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POLICY IMPLICATIONS OF MANAGING BIODIVERSITY AND NATURAL RESOURCES ACROSS INTERNATIONAL BOUNDARIES

by

Dillon Paul Brown

A Dissertation
Submitted to the Graduate School,
the College of Arts and Sciences
and the School of Social Science and Global Studies
at The University of Southern Mississippi
in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy

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ABSTRACT

Fisheries Management under the best of scenarios is a complex action. It requires thoughtful consideration of resources that tend to be out of sight, widely distributed, highly variable both spatially and temporally, and present dramatic variation in life history and ecology. No one management approach has been developed which can effectively incorporate all these variables. Add to this the issue of transnational boundary movements of these resources, and one discovers that this complex issue needs to be addressed by multiple entities, agencies, and nations to have any chance of success.

This research set out to discover ways in which fisheries management could be improved across transnational boundaries. With a multi-tiered approach, using interviews, surveys, and literature review, I discovered the state of cooperative management on transnational fisheries management in the populations of Lake Trout (a success) and Atlantic Cod (a failure) that occur in the United States and Canada as case studies. Fishery management decisions were not being guided by the life histories of fish, stakeholders are generally well informed on fisheries actions that are occurring across borders, and there is a lack of commitment from governments to make sacrifices to reduce overfishing.

Ultimately, fisheries management is people management because politics, socioeconomics, public perceptions, as well as available science must all be considered. Data from this research then provides rationale for a series of recommendations for policy action which can broadly be applied to further improve transnational fisheries management into the future so that we can reliably reproduce the success of trout management and avoid the failures of cod management. The lessons learned, and policy

prescriptions, should be transferable to co-management of other transnational fisheries populations across international borders.

ACKNOWLEDGMENTS

The author would like to acknowledge the substantial support and professional guidance received from Dr. David Butler, who previously had served as a faculty advisor prior to moving on to a different position at another academic institution. Dr. Butler was exceptionally helpful even after departing and his advice, insights, and wisdom were certainly appreciated.

DEDICATION

This work is dedicated to six brilliant women. The first, my exceptional wife Melanie. For nearly two decades, her love, support, encouragement, feedback, and persistent oversight kept me grounded. One of the most wonderful people I have ever known, she is both exceedingly intelligent and exceptionally kind. She was invaluable in making this project possible and thinking about how to move the project forward when it stalled. Second, my daughters Emma and Ona, who have taught me how to be a better person, showed me what is truly important in life, and kept me determined to succeed. Third, my oldest friend Amanda, who gave me the kick which was needed toward the end to finish. Fourth, my sister Amy, who has always reminded me to push myself and do my best. Finally, my mom Michele, who has selflessly given more of herself to those around her than she ever received. My mom is my greatest cheerleader and one of the wisest people I have ever met. Early on she imparted in me the desire to learn everything I could about the world around us. I would not be where I am today if it were not for the support, wisdom, kindness, and love of these amazing people. Thank you.

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LIST OF ABBREVIATIONS

AGC	Atlantic Groundfish Council
CPUE	Catch per Unit Effort
FA	Fisheries Act
FAO	Food and Agriculture Organization of the United Nations
FIP	Fisheries Improvement Project
GLFC	Great Lakes Fishery Commission
IGO	Inter-Governmental Organizations
IMTA	Integrated Multi-Trophic Aquaculture
IRB	Institutional Review Board
IUCN	International Union for the Conservation of Nature
IUU	Illegal, Unregulated, and Unreported
MSA	Magnuson-Stevens Fishery Conservation and Management Act
MSC	Marine Stewardship Council
MSY	Maximum Sustainable Yield
NGO	Non-Governmental Organization
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
TAC	Total Allowable Catch

UNCED	United Nations Conference on Environment and Development
UNCLOS	United Nations Convention on the Law of the Sea
UNFSA	United Nations Fish Stock Agreement
USFWS	U.S. Fish and Wildlife Service
USM	The University of Southern Mississippi

CHAPTER I – INTRODUCTION

Specification of Topic

Fisheries Management under the best of scenarios is a complex action. It requires thoughtful consideration of resources that tend to be out of sight, widely distributed, highly variable both spatially and temporally, and present dramatic variation in life history and ecology. No one management approach has been developed that can effectively incorporate all these variables. Add to this the issue of transnational boundary movements of these resources, and one discovers that this complex issue needs to be addressed by multiple entities, agencies, and states to have any chance of success. With this understanding, we must ask ourselves how nations do (or do not) work cooperatively in order to manage natural resources (fishes) that move across international boundaries.

