. 600.310 et seq.). For the sake of this paper these terms will be generally applied to fisheries within the Great Lakes that are severely impacted due to fishing and that are currently being threatened from fishing activities. For additional information, Appendix C contains data about commercial fisheries within the Great Lakes and whether they are assessed in some way and if the species is a targeted fishery. Information such as this could eventually be used by the Great Lakes to establish stock status terms similar to overfishing and overfished. Under the current management regime it is accepted that overfishing does not currently threaten any species in the Great Lakes (Mandrak and Cudmore 2012). Historically though, overfishing did lead to some species becoming diminished in the early 1900's and have yet to recover(Brown, Ebener, and Gorenflo 1999). The GLFC recognizes three species of fish that are identified as overfished: the lake trout, sturgeon and deep-water cisco. All three of these species are specifically identified as targets for rehabilitation and improvement in the strategic plan of the GLFC (Great Lakes Fishery Commission 2011). The degree to which these species are overfished is variable, lake trout have made large improvements in many of the Great Lakes Basins remaining low primarily in Lake

Huron. The deep-water cisco and lake sturgeon though are still severely below historical levels in the lakes. The rebuilding plans of the overfished species in the Great Lakes while not regulated under the MSA have an overall similar structure identifying clear measurable goals and setting a timeline that takes into account the natural history of the species they are managing (United States Congress 2007). For example, the Lake Erie lake trout rebuilding plan is structured around three objectives for the species, which include: limiting annual mortality, allowing population to build to a certain level, attain a harvestable surplus while having natural production of the species(Markham et al. 2008).

Delineate extent of ecosystem/interactions.

The management for the Great Lakes has long considered the extent of ecosystem interactions(Taylor, Lynch, and Leonard 2012). Management plans and policy consider many if not all components of the ecosystem including biotic aspects such as plant and animal life but also abiotic factors such as habitat and water quality. The Great Lakes management recognizes the importance of the health of the watershed feeding the Great Lakes. Regional action has been taken in order to address these factors. The Joint Strategic Plan, places a strong emphasis of ecosystem connections as one of the four main strategies for the management of fisheries (Great Lakes Fishery Commission 2007). The GLFC then also references to guiding actions based upon the binational Great Lakes Water Quality Agreement (GLWQA) (The Government of the United States of America and the Government of Canada 2012). The structure of the management of the lakes also demonstrates the overall ideal of ecosystem interactions within the lakes. The GLFC looks at the lakes as a complete ecosystem focusing on the state of the Great Lakes as a whole while individual lake management is then separated into the Lake Committees responsible for each lake (Great Lakes Fishery Commission 2007). The GLWQA also demonstrates these connections as well having components that address the Great Lakes together but then also requires the development of Lakewide Management Plans (LaMPs), which focus on the individual lakes (The Government of the United States of America and the Government of Canada 2012).

Develop a conceptual model of the foodweb

All five of the great lakes have a conceptual model of the foodweb (Krause et al. 2003, Mason 2003, U. S. Department of Commerce 2014). While it is unclear how commonly each of these foodwebs are used in day-to-day management there are clear examples of management taking into account the relationships and interactions between species in the Great Lakes ecosystem. For example, all of the LaMPs address threats to different aspects of the food web such as preyfish populations, phytoplankton, zooplankton, and other invertebrates by either by focusing on individual species or placing species into categories such as upper and lower foodweb (Environment Canada and the U.S EPA 2008b; Environment Canada and the U.S EPA 2008a; Lake Huron Binational Partnership 2008; Lake Michigan Technical Committee 2008; Lake Superior Binational Program 2008). The understanding of these foodwebs has been critical to management actions taken by the Great Lakes. The success of introducing non-native salmonids to the Great Lakes was only a success because they were able to capitalize on the thriving populations of alewife in the lakes (O'Gorman et al. 2012).

Describe habitat needs of different life history stages of animals and plants in the "significant foodweb" and develop conservation measures

The Great Lakes management bodies have described and understood the importance of identifying which habitats are important to the fish species that reside within. They have also recognized that there is a critical aspect to including the needs at different life stages. There are many species within the Great Lakes, which undergo ontological shifts in habitat use through the animal's life(Hayes 2012). As such the policy for the Great Lakes reflects the importance of the wide use of the different habitats recognizing that wetlands, nearshore, rivers, and various deeper layers of the lake are important to certain species(Hayes 2012). The species of fish within the Great Lakes have been separated into thirteen different groups called guilds which identify which aspects of the lake ecosystem are important to those species and with which species might compete (Hayes 2012).

Calculate total removals – including incidental mortality and relate them to standing biomass, production, optimum yields, natural mortality and trophic structure

Total removals from the Great Lakes are calculated to some degree. Fisheries management commonly uses target fishing mortality rate or total mortality rate as the indicator in stock assessments and management decisions on stock levels(Jones and Bence 2009). Fisheries are generally set to levels that are based on previous stock assessments and fishing rates that are either less than what has caused collapses in the past or to standard fishing targets such as $F_{0.1}$ (Jones and Bence 2009). Additionally, these fisheries use quotas based upon statistical catch at age models and allocate certain portions of the fisheries based on the population levels of the fisheries(Belore et al. 2014). This means that the fisheries are attempting to calculate the total removals from the recreational and commercial fisheries that occur within the Great Lakes and that Lake Committees will make adjustments based on fluctuations in the populations based off of these removals.

Assess how uncertainty is characterized and define what buffers against uncertainty are included in management actions

Fishery management has not generally considered uncertainty except subjectively wherein some measure of caution has been introduced ad hoc(Jones and Bence 2009). The primary form of recognition of uncertainty is just considered through adopting a conservative approach to harvests. However, there are an increasing number of tools that Great Lakes management has been using. For example, Jones and Bence (2009) working off a growing interest by Great Lakes fishery managers employed a management strategy evaluation system first used by Peterman and Anderson (1999) in which key uncertainties and risk are identified and then a model is developed to assess the possible outcomes of management options and proceed with the best available option. Assessment of uncertainty has been identified as important for the management of invasive species, stocking, determining recruitment and preventing stocks from becoming overfished (Jones and Bence 2009).

Set ecosystem goal and develop indices of ecosystem health as targets for management?

LaMPs include clear ecosystem goals for each of the five Great Lakes (Great Lakes Fishery Commission 2007). However, the use of clear and measurable indicators is variable in these plans. Three of the five lakes have qualitative and quantitative indicators that have been put into use in order to determine progress in achieving ecosystem goals set by LaMPs (Environment Canada and the U.S EPA 2008b, Lake Michigan Technical Committee 2008, Lake Superior Binational Program 2008). Goals include categories such as those outlined in the Lake Michigan LaMP that are structured in the form of questions as seen in the Table 4 below. Lake Erie is currently developing indicators and it is unclear if Lake Huron is developing indicators, as there is no discussion in the Lake Huron Binational Agreement Action Plan (Environment Canada and the U.S EPA 2008a, Lake Huron Binational Partnership 2008). However, LaMPs, are not the only documents to contain indicators, each of the Great Lakes are assessed through the State of the Great Lakes Ecosystem Conference. The State of the Great Lakes Ecosystem Conference establishes its own set of ecosystem goals as well as including a set of over 60 indicators. These indicators assess the water quality, biotic communities, habitat quality, and human health of the Great Lakes(Environment Canada and the U.S EPA 2014). A list of these indicators is included in Appendix (D) (Environment Canada and the U.S EPA 2014).

Table 4: Example of Lakewide Management goals. Taken from the Lake Michigan LaMP

Ecosystem Goals of Lake Michigan LaMP
Can we all eat any fish?
Can we drink the water?
Can we swim in the water?
Are all habitats healthy, naturally diverse, and sufficient to sutain viable biological communities?
Does the public have access to abundant open space, shoreline, and natural areas, and does the public have enhanced opportunities for interaction with the Lake Michigan ecosystem?
Are land use, recreation, and economic activities sustainable and supportive of a healthy

ecosystem?
Are sediments, air, land, and water sources or pathways of contamination that affect the integrity of the ecosystem?
Are aquatic and terrestrial nuisance species prevented and controlled?
Are ecosystem stewardship activities common and undertaken by public and private organizations in communities around the basin?
Is collaborative ecosystem management the basis for decision-making in the Lake Michigan basin?
Do we have enough information, data, understanding, and indicators to inform the decision-making process?
What is the status of Lake Michigan's Watersheds?

Source: (Lake Michigan Technical Committee 2008).

Describe long term monitoring data and how they are used.

There are a variety of sources for long term monitoring of data for the Great Lakes. NOAA through its Great Lakes Environmental Research Laboratory has a long term monitoring program in place for Lake Michigan that has been ongoing since the 1970's but it is unclear if fishery managers are actively using this information in making decisions. The EPA also monitors water quality standards and biocontaminants in fish species in the Great Lakes as well to reach the goals of the GLWQA (The Government of the United States of America and the Government of Canada 2012). Commercial catch records are also recorded for all fisheries and date back to the 1800's. As related above the LaMPs and the State of the Great Lakes Ecosystem Conference have long term monitoring in order to assess the indicators used to evaluate ecosystem health. The indicators assess, water quality, biotic communities, invasive species, coastal zone, aquatic habitats, human health, land use, resource utilization and climate change (Environment Canada and the U.S EPA 2014). There are also data and information from NOAA that includes monitoring lake levels and coastal resilience to hazards (NOAA Great Lakes Environmental Research 2015).