This dissertation research attempts to discover new ways in which fisheries management could be improved across transnational boundaries. Employing a multi-tiered approach using interviews, surveys, the research will shed light on the state of cooperative management on transnational fisheries management using the populations of Lake Trout and Atlantic Cod that occur in the United States and Canada as case studies. Lake Trout in the Great Lakes region are considered a fisheries management success, while Atlantic Cod are considered a failure.

How can two countries, and two fisheries management scenarios, be so divergent in their outcomes? By understanding the insights from these case studies, and the opinions and knowledge of managers, policy makers, fishermen, and scientists, this dissertation intends to provide direction for policy action, which can broadly be applied

to further improve transnational fisheries management into the future so that we can reliably reproduce the success of trout management and avoid the failures of cod management. The lessons learned, and policy prescriptions, should be transferable to co-management of other transnational fisheries populations across international borders.

Specification of Research Questions and Hypotheses

The dissertation addresses the following central research question. Why do states not have uniform outcomes in fisheries management? In response to that question, the following three hypotheses will be presented and tested. First, the failure of policymakers and practitioners to take into account the biology (the natural ecology and life histories) of species and treat all fish as the same, results in mismanagement of fishery stocks. Second, these same officials do not take stock of their actions (and those of their constituents) relative to those of their international neighbors—falling into a classic tragedy of the commons, where all parties seek to maximize their own catches despite dwindling resources. Policymakers' emphasis on their own fishing interests relative to those of competing states results in the diminution of global fishery stocks. Third, the four Cs (Concern—Is there a problem?; Cooperation-Should/Do we work together?; Coordination—Do we work toward common goals?; and Commitment—Is there will to make sacrifices to the greater good?) are addressed at various, and often low, levels within the governmental hierarchy, with biologists and local managers using some or all of them, while senior officials and those at higher levels fail to do so. This is because policymakers are inundated with many other stakeholders and ultimately base policy decisions on economics rather than biology, choosing to listen to lobbyists and ignoring

the advice of working level biologists and managers in making decisions on fishery management matters.

The extent to which these hypotheses are valid will help to explain why policy makers and practitioners know overfishing is a problem yet continue to have the inability or lack the political will to alter human behavior. As Daniel Pauly and his colleagues (2009, 1998) have eloquently stated we continue to, "fish down the food web"— the concept that fisheries, faced with declining catches of previously harvested species, switch to invertebrates and smaller (previously undesirable) fish to maintain the same (unsustainable) level of fisheries catches.

The United States and Canada share a vast border, which is largely unregulated. This laxity of border control is a testament to the innumerable ways these two nations interact in highly collaborative and peaceful ways. There have been long-standing treaties in place that regulate the intergovernmental relations, trade, border control, and virtually all aspects of cooperation between these countries (including fisheries). As a result, there has historically been little need for international institutions (e.g., United Nations, International Monetary Fund, World Trade Organization) to assist in monitoring the ground conditions. However, the continued decline of some fisheries stocks that cross the boundaries between these countries, and the limited success which has been demonstrated by treaties and their enforcement may demonstrate a need to incorporate international institutions, inter-governmental organizations (IGOs), and non-governmental organizations (NGOs) to help facilitate multilateral cooperation on natural resource management for commodities (i.e., fishes) that have mobility and can freely cross the boundaries between the United States and Canada. The extent of the explanatory value

of neo-liberal institutionalism will be addressed in this context to try to explain the current conditions and formulate a best management practice for cooperative regulation.