Assess the ecological, human and institutional elements of the ecosystem, which most significantly affect fisheries, and are outside Council/NMFS/Lake Management jurisdiction and define a strategy to address those influences.

Due to the joint management of the lakes ecological, human and institutional elements are incorporated through the number of agencies involved. Particularly because of the integration of fisheries management with water quality management, LaMPs contain information ranging from biotic to abiotic factors in the lakes. The GLWQA addresses water quality concerns, which have varying impacts on the lakes(The Government of the United States of America and the Government of Canada 2012). For example, Harmful Algal Blooms (HABs) are a serious concern particularly in Lake Erie("Harmful Algal Blooms in the Great Lakes" 2015). Management bodies in the Great Lakes also identify of Areas of Concern (AOCs), which, are degraded sections of habitat in the Great Lakes that have been degraded by wide variety of impacts(U.S EPA 2001). When an AOC is identified federal and state governments develop a Remedial Action Plans (RAP's), which outline goals and benchmarks to restore the AOCs and delist them(U.S EPA 2001). Current studies/monitoring are also ongoing by NOAA's Great Lakes Integrated Sciences and Assessments team to assess the impacts climate change will have on the system as well("GLISA Approach | GLISA" 2015). Additionally, fishery management has recognized the important role that shipping and transport plays as a vector for introducing invasive species that can have large impacts on the ecosystems (Roth et al. 2012).

Is there a Fishery Ecosystem Plan/ Fishery Management Plan/Lakewide Management Plans (LaMPs) employing EBFM?

Four out of five lakes have LaMPs in place for fishery management (Environment Canada and the U.S EPA 2008b, Environment Canada and the U.S EPA 2008a, Lake Michigan Technical Committee 2008, Lake Superior Binational Program 2008). The fifth, Lake Huron does not have an LaMP but rather a Binational Intitiative that was created prior to the other LaMPs and fills the requirements of the ecosystem approach (Lake Huron Binational Partnership 2008). Each lake also has its own Lake Committee and Lake Technical Committee to further the science and act a forum of discussion and

cooperation among the different management agencies that have jurisdiction in each lake. The LaMPs are key documents that identify the overall status of the lakes ecosystem. Ecosystem objectives and indicators are identified along with major threats to the ecosystem. Importantly as well the LaMPs identify the important relationship and activities that people have with the lakes ecosystem as well and include these into the monitoring and goals of the LaMP(Lake Michigan Technical Committee 2008; Lake Huron Binational Partnership 2008; Environment Canada and the U.S EPA 2008a; Lake Superior Binational Program 2008; Environment Canada and the U.S EPA 2008b).

Does Council/Lake Committee/Great Lakes Fishery Commission have a lead entity designated to advance EBFM in the management process?

The Ecosystem Approach is one of the four tenants of the Joint Strategic Plan(Great Lakes Fishery Commission 2007). Each lake is then delegated its own Lake Committee which then works towards the benefit of managing the lakes under the tenets of the Strategic Plan. Each Lake Committee has its own Technical Committee to conduct research and further information needs by the lake committee but these committees are not for the sole purpose of advancing EBFM rather EBFM is integrated throughout. There is however, a lead entity for advancing habitat management in the lakes through the Great Lakes Fishery Commission through the Fish Habitat Conservation Committee, which was previously known as the Habitat Advisory Board(Great Lakes Fishery Commission 2007). This committee is responsible for assisting each of the Lake Committees with environmental objectives that include monitoring habitat and environmental needs of fish within the Great Lakes (Great Lakes Fishery Commission 2007).

Are ecosystem models developed and available for use in the Lake Council/GLFC process?

There are either ecosystem models available or in the works for each of the Laurentian Great Lakes through Ecopath with Ecosim modeling software (Rogers and Bunnell 2011). Workshops have been held to further the use of the models and increase

the utility of the models(Rogers and Bunnell 2011). Additional models are used through NOAA particularly with reference to human effects as well as the use of long-term data collection and modeling. Additional agencies such as the USGS and EPA also have ecosystem models available for some of the lakes as well(Langseth, Rogers, and Zhang 2012, Miller et al. 2005).

Are decision support tools for EBFM / trade-off analysis employed [e.g., management strategy evaluation, risk assessments, ecosystem indicators, and scenarios?

Decision Support tools for EBFM are still within the developmental stages for management in the Great Lakes. One source of these decision support tools is the Great Lakes Integrated Sciences and Assessments which has worked to develop decision support tools that take into account climate conditions to better inform fishery managers ("GLISA Approach | GLISA" 2015). There are also decision support tools available through NOAA for monitoring lake levels and coastal resilience to hazards (NOAA Great Lakes Environmental Research 2015). Overall the GLFC recognizes the need for additional information and research to occur particularly in the human dimensions of the fishery(Heck, Stedman, and Gaden 2014). Tools such as risk assessments are commonly used particularly in reference to invasive species(Cudmore et al. 2012). Ecosystem indicators have been created for the lakes and are being monitored. Management strategy evaluation has become more common and is used particularly to assess uncertainty(Jones and Bence 2009). Statistical methods of decision analysis have been successfully used to inform management on issues such as stocking, invasive control and quota allocation (Jones and Bence 2009).

To what extent are spatial management tools applied (besides Essential Fish Habitat measures above) to accomplish EBFM? Or in the case of the Great Lakes what extent are spatial management tools applied including any Essential Fish Habitat measures to accomplish EBFM?

Spatial management tools are used in several situations within the Great Lakes. The lakes are divided into management units. These units then allow the fisheries managers to set different limits and allocations based on the condition of the stocks

within the management units(Michigan DNR 2015). This technique has allowed for important refugia for species to be identified as no-take zones(Michigan DNR 2015). For example, the there are management units identified in Lake Michigan and Lake Huron that are no take zones for lake trout(Michigan DNR 2015). Another tool that is used is allocations of the total allowable catch of fisheries are distributed between states/province based upon the amount of habitat of target species that are found in each entity's waters(Lake Erie Standing Technical Committee 2007). This is seen in the Lake Erie walleye fishery in which Michigan, Ohio and Ontario are allocated portions of the TAC based on habitat surveys and information about the amount of surface area of walleye habitat their jurisdiction(Lake Erie Standing Technical Committee 2007).

Other – Unique actions furthering EBFM

Perhaps the largest concern for the Great Lakes in recent years has been dealing with invasive species(Taylor, Lynch, and Leonard 2012). Currently it is recognized that there are around 69 different invasive species in the Great Lakes and of these 35 have established populations(Mandrak and Cudmore 2012). These invasive species have a suite of effects on the Great Lakes ecosystem including, introducing viruses, degrading lower trophic levels and impacting predators(Mandrak and Cudmore 2012). In particular, the sea lamprey (*Petromyzon marinus*) has been a large nuisance affecting salmonids and other sports fish within the lakes(Siefkes et al. 2012). To deal with these pest species the GLFMC has had to consider them within an ecosystem context. Current control of sea lampreys focuses on targeting critical life stages of the lamprey. Lampricides are used to kill off juvenile lamprey before they are able to become full adults and start feeding on fish(Siefkes et al. 2012). Barriers and traps are also used to target adult lampreys that are returning to tributaries to breed. These tools are used ecosystem wide within the Great Lakes to control these invasive and detrimental lampreys(Siefkes et al. 2012).

Additionally, while the goal with sea lampreys is the elimination of the species there are invasive species in which management actions are taken in order to protect and promote them. The first of these is the purposefully introduced salmon species that have become a staple of the recreational fishery community in the Great Lakes (O'Gorman et

al. 2012). These fish filled a gap that had formed from the depletion and overfishing of indigenous local lake trout and are now stocked annually. The other invasive species that has played a very unique role in fisheries is the alewife. Initially when the alewife invaded it was targeted as a commercial fishery, however, after the alewife started to decline in the lake from a combination of fishing, predation from introduced salmonids and having reached a natural carrying capacity within the lakes, actions were taken to limit the harvest of this species to ensure adequate food supply for the introduced salmon(O'Gorman et al. 2012).

5. Overall Results on Implementation of EBFM from the Great Lakes

The Great Lakes demonstrate a cooperative approach to developing EBFM for fishery management. However, this approach uses the same principles and thoughts behind developing EBFM for federally managed fisheries. The Great Lakes Commission like the RFMCs has made a great deal of progress in developing management into a more comprehensive system including various aspects of ecosystem in management actions. This is not to say that the management is perfect. There are still areas that management and policy in the Great Lakes could expand upon to improve natural resource management. Overall because of the broad perspective taken by the management bodies in the Great Lakes, along with the coordination and diversity of ecosystem indicators the Great Lakes management regime exceeds in some cases the defined status of what NOAA perceives as EBFM and progresses to the level above that addressing EBM. In this case the quantitative ratings should exceed four or there should be additional actions assessed that relate to the broader scope of EBM.

The overarching ecosystem perspective that is carried out by the management and policy bodies in the Great Lakes is what sets the stage for being able to progress with many of the actions looked at in this thesis. Having the ecosystem goals identified as a guiding policy of a Joint Strategic Plan for Fisheries Management of the Great Lakes allows policy to take a much broader look at the potential threats and needs of the Great Lakes as a whole. With the integration of the Joint Strategic Plan with the GLWQA fisheries management is considered in conjunction with water quality and overall

ecosystem health. As demonstrated from the assessment of fish, birds, mammals, amphibians, invertebrates, plants and various aspects the ecosystem including near shore aquatic habitats, coastal wetlands, terrestrial, open lake and groundwater.

In quantitatively ranking the Great Lakes management actions the Great Lakes region scored just above highest federal RFMC, the North Pacific Fishery Management Council. The Pacific, New England, and South Atlantic fishery management councils were also ranked very high. When comparing the Great Lakes region to federal fisheries as a whole the Great Lakes scored approximately 10 points higher on the quantitative scoring. This demonstrates that the EBFM occurring within the Great Lakes is comparatively similar to that occurring within federal fisheries. The results are summarized in Appendix E. Figure 3 demonstrates a visual comparison of the total scores from assessing the actions for the Great Lakes and RFMC.

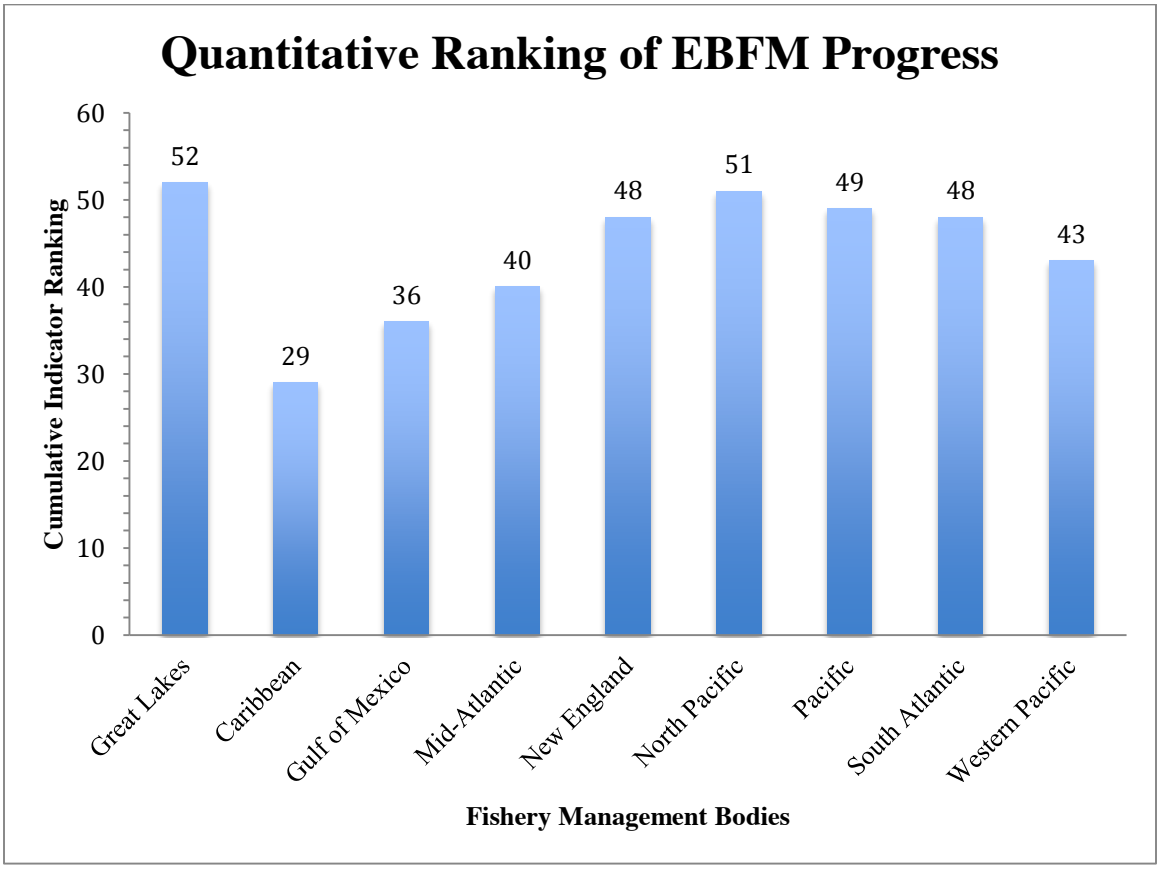

Figure 3. Quantitative Ranking of EBFM Progress. Totals of the Great Lakes and RFMC from the quantitative assessment conducted in this thesis. For a full breakdown of the scoring consult Appendix E

5.1 Lessons for Federal Fisheries Management

One of the greatest strengths of the Great Lakes management bodies, that allows them to engage in EBFM comes from the cooperation and coordination among all of the natural resource management bodies in the region. A Joint Strategic Plan for Fisheries Management of the Great Lakes with its connection to the GLWQA serves a key role of bringing together all of the agencies involved in the management and regulation of natural resources of the Great Lakes. Communication occurs between branches of management that on their own would only consider a small portion of the ecosystem but that together they are capable of creating a more comprehensive management for the Great Lakes by addressing not only individual lakes as a whole but also all of the lakes as a whole as well. For example, because of the coordination that the Strategic Plan fosters, the GLFC are able to take into account water quality conditions and management actions taken by management bodies under the GLWQA while the LaMPs are able to rely on the GLFC for assisting in reaching their goals. This also a demonstrates the capability of two countries ability to work together to manage a natural resource under the use of common goals and a non-binding document such as the Joint Strategic Plan. Translating this cooperative regime to federal fisheries and encouraging agencies to coordinate and work together would strengthen saltwater EBFM. For example, one of the limiting factors in the Caribbean for federal fisheries is working with ecosystems that are split among multiple countries(Ecosystem Sciences and Management Working Group 2014). Establishing a regional plan that would bring these countries together would allow EBFM to progress.

A second strength of the Great Lakes management stems from their ability to coordinate and this is taking into account and focusing on the ecosystem interactions that are occurring within the lakes. By doing so the Great Lakes are able to identify activities that may be negatively affecting fisheries but that fall outside of the fishery managers jurisdiction. This then in turn can allow the managers to better react and proceed with managing fisheries more appropriately. For example, the Great Lakes have identified habitat loss and impacts due to harmful invasive species to be of the greatest concern for fish populations rather than the impact of overfishing(Hayes 2012). By identifying the

real concern agencies can work to rectify the situation and improve fisheries. If managers did not identify the actual threats to fisheries the stocks could keep declining even if overall fishing effort were decreased.

Another strength of the EBFM that occurs within the Great Lakes originates within the development of its ecosystem indicators. Federal fisheries have not yet implemented ecosystem health targets as the Great Lakes have. Documents such as the State of the Great Lakes Ecosystem Conference allow the Great Lakes to present ecosystem health in both a qualitative and quantitative fashion. The range of indicators concerning the Great Lakes ecosystem is also testament to the management being dedicated and open to including a wide range of ecosystem interactions into account. These indicators can act as a first level check for RFMC's that are seeking to implement their own. Seeing which indicators are used in one system such as the Great Lakes could help shape and inform the development of indicators specific to another region. Currently the North Pacific Council, the Western Pacific Council, the Pacific Council and the South Atlantic Council have Fishery Ecosystem Plans (FEP's) or Fishery Management Plan documents("Fishery-Ecosystem-Plan" 2015). In addition, other Councils are considering developing FEP's documents as well(Ecosystem Sciences and Management Working Group 2014). These FEPs report annually on status and trends in the ecosystem e.g Ecosystem Chapter of the Stock Assessment Fisheries Evaluation of NPFCM, and the California Current Annual report of the PFMC. The format and structure of the LaMPs is very similar to that of these existing plans but expand on several key areas. First and foremost many of the LaMPs have been enacted now for over fifteen years providing a source of documents that haven been revised and improved many times. Additionally, the LaMPs have measurable indicators that broach a wide range of the socio-ecological systems within the Great Lakes. As such these documents can act as possible starting places for the guidance and development of EBFM documents within the regional councils.

5.2 Lessons for Great Lakes Fishery Management

There are some limitations seen in the Great Lakes progress towards EBFM. Without the MSFMCA elements of management within the Great Lakes are not subject to as periodic evaluation and review. For example, while the Great Lakes have taken approaches to evaluating important fish habitat there is not requirement as there is for Essential Fish Habitat to assess this information every five years. Because of this the known status of particular components of a fish's habitat may not be as accurately depicted. Additionally, while the success of Essential Fish Habitat is debated it at least sets a minimum standard for fished species. By including these aspects from the MSFCMA the Great Lakes fisheries managers would be able to increase the systematic rigor of their management.

While the Great Lakes management bodies have a wide array of ecosystem indicators to work with in assessing the status of the ecosystem there are still some gaps that can be identified. The largest gap is seen in the assessment of socio-economic indicators. While there are a few indicators that address portions of this part of the Great Lakes they are not encompassing all of the social economic factors as thoroughly as the biological components are assessing the ecological system. Additional indicators can be developed to take into account concepts like social well-being, and economic success of the lakes. Currently the few indicators that are available are not determined to have a quantitative or qualitative status as of the 2011 State of the Great Lakes Ecosystem report(Environment Canada and the U.S EPA 2014).

Another limitation seen in the Great Lakes management is the lack of definable criteria for determining stock status. The definitions of overfished and overfishing provided by the MSA for federal fisheries provide a transparent and measurable indicator for not only managers but also for citizens wondering about the status of fisheries. For the Great Lakes the status of fish, perhaps well known by individuals conducting assessments are not as transparently presented on a yearly basis such as those in federal fisheries through reports to congress like the Status of Stocks report. Having these definitions of overfishing and overfished would allow Great Lakes management to better include and

inform the stakeholders in the region which could translate into a better understanding of the social system around the lakes.

Finally because the Great Lakes have been historically completely separate from the RFMCs they too were limited in the number of approaches they were using to implement EBFM. Many of the RFMCs such as the North Pacific, Pacific, South Atlantic, New England and Western Pacific have demonstrated an initiative putting much more effort and resources than what was required by the MSFMCA into EBFM. Because of this they have come up with similar but still separate approaches to creating FEP's or implementing aspects of the ecosystem in their overall management. The Great Lakes management bodies while following the overall ecosystem drive of the Joint Strategic Plan can still learn from these different approaches.

6. Conclusions

The status of fisheries in the U.S has been improving. The number of stocks that are overfished or experiencing overfishing is on the decline. However, there is the desire to obtain more comprehensive management that takes the health of the ecosystem and incorporates socio-economic health into account. Furthering the implementation of EBFM is one way to help bolster management. One of the ways in which federal fisheries have been limited in implementing EBFM is due to there not being a large amount of experience in implementing ecosystem aspects into the management of fisheries. RFMCs have essentially operated as entities unto themselves although the SE Atlantic Council may be more successful than others at developing partnerships.

The comparison that has occurred in this paper demonstrates the EBFM approach of the Great Lakes regional management is very similar to that of the federal RFMCs. In fact, in some cases it appears that Great Lakes have progressed further along in the implementation of the 15 actions identified in this paper. Therefore conducting comparisons between federal RFMCs and the Great Lakes fishery management is supported. Specifically the Great Lakes region can act as an excellent source of information and experience that the RFMCs can use as guidance in developing EBFM for their specific regions. Likewise federal fisheries can also be a reference for the use of EBFM within the Great Lakes as well.

Management within the Great Lakes has demonstrated an interesting aptitude in their approach to fisheries management. Cooperation and coordination among the various agencies both state and federal have allowed the Great Lakes management bodies to approach the system from a holistic view. By doing so fisheries management has been able to take into account various factors that impact fisheries besides those directly from fishing. In order to take these outside factors into account the Great Lakes management bodies have also created a plethora amount of indicators that are set as ecosystem health targets. Federal fisheries by taking into account these strengths can in turn fortify their approach to EBFM

There is opportunity for the Great Lakes to benefit from looking into the EBFM work being conducted by the Council fisheries as well. With the marine fisheries management gaining more momentum in the development of EBFM practices the Great Lakes would benefit from observing the strategies that are being taken in its federally managed counterparts. Clear re-assessment requirements included in the language of Essential Fish Habitat could help Great Lakes establish similar collections of information about its commercial fisheries and ensure that this information contains the best available science. Furthermore, by including clear definitions of stock statuses fishery managers can better communicate the status of fisheries to stakeholders and work to incorporate this into more comprehensive involvement of the social aspect of the ecosystem. Finally the array of approaches and initiative that federal fisheries have taken to go beyond the current requirements of the MSFCMA demonstrate different approaches that could provide new ideas for Great Lakes fishery managers.

It is important to note though that while there is much that can be learned between a comparison of the Great Lakes and the RFMC's there are some stipulations. Primarily due to the nature of EBFM there is not a one approach fits all. Ecosystems are unique along with the socio-economic conditions within each. Not all solutions found in one region will work for another. But just because there are differences does not mean that comparisons of management practices in between regions are not worthwhile. Rather these comparison can be used as guidelines to help inform and shape but not be a one solution fits all for fisheries management. Comparative approaches between can help identify weaknesses, shortcomings, and strengths of different implementation strategies.

This solidifies the cross comparison being done by this thesis to be used as a supplementary source of information to help inform fisheries management in both freshwater and saltwater fisheries.

While the origin of the management regime of the Great Lakes derives from different guiding documents, fisheries management in these basins can nonetheless be a wealth of information for supporting and improving upon the practices taken in federally managed fisheries and vice versa. As fisheries strive to continue to improve management and begin branching into forms of management such as EBFM it no longer makes sense for saltwater and freshwater fisheries to be considered completely disparate from each other. Instead the two can help to inform and improve management practices in both.

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Appendices:

Appendix A: Qualitative Ranking System.

Qualitative Ranking System used to assess status of indicators. System created by the Ecosystem Sciences and Management Working Group.

Action	**Assessment Rating**
Cease overfishing and develop rebuilding plans for overfished species	Overfishing stopped and rebuilding plans in place [stocks may not be rebuilt] Overfishing for some species still occurring – rebuilding plans in place Overfishing and rebuilding plans not in place Not being addressed
Delineate extent of ecosystem/interactions	Formal recognition by Regional Action Consideration given but not formal Under discussion Not under discussion
Develop a conceptual model of the foodweb	One or more conceptual foodweb model is available and their use evaluated in decision-making for stock assessments and other management decisions Consideration given but incomplete and /or ad hoc Under discussion Not under discussion

Describe habitat needs of different life history stages of animals and plants in the "significant foodweb" and develop conservation measures.	Full implementation of EFH Limited implementation of EFH Not used because MSA requirements constitute baseline, i.e., they require that EFH is implemented according to national standards. EFH implementation is thus not a choice.
Calculate total removals-including incidental mortality and relate to standing biomass, production, optimum yields, natural mortality and trophic structure	Full implementation of MSA requirements with good estimates of all significant sources of incidental mortality, etc. Implementation of MSA requirements but incidental mortality insufficiently accounted for. Not used – compliance with MSA required
Does council assess how uncertainty is characterized and define what buffers against uncertainty are included in management actions?	Full accounting of uncertainty / risk based assessments Partial accounting of uncertainty / use of risk based assessments Discussion of uncertainty and risk No discernible progress in this area
A. Has council set an ecosystem goal (s) and B. Developed indices of ecosystem health as targets for management?	Clearly articulated set of ecosystem goals that quantitatively or qualitatively describe desired ecological, economic and social outcomes of management. Conceptual descriptive (qualitative) ecosystem goals set for ecological, economic and social outcomes. Conceptual descriptive goals set for some outcomes of management No goals set Indicators selected for all three types of goals and quantitative benchmarks and the

	indicators have been identified and applied. Indicators selected for all three types of goals, but quantitative reference points consistent with the goals not identified. Goals articulated but indices not defined as targets Ecosystem goals and indices not under discussion
Describe long-term monitoring data and how they are used	Region developed monitoring plan relative to EBFM can be identified and reported on a regular basis Regional monitoring plan for fisheries but not necessarily ecosystem based fishery Regional monitoring plan under discussion Not under discussion
Assess the ecological, human and institutional elements of the ecosystem which most significantly affect the fisheries, and are OUTSIDE Council/NMFS jurisdiction and define a strategy to address those influences	Proactive plan with respect to outside impacts, taking account of all major known exogenous drivers of fisheries performance No plan but Region is responsive to threats as they arise Region discusses but has limited engagement with outside influences Limited or no response to external influences
Is there a Fishery Ecosystem Plan (FEP)/Fishery Management Plan (FMP) employing EBFM?	FEP or comprehensive FMP using EBFM appropriately for the relevant ecosystem FEP or FMP covering significant portions and or management actions for the relevant ecosystem (less comprehensive than above) Discussion of FEP or FMP for relevant ecosystem

	No discussion of FEP or FMP for relevant ecosystem or because it is not appropriate
Does the Council have a lead entity designated to advance EBFM in the Council process?	Yes, a focal point and process for developing EBFM actions for Council consideration Mostly follows Council direction as a whole Being developed No lead entity and limited or no discussion
Are ecosystem models developed and available for use in the Council process?	Models of appropriate complexity are available and in use Models available but not systematically in use Use of models is under discussion/development No discussion or use of models
Are decision support tools for EBFM/trade-off analysis employed (e.g., management strategy evaluation risk assessments, ecosystem indicators, scenarios)?	All significant uses of ecosystem considerations in management are informed by appropriate decision-support tools Some of the considerations are informed by appropriate decision-support tools A few considerations are informed by decision-support tools or are under discussion No discussion and no use of formal tools

To what extent are spatial management tools applied (besides EFH measures above) to accomplish EBFM?	Significant spatial management tools applied as well as EFH where appropriate Some spatial management tools applied as well as EFH Spatial management tools discussed and under development Not under discussion

Is there a Fishery Ecosystem Plan (FEP)/Fishery Management Plan (FMP) employing EBFM?	FEP or comprehensive FMP using EBFM appropriately for the relevant ecosystem FEP or FMP covering significant portions and or management actions for the relevant ecosystem (less comprehensive than above) Discussion of FEP or FMP for relevant ecosystem No discussion of FEP or FMP for relevant ecosystem or because it is not appropriate
Does the Council have a lead entity designated to advance EBFM in the Council process?	Yes, a focal point and process for developing EBFM actions for Council consideration Mostly follows Council direction as a whole Being developed No lead entity and limited or no discussion
Are ecosystem models developed and available for use in the Council process?	Models of appropriate complexity are available and in use Models available but not systematically in use

	Use of models is under discussion/development No discussion or use of models
Are decision support tools for EBFM/trade-off analysis employed (e.g., management strategy evaluation risk assessments, ecosystem indicators, scenarios)?	All significant uses of ecosystem considerations in management are informed by appropriate decision-support tools Some of the considerations are informed by appropriate decision-support tools A few considerations are informed by decision-support tools or are under discussion No discussion and no use of formal tools
To what extent are spatial management tools applied (besides EFH measures above) to accomplish EBFM?	Significant spatial management tools applied as well as EFH where appropriate Some spatial management tools applied as well as EFH Spatial management tools discussed and under development Not under discussion
Other	Verbal description

Source:

Ecosystem Sciences and Management Working Group. 2014. "Exploration of Ecosystem Based Fishery Management in the United States." NOAA Science Advisory Board..

Appendix B: Qualitative Assessment of Regional Fishery Management Councils

Extent of Implementation of EBFM – Qualitativ	**Caribbean FMC**	**Gulf of Mexico FMC**	**Mid-Atlantic FMC**	**New England FMC**	**North Pacific FMC**	**Pacific FMC**	**South Atlantic FMC**	**Western Pacific FMC**

e Assessment								
Cease overfishing (OF) and develop rebuilding plans for overfished species.	OF stopped; rebuilding plans in place [stocks may not be rebuilt]	OF for some species still occurring; rebuilding plans in place	OF stopped; rebuilding plans in place [stocks may not be rebuilt]	OF for some species still occurring; rebuilding plans in place	OF stopped; rebuilding plans in place [stocks may not be rebuilt]	OF stopped; rebuilding plans in place [stocks may not be rebuilt]	OF and rebuilding plans not in place	OF and rebuilding plans not in place
Delineate extent of ecosystem/ interactions.	Under discussion	Under discussion	Consideration given but not formal	Formal recognition by Regional Action	Formal recognition by Regional Action	Formal recognition by Regional Action	Formal recognition by Regional Action	Formal recognition by Regional Action
Develop a conceptual model of the foodweb.	Under discussion	Model(s) available and evaluated in stock assessments, management decisions	Consideration given but incomplete and/or *ad-hoc*	Model(s) available and evaluated in stock assessments, management decisions	Model(s) available and evaluated in stock assessments, management decisions	Model(s) available and evaluated in stock assessments, management decisions	Model(s) available and evaluated in stock assessments, management decisions	Model(s) available and evaluated in stock assessments, management decisions
Describe habitat needs of different life history stages of animals and plants in the "significant foodweb" and develop	Not used because MSA requirements constitute baseline	EFH fully implemented	Not used because MSA requirements constitute baseline	EFH fully implemented	EFH fully implemented	EFH fully implemented	EFH fully implemented	Not used because MSA requirements constitute baseline

conservation measures.								
Calculate total removals-including incidental mortality and relate to standing biomass, production, optimum yields, natural mortality and trophic structure.	MSA requirements implemented but incidental mortality insufficiently accounted for	MSA requirements fully implemented with good estimates of incidental mortality, etc.	Compliance with MSA as required	MSA requirements implemented but incidental mortality insufficiently accounted for	MSA requirements fully implemented with good estimates of incidental mortality, etc.	MSA requirements implemented but incidental mortality insufficiently accounted for	MSA requirements implemented but incidental mortality insufficiently accounted for	Compliance with MSA as required
Does council assess how uncertainty is characterized and define what buffers against uncertainty are included in management actions?	Partial accounting of uncertainty / use of risk based assessments	Partial accounting of uncertainty / use of risk based assessments	Partial accounting of uncertainty / use of risk based assessments	Partial accounting of uncertainty / use of risk based assessments	Partial accounting of uncertainty / use of risk based assessments	Partial accounting of uncertainty / use of risk based assessments	Partial accounting of uncertainty / use of risk based assessment	Partial accounting of uncertainty / use of risk based assessments
Has council: A. set an ecosystem goal (s)	Ecosystem goals under discussi	Ecosystem goals under discussi	Ecosystem goals articulated	Ecosystem goals articulated	Ecosystem goals articulated	Ecosystem goals articulated	Ecosystem goals articulated	Ecosystem goals articulated

and	on	on						
B.developed indicators of ecosystem health as targets for management?	Ecosystem indicators under discussion	Ecosystem indicators under discussion	Ecosystem indicators not defined as targets	Ecosystem indicators not defined as targets	Ecosystem indicators not defined as targets	Ecosystem indicators not defined as targets	Ecosystem indicators not defined as targets	Ecosystem indicators not defined as targets
Describe long-term monitoring data and how they are used.	Regional monitoring plan under discussion	Regional monitoring plan for fisheries but not necessarily ecosystem based fishery	Regional monitoring plan for fisheries but not necessarily ecosystem based fishery	Region developed monitoring plan relative to EBFM can be identified	Region developed monitoring plan relative to EBFM can be identified	Regional monitoring plan for fisheries but not necessarily ecosystem based fishery	Region developed monitoring plan relative to EBFM can be identified	Regional monitoring plan for fisheries but not necessarily ecosystem based fishery
Assess the ecological, human and institutional elements of the ecosystem which most significantly affect the fisheries, and are outside Council/ NMFS jurisdiction and	Limited or no response to external influences	Region discusses but has limited engagement with outside influences	Region discusses but has limited engagement with outside influences	Fully proactive plan with respect to outside impacts	Fully proactive plan with respect to outside impacts	No plan but region is responsive to threats as they arise	Fully proactive plan with respect to outside impacts	Fully proactive plan with respect to outside impacts (C)

define a strategy to address those influences.								
Is there a Fishery Ecosystem Plan/Fishery Management Plan employing EBFM?	Discussion of FEP or FMP for relevant ecosystem	FEP or FMP covering significant portions of the relevant ecosystem	Discussion of FEP or FMP for relevant ecosystem	FEP or FMP covering significant portions of the relevant ecosystem	*FEP or thorough FMP using EBFM for the relevant ecosystem	FEP or thorough FMP using EBFM for the relevant ecosystem	FEP or thorough FMP using EBFM for the relevant ecosystem	FEP or thorough FMP using EBFM for the relevant ecosystem
Does the Council have a lead entity designated to advance EBFM in the Council process?	No lead entity and limited or no discussion	Being developed	Yes, proactive lead in developing EBFM actions for Council	Yes, proactive lead in developing EBFM actions for Council	Yes, proactive lead in developing EBFM actions for Council	Yes, proactive lead in developing EBFM actions for Council	Yes, proactive lead in developing EBFM actions for Council	Yes, proactive lead in developing EBFM actions for Council
Are ecosystem models developed and available for use in the Council process?	No discussion or use of models	Use of models is under discussion / development	Yes, models available but not in use	Yes, models available and in use	Yes, models available and in use	Yes, models available and in use	Yes, models available and in use	Use of models is under discussion / development
Are decision support tools for EBFM/trade-off analysis	No discussion and no use of formal tools	Yes to some of the elements	Yes to some of the elements	Yes to some of the elements	Yes to some of the elements	Yes to some of the elements	Yes to some of the elements	Some or all elements under discussion

employed (e.g., management strategy evaluation, risk assessments, ecosystem indicators and scenarios)?								
To what extent are spatial management tools applied (besides EFH measures above) to accomplish EBFM?	Some spatial management tools applied as well to EFH	Some spatial management tools applied as well to EFH	Some spatial management tools applied as well to EFH	Significant spatial management tools applied as well to EFH	Significant spatial management tools applied as well to EFH	Significant spatial management tools applied as well to EFH	Significant spatial management tools applied as well to EFH	Some spatial management tools applied as well to EFH
Other					ACL-Cap on Total Removals BS/GOA	EBFM Initiative Agenda for Council		Archipelagic FMPs

Source:
Ecosystem Sciences and Management Working Group. 2014. "Exploration of Ecosystem Based Fishery Management in the United States." NOAA Science Advisory Board.

Appendix C: Great Lakes Commercial Fishing Data.

List of commercial fisheries catch data in the Great Lakes from U.S fisheries. Including whether or not the fishery is assessed in some way and whether or not it is a targeted fishery.

Lake	Species	U.S Catch in 2012 (lbs)	Value of U.S Landing (U.S $)	Level of Assessment	Targeted Fishery in U.S or Canada
ERIE	BIGMOUTH BUFFALO	530,085	248,114	Not Assessed	Yes
ERIE	BOWFIN	1,915	959	Not Assessed	No
ERIE	BROWN BULLHEAD	48,592	17,560	Not Assessed	Yes
ERIE	BURBOT	1,140	1,115	Assessed	No
ERIE	CARP	709,350	187,615	Not Assessed	Yes
ERIE	CHANNEL CATFISH	507,841	199,867	Not Assessed	Yes
ERIE	FRESHWATER DRUM	653,057	159,217	Not Assessed	Yes
ERIE	GIZZARD SHAD	141,034	23,064	Assessed	Yes
ERIE	GOLDFISH	99,073	81,699	Not Assessed	No
ERIE	LAKE WHITEFISH	126,323	130,377	Assessed	Yes
ERIE	MINNOWS	19,612	66,288	Assessed	No
ERIE	QUILLBACK	230,468	64,164	Not Assessed	Yes
ERIE	RAINBOW SMELT	54	54	Assessed	Yes
ERIE	ROCKBASS	210	0	Not Assessed	No
ERIE	SMALLMOUTH BASS	84	0	Not Assessed	No
ERIE	SUCKERS	33,173	5,532	Not Assessed	No
ERIE	SUNFISH AND BASS	48	0	Not Assessed	No
ERIE	WALLEYE	53	183	Assessed	Yes
ERIE	WHITE BASS	586,306	443,028	Not Assessed	Yes
ERIE	WHITE PERCH	825,596	375,256	Assessed	Yes

ERIE	WHITE SUCKER	390	332	Not Assessed	No
ERIE	YELLOW PERCH	1,787,851	4,539,891	Assessed	Yes
-- Lake Total --		6,302,256	6,544,315		
HURON	BIGMOUTH BUFFALO	5,291	2,487	Not Assessed	No
HURON	BROWN BULLHEAD	824	387	Not Assessed	No
HURON	BURBOT	479	479	Not Assessed	No
HURON	CARP	9,621	2,602	Not Assessed	No
HURON	CHANNEL CATFISH	164,782	84,043	Not Assessed	Yes
HURON	CHINOOK SALMON	185,403	158,625	Assessed	Yes
HURON	CISCO (LAKE HERRING)	26,617	13,863	Assessed	Yes
HURON	CRAPPIES	583	1,435	Not Assessed	No
HURON	FRESHWATER DRUM	33,308	7,332	Not Assessed	No
HURON	LAKE TROUT	297,617	161,287	Assessed	Yes
HURON	LAKE WHITEFISH	1,961,923	2,757,729	Assessed	Yes
HURON	QUILLBACK	27,894	8,929	Not Assessed	No
HURON	ROCKBASS	1,688	1,549	Not Assessed	No
HURON	ROUND WHITEFISH	6,439	3,556	Not Assessed	No
HURON	SUCKERS	5,684	1,080	Assessed	No
HURON	WALLEYE	25,814	57,359	Assessed	Yes
HURON	WHITE BASS	4,545	3,139	Not Assessed	No
HURON	WHITE PERCH	2,721	1,333	Assessed	No
HURON	YELLOW PERCH	86,465	218,742	Assessed	Yes

-- Lake Total --		2,847,698	3,485,956		
MICHIGAN	ALEWIFE	41,590	4,163	Assessed	No (Allowed to be sold if caught as bycatch)
MICHIGAN	BURBOT	12,108	4,286	Assessed	No
MICHIGAN	CARP	109	30	Not Assessed	No
MICHIGAN	CHANNEL CATFISH	628	2,366	Not Assessed	No
MICHIGAN	CHINOOK SALMON	3,399	2,370	Assessed	Yes
MICHIGAN	CHUBS	27,448	82,733	Assessed	Yes
MICHIGAN	CISCO (LAKE HERRING)	510	302	Not Assessed	No
MICHIGAN	FRESHWATER DRUM	3,053	1,047	Not Assessed	No
MICHIGAN	LAKE TROUT	506,783	282,434	Assessed	Yes
MICHIGAN	LAKE WHITEFISH	5,014,597	8,601,851	Assessed	Yes
MICHIGAN	RAINBOW SMELT	32,417	129,668	Assessed	Yes
MICHIGAN	ROUND WHITEFISH	4,275	2,531	Not Assessed	Yes
MICHIGAN	SUCKERS	2,773	1,823	Not Assessed	Yes
MICHIGAN	WALLEYE	9,193	17,304	Not Assessed	No
MICHIGAN	WHITE BASS	162	106	Not Assessed	No
MICHIGAN	WHITE PERCH	399	203	Not Assessed	No
MICHIGAN	YELLOW PERCH	66,177	165,500	Assessed	Yes
-- Lake Total --		5,725,621	9,298,717		
ONTARIO	BROWN BULLHEAD	105	0	Not Assessed	Yes

ONTARIO	CISCO (LAKE HERRING)	44	0	Assessed	No
ONTARIO	WHITE PERCH	1,130	763	Assessed	Yes
ONTARIO	WHITEFISHES	18	0	Not Assessed	Yes
ONTARIO	YELLOW PERCH	59,989	92,149	Assessed	Yes
-- Lake Total --		61,286	92,912		
SUPERIOR	BURBOT	442	107	Assessed	No
SUPERIOR	CHUBS	69,174	142,182	Assessed	Yes
SUPERIOR	CISCO (LAKE HERRING)	1,579,418	1,233,221	Assessed	Yes
SUPERIOR	COHO SALMON	5,761	3,122	Assessed	No
SUPERIOR	LAKE TROUT	164,548	87,389	Assessed	Yes
SUPERIOR	LAKE WHITEFISH	1,745,827	2,019,657	Assessed	Yes
SUPERIOR	RAINBOW SMELT	80,864	55,252	Assessed	Yes
SUPERIOR	ROUND WHITEFISH	206	84	Not Assessed	No
SUPERIOR	SISCOWET (FAT TROUT)	140,022	56,631	Assessed	Yes
SUPERIOR	SUCKERS	1,090	279	Not Assessed	No
SUPERIOR	WALLEYE	1,191	2,529	Not Assessed	No
-- Lake Total --		3,788,543	3,600,453		
-- Year Total --		18,725,404	23,022,353		

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Appendix D: Ecosystem Indicators for the State of the Great Lakes.

List of ecosystem indicators used by the State of the Great Lakes Ecosystem Conference to assess the Great Lakes as taken from the State of the Great Lakes report 2007. (Environment Canada and the U.S EPA 2007)

ID #	Indicator Name	2007 Assessment (Status, Trend)	2005 Assessment (Status, Trend)	2003 Assessment	2001 Assessment
CONTAMINATION					
Nutrients					
111	Phosphorus Concentrations and Loadings	Open Lake: Mixed, Undetermined Nearshore: Poor, Undetermined	Mixed, Undetermined	Mixed	Mixed
4860	*Phosphorus and Nitrogen Levels (Coastal Wetlands)*				
7061	Nutrient Management Plans	N/A (2005 report)	N/A	N/A	
Toxics in Biota					
114	Contaminants in Young-of-the-Year Spottail Shiners	Mixed, Improving	Mixed, Improving	Mixed Improving	
115	Contaminants in Colonial Nesting Waterbirds	Mixed, Improving	Mixed, Improving	Mixed Improving	Good
121	Contaminants in Whole Fish	Mixed, Improving	Mixed, Improving	N/A	
124	External Anomaly Prevalence Index for Nearshore Fish	Poor, Unchanging	Poor-Mixed, Undetermined	N/A (#101)	
4177	Biologic Markers of Human Exposure to Persistent Chemicals	Not Assessed, Undetermined	Mixed, Undetermined		
4201	Contaminants in Sport Fish	Mixed, Improving	Mixed, Improving	Mixed Improving (#4083)	Mixed Improving (#4083)
4506	Contaminants in Snapping Turtle Eggs	Mixed, Undetermined	Mixed, N/A	Mixed	Mixed
8135	Contaminants Affecting Productivity of Bald Eagles	Mixed, Improving (2005 report)	Mixed, Improving	Mixed Improving	Mixed Improving
8147	Population Monitoring and Contaminants Affecting the American Otter	Mixed, Undetermined (2003 report)	Mixed, Undetermined (2003 report)	Mixed	N/A
Toxics in Media					
117	Atmospheric Deposition of Toxic Chemicals	Mixed, Improving & Mixed, Unchanging/ Improving	Mixed, Improving & Mixed, Unchanging	Mixed	Mixed Improving
118	Toxic Chemical Concentrations in Offshore Waters	Mixed, Undetermined	Mixed, Improving	Mixed Improving	Mixed
119	Concentrations of Contaminants in Sediment Cores	Mixed, Improving/ Undetermined	Mixed, Improving	Mixed Improving	
4175	Drinking Water Quality	Good, Unchanging	Good, Unchanging	Good	Good
4202	Air Quality	Mixed, Improving	Mixed, Improving	Mixed (#4176)	Mixed (#4176)
9000	Acid Rain	Mixed, Improving (2005 report)	Mixed, Improving	Mixed Improving	Mixed
Sources and Loadings					
117	Atmospheric Deposition of Toxic Chemicals	Mixed, Improving & Mixed, Unchanging/ Improving	Mixed, Improving & Mixed, Unchanging	Mixed	Mixed Improving
4202	Air Quality	Mixed, Improving	Mixed, Improving	Mixed (#4176)	Mixed (#4176)
7065	Wastewater Treatment and Pollution	N/A Progress Report			
9000	Acid Rain	Mixed, Improving (2005 report)	Mixed, Improving	Mixed Improving	Mixed

N/A = Not Assessed; Number in brackets indicates related indicator; Reports are currently unavailable for the indicators in italics.

ID #	Indicator Name	2007 Assessment (Status, Trend)	2005 Assessment (Status, Trend)	2003 Assessment	2001 Assessment
BIOTIC COMMUNITIES					
Fish					
8	Salmon and Trout	Mixed, Improving	Mixed, Improving	Mixed	
9	Walleye	Fair, Unchanging	Good, Unchanging	Mixed	Good
17	Preyfish Populations	Mixed, Deteriorating	Mixed, Deteriorating & Mixed, Improving	Mixed Deteriorating	Mixed Improving
93	Lake Trout	Mixed, Unchanging	Mixed, Improving & Mixed, Unchanging	Mixed	Mixed
125	Status of Lake Sturgeon in the Great Lakes	Mixed, Improving	Mixed, Undetermined	N/A	
4502	Coastal Wetland Fish Community Health	N/A Progress Report	N/A		
Birds					
115	Contaminants in Colonial Nesting Waterbirds	Mixed, Improving	Mixed, Improving	Mixed Improving	Good
4507	Wetland-Dependent Bird Diversity and Abundance	Mixed, Deteriorating	Mixed, Deteriorating	Mixed Deteriorating	Mixed Deteriorating
8135	Contaminants Affecting Productivity of Bald Eagles	Mixed, Improving (2005 report)	Mixed, Improving	Mixed Improving	Mixed Improving
8150	*Breeding Bird Diversity and Abundance*				
Mammals					
8147	Population Monitoring and Contaminants Affecting the American Otter	Mixed, Undetermined (2003 report)	Mixed, Undetermined (2003 report)	Mixed	N/A
Amphibians					
4504	Coastal Wetland Amphibian Diversity and Abundance	Mixed, Deteriorating	Mixed, Deteriorating	Mixed Deteriorating	Mixed Deteriorating
7103	Groundwater Dependant Plant and Animal Communities	N/A (2005 report)	N/A		
Invertebrates					
68	Native Freshwater Mussels	N/A (2005 report)	N/A	N/A	Mixed Deteriorating
104	Benthos Diversity and Abundance - Aquatic Oligochaete Communities	Mixed, Unchanging/ Deteriorating	Mixed, Undetermined (2003 report)	Mixed	
116	Zooplankon Populations	Mixed, Undetermined	N/A (2003 report)	N/A	Mixed
122	Hexagenia	Mixed, Improving	Mixed, Improving	Mixed Improving	Mixed Improving
123	Abundances of the Benthic Amphipod *Diporeia* spp.	Mixed, Deteriorating	Mixed, Deteriorating	Mixed Deteriorating	Mixed
4501	Coastal Wetland Invertebrate Community Health	N/A (2005 Progress Report)	N/A Progress Report		
Plants					
109	Phytoplankton Populations	Mixed, Undetermined (2003 report)	Mixed, Undetermined (2003 report)	Mixed	Mixed
4862	Coastal Wetland Plant Community Health	Mixed, Undetermined	Mixed, Undetermined		
8162	*Health of Terrestrial Plant Communities*				
8500	Forest Lands - Conservation of Biological Diversity	Mixed, Undetermined	Mixed, Improving		

N/A = Not Assessed; Number in brackets indicates related indicator; Reports are currently unavailable for the indicators in italics.

ID #	Indicator Name	2007 Assessment (Status, Trend)	2005 Assessment (Status, Trend)	2003 Assessment	2001 Assessment
BIOTIC COMMUNITIES (continued)					
General					
8114	*Habitat Fragmentation*				
8137	*Nearshore Species Diversity and Stability*				
8161	*Threatened Species*				
8163	*Status and Protection of Special Places and Species*				
INVASIVE SPECIES					
Aquatic					
18	Sea Lamprey	Good-Fair, Improving (2005 Report)	Good-Fair, Improving	Mixed Improving	Mixed
9002	Non-Native Species (Aquatic)	Poor, Deteriorating	Poor, Deteriorating	Poor	Poor
Terrestrial					
9002	Non-Native Species (Terrestrial)	N/A, Undetermined			
COASTAL ZONES					
Nearshore Aquatic					
6	*Fish Habitat*				
4860	*Phosphorus and Nitrogen Levels (Coastal Wetlands)*				
4861	Effects of Water Level Fluctuations	Mixed, N/A (2003 Report)	Mixed, N/A (2003 report)	Mixed	Mixed Deteriorating
4864	*Human Impact Measures (Coastal Wetlands)*				
8131	Extent of Hardened Shoreline	Mixed, Deteriorating (2001 Report)	Mixed, Deteriorating (2001 report)	Mixed Deteriorating (2001 report)	Mixed Deteriorating
8142	*Sediment Available for Coastal Nourishment*				
8146	*[illegible]*				
Coastal Wetlands					
4501	Coastal Wetland Invertebrate Community Health	N/A (2005 Progress Report)	N/A Progress Report		
4502	Coastal Wetland Fish Community Health	N/A Progress Report	N/A		
4504	Coastal Wetland Amphibian Diversity and Abundance	Mixed, Deteriorating	Mixed, Deteriorating	Mixed Deteriorating	Mixed Deteriorating
4506	Contaminants in Snapping Turtle Eggs	Mixed, Undetermined	Mixed, N/A	Mixed	Mixed
4507	Wetland-Dependent Bird Diversity and Abundance	Mixed, Deteriorating	Mixed, Deteriorating	Mixed Deteriorating	Mixed Deteriorating
4510	Coastal Wetland Area by Type	Mixed, Deteriorating	Mixed, Deteriorating	(2001 report)	Mixed Deteriorating
4511	*Coastal Wetland Restored Area by Type*				
4516	*Sediment Flowing into Coastal Wetlands*				
4860	*Phosphorus and Nitrogen Levels*				
4861	Effects of Water Level Fluctuations	Mixed, N/A (2003 Report)	Mixed, N/A (2003 report)	Mixed	Mixed Deteriorating
4862	Coastal Wetland Plant Community Health	Mixed, Undetermined	Mixed, Undetermined		
4863	Land Cover Adjacent to Coastal Wetlands	N/A Progress Report			
4864	*Human Impact Measures*				
8142	*Sediment Available for Coastal Nourishment*				

N/A = Not Assessed; Number in brackets indicates related indicator; Reports are currently unavailable for the indicators in italics.

ID #	Indicator Name	2007 Assessment (Status, Trend)	2005 Assessment (Status, Trend)	2003 Assessment	2001 Assessment
COASTAL ZONES (continued)					
Terrestrial					
4861	Effects of Water Level Fluctuations	Mixed, N/A (2003 Report)	Mixed, N/A (2003 report)	Mixed	Mixed Deteriorating
4864	*Human Impact Measures (Coastal Wetlands)*				
8129	Area, Quality, and Protection of Special Lakeshore Communities - Alvars	Mixed, Undetermined (2001 Report)	Mixed, Undetermined (2001 report)	Mixed (2001 report)	Mixed
8129	Area, Quality, and Protection of Special Lakeshore Communities - Islands	Mixed, Undetermined			
8129	Area, Quality, and Protection of Special Lakeshore Communities - Cobble Beaches	Mixed, Deteriorating (2005 Report)	Mixed, Deteriorating		
8129	Area, Quality, and Protection of Special Lakeshore Communities - Sand Dunes	N/A (2005 Progress Report)	N/A Progress Report		
8131	Extent of Hardened Shoreline	Mixed, Deteriorating (2001 Report)	Mixed, Deteriorating (2001 Report)	Mixed Deteriorating (2001 Report)	Mixed Deteriorating
8132	*Nearshore Land Use*				
8136	*Extent and Quality of Nearshore Natural Land Cover*				
8137	*Nearshore Species Diversity and Stability*				
8142	*Sediment Available for Coastal Nourishment*				
8149	*Protected Nearshore Areas*				
AQUATIC HABITATS					
Open Lake					
6	*Fish Habitat*				
111	Phosphorus Concentrations and Loadings	Open Lake: Mixed, Undetermined Nearshore: Poor, Undetermined	Mixed	Mixed	Mixed
118	Toxic Chemical Concentrations in Offshore Waters	Mixed, Improving	Mixed, Improving	Mixed Improving	Mixed
119	Concentrations of Contaminants in Sediment Cores	Mixed, Improving/ Undetermined	Mixed, Improving	Mixed Improving	
8131	Extent of Hardened Shoreline	Mixed, Deteriorating (2001 Report)	Mixed, Deteriorating (2001 Report)	Mixed Deteriorating (2001 Report)	Mixed Deteriorating
8142	*Sediment Available for Coastal Nourishment*				
8146	[illegible]				
Groundwater					
7100	Natural Groundwater Quality and Human-Induced Changes	N/A (2005 Report)	N/A	N/A	
7101	Groundwater and Land: Use and Intensity	N/A (2005 Report)	N/A	N/A	
7102	Base Flow Due to Groundwater Discharge	Mixed, Deteriorating	Mixed, Deteriorating	N/A	
7103	Groundwater Dependant Plant and Animal Communities	N/A (2005 Report)	N/A		

N/A = Not Assessed; Number in brackets indicates related indicator; Reports are currently unavailable for the indicators in italics.

ID #	Indicator Name	2007 Assessment (Status, Trend)	2005 Assessment (Status, Trend)	2003 Assessment	2001 Assessment
HUMAN HEALTH					
4175	Drinking Water Quality	Good, Unchanging	Good, Unchanging	Good	Good
4177	Biologic Markers of Human Exposure to Persistent Chemicals	N/A, Undetermined	Mixed, Undetermined		
4179	*Geographic Patterns and Trends in Disease Incidence*				
4200	Beach Advisories, Postings and Closures	Mixed, Undetermined	Mixed, Undetermined	Mixed (#4081)	Mixed (#4081)
4201	Contaminants in Sport Fish	Mixed, Improving	Mixed, Improving	Mixed Improving (#4083)	Mixed Improving (#4083)
4202	Air Quality	Mixed, Improving	Mixed, Improving	Mixed (#4176)	Mixed (#4176)
LAND USE - LAND COVER					
General					
4863	Land Cover Adjacent to Coastal Wetlands	N/A Progress Report			
7002	Land Cover - Land Conversion	Mixed, Undetermined	N/A		
7101	Groundwater and Land: Use and Intensity	N/A (2005 Report)	N/A	N/A	
8114	*Habitat Fragmentation*				
8132	*Nearshore Land Use*				
8136	*Extent and Quality of Nearshore Natural Land Cover*				
Forest Lands					
8500	Forest Lands - Conservation of Biological Diversity	Mixed, Undetermined	Mixed, Improving		
8501	Forest Lands - Maintenance and Productive Capacity of Forest Ecosystems	N/A, Undetermined			
8502	*Maintenance of Forest Ecosystem Health and Vitality*				
8503	Forest Lands - Conservation & Maintenance of Soil & Water Resources	Mixed, Undetermined			
Agricultural Lands					
7028	Sustainable Agriculture Practices	N/A (2005 Report)	N/A	N/A	Mixed
7061	Nutrient Management Plans	N/A (2005 Report)	N/A		
7062	Integrated Pest Management	N/A (2005 Report)	N/A		
Urban/Suburban Lands					
7000	Urban Density	Mixed, Undetermined	Mixed, N/A	Mixed Deteriorating	Unable to Assess
7006	Brownfields Redevelopment	Mixed, Improving	Mixed, Improving (2003 report)	Mixed Improving	Mixed Improving
7054	Ground Surface Hardening	N/A (2005 Progress Report)	N/A Progress Report		

N/A = Not Assessed; Number in brackets indicates related indicator; Reports are currently unavailable for the indicators in italics.

ID #	Indicator Name	2007 Assessment (Status, Trend)	2005 Assessment (Status, Trend)	2003 Assessment	2001 Assessment
LAND USE - LAND COVER (continued)					
Protected Areas					
8129	Area, Quality, and Protection of Special Lakeshore Communities - Alvars	Mixed, Undetermined (2001 Report)	Mixed, Undetermined (2001 report)	Mixed (2001 report)	Mixed
8129	Area, Quality, and Protection of Special Lakeshore Communities - Islands	Mixed, Undetermined			
8129	Area, Quality, and Protection of Special Lakeshore Communities - Cobble Beaches	Mixed, Deteriorating (2005 Report)	Mixed, Deteriorating		
8129	Area, Quality, and Protection of Special Lakeshore Communities - Sand Dunes	N/A (2005 Progress Report)	N/A Progress Report		
8149	*Protected Nearshore Areas*				
8163	*Status and Protection of Special Places and Species*				
RESOURCE UTILIZATION					
3514	Commercial/Industrial Eco-Efficiency Measures	N/A (2003 Report)	N/A (2003 report)	N/A	
3516	*Household Stormwater Recycling*				
7043	Economic Prosperity	Mixed, Undetermined (2003 Report)	Mixed, Undetermined (2003 report)	Mixed (L. Superior basin)	Mixed
7056	Water Withdrawals	Mixed, Unchanging (2005 Report)	Mixed, Unchanging		
7057	Energy Consumption	Mixed, N/A (2005 Report)	Mixed, N/A	Mixed Deteriorating	
7060	Solid Waste Disposal	N/A, Undetermined	Mixed (2003 report)	Mixed	
7064	Vehicle Use	Poor, Deteriorating			
7065	Wastewater Treatment and Pollution	N/A Progress Report			
CLIMATE CHANGE					
4858	Climate Change: Ice Duration on the Great Lakes	Mixed, Deteriorating	Mixed, Deteriorating (2003 report)	Mixed Deteriorating	
9003	*Climate Change: Effect on Crop Heat Units*				
PROPOSED INDICATOR					
8164	Biodiversity Conservation Sites	N/A, Undetermined			

N/A = Not Assessed; Number in brackets indicates related indicator; Reports are currently unavailable for the indicators in italics.

Source:

Environment Canada and the U.S EPA. 2007. “State of the Great Lakes.” The Government of Canada and The United States of America.

Appendix E: Quantitative Assessment of Actions for Great Lakes and Federal Fisheries.

Quantitative Assessment of Actions for Great Lakes and Federal Fisheries										
Actions	Great Lakes	Average Federal	Caribbean	Gulf of Mexico	Mid-Atlantic	New England	North Pacific	Pacific	South Atlantic	Western Pacific
Cease overfishing and develop rebuilding plans for overfished species	4	3.25	4	3	4	3	4	4	2	2
Delineate extent of ecosystem/ interactions	4	3.375	2	2	3	4	4	4	4	4
Develop a conceptual model of the foodweb	4	3.625	2	4	3	4	4	4	4	4
Describe habitat needs of different life history stages of animals and plants in the "significant foodweb" and develop	3	3.25	2	2	4	4	4	4	4	2

conservation measures										
Calculate total removals – including incidental mortality and relate them to standing biomass, production, optimum yields, natural mortality and trophic structure	2	1.75	2	2	1	2	2	2	2	1
Assess how uncertainty is characterized and define what buffers against uncertainty are included in management actions	3	3	3	3	3	3	3	3	3	3
Set ecosystem goal and develop indices of	3	2	2	2	2	2	2	2	2	2

ecosystem health as targets for management?										
Describe long term monitoring data and how they are used.	4	3.25	2	3	3	4	4	3	4	3
Assess the ecological, human and institutional elements of the ecosystem, which most significantly affect fisheries, and are outside Council/NMFS /Lake Management jurisdiction and define a strategy to address those influences.	4	3	1	2	2	4	4	3	4	4

Is there a Fishery Ecosystem Plan/ Fishery Management Plan/Lakewide Management Plans (LaMPs) employing EBFM?	4	3.25	2	3	2	3	4	4	4	4
Do the Lake Committees or Fishery Commission have a lead entity designated to advance EBFM in the management process?	4	3.375	1	2	4	4	4	4	4	4
Are ecosystem models developed and available for use in the Lake Council/GLFC process?	3	3	1	2	3	4	4	4	4	2
Are decision support tools	3	2	1	2	2	2	2	2	2	3

for EBFM / trade-off analysis employed [e.g., management strategy evaluation, risk assessments, ecosystem indicators, and scenarios?										
To what extent are spatial management tools applied (besides Essential Fish Habitat measures above) to accomplish EBFM? Or in the case of the Great Lakes what extent are spatial management tools applied including any Essential Fish Habitat	3	3.5	3	3	3	4	4	4	4	3

measures to accomplish EBFM?										
Other – Unique actions furthering EBFM	4	1.375	1	1	1	1	2	2	1	2
Total	52	43	29	36	40	48	51	49	48	43

Source:
Ecosystem Sciences and Management Working Group. 2014. "Exploration of Ecosystem Based Fishery Management in the United States." NOAA Science Advisory Board.