Contributions to the Extant Literature

The lessons learned, and policy prescriptions, should be transferable to the management of other transnational fisheries populations across international borders. There is a robust literature on fisheries management. Additionally, the scholarship regarding policy is equally voluminous. Yet, very little of the existing literature seeks to understand the nexus between the biology and the policy as it relates to the management of fisheries species. An understanding between the two fields will help all parties engaged in this effort with the 4 Cs (concern, cooperation, coordination, and commitment). It will allow policy makers to better understand the nuances of species life history and the importance and uncertainty of biological data, and it will help scientists and managers to better understand the complexities of politics and social requirements. All stakeholders will be able to understand how to recognize if and when there is a problem with fisheries stocks, how to work together towards common understanding and goals, and recognize the need for compromise and commitment to achieve the most positive outcomes.

Synopsis of the Methodological Approach

A fundamental question in any social science research design is whether that data to be collected is qualitative or quantitative. Dabbs, for example, contends “quality is essential to the nature of things.” (Dabbs 1982). It focuses on what, when, where, why,

and how. While the quantity, reflects the amount of something. Due to the type of the data to be collected, the topic at hand to be understood, and the nature of collecting data directly from human subjects, this research design will focus predominantly on qualitative information. It will rely on three major data collection methodologies, which are synergistically combined to present robust answers to each of the research questions and assess the extent of the validity of the hypotheses in an objectively measurable fashion. The methods to be employed are content analysis, surveys, and interviews. This technique, known as triangulation, or convergent validation, allows the researcher to garner overlapping data collection techniques to arrive at a more robust answer to the research question (Berg & Lune 2012, Denzin 1978, Campbell & Fiske 1959).

Survey Development- Self-administered Questionnaire

Since the focus of this work will be on fisheries management across international boundary lines, an initial examination of the commercial fishing industry was made with an on-line search engine (www.google.com) with the keywords "commercial fisheries survey questionnaire." Over 212,000 results were returned. Numerous scholarly articles regarding the use of survey questionnaires were returned with the results, as well as examples of surveys which had been, and are currently used, in the United States and abroad.

Clearly the self-administered survey questionnaire methodology is applicable and undertaken in this industry with great frequency to help inform managers and policy makers how best to manage the resources of the region. Based on this simple metric, it can be seen that surveys within the fishing industry are used with some regularity. In fact,

they have been used for decades as a primary data collection methodology in order to garner a wide variety of information. This study focuses on the interview and self-administered questionnaire techniques to gather the research data. The target population for this research is fisheries managers, fish biologists and ecologists, government employees, and potentially political figures from the United States and Canada.

Self-administered questionnaires rely on informants completing questions themselves and tend to be the most burdensome to respondents (Bowling 2005). These questions, like those for other data collection modes, are developed by the researcher to extract certain information from the respondents related to the specific research question. Distribution of the questionnaires was done via on-line e-mail solicitation to various user groups. Given the dispersal of potential respondents, this methodology allows for the greatest potential to reach the target audience. First, the potential user groups were identified and then a point of contact was identified for each group. An e-mail inquiry was sent to the point of contact to determine if they could be of assistance in sending out the on-line survey link to their membership. Once concurrence was granted, the informed consent statement was sent to the point of contact. This statement was included in the email solicitation of the membership and additionally appears on the start page of the on-line survey. This information also lists the Institutional Review Board (IRB) protocol approval for the research to be conducted as well as contact information for those who seek additional information. This method is excellent at reaching large existing audiences and distinct user groups. Biologists and other scientists, resource managers, and fishermen were the key targets.

It is often difficult and impractical, if not impossible, to administer a self-administered questionnaire to all of a given population (Burns et al. 2008, Rubenfeld 2004); in this case all fisheries managers across North America. Therefore, a subset, or sample, of the target population (the sample frame) is usually surveyed rather than trying to census the entire population. Since the sample frame should represent the larger group, various sampling methodologies have been derived to accommodate different types of data that may be collected. Sampling can be based on a randomized (probability) or deliberate (non-probability) design (Burns et al. 2008, Aday & Cornelius 2006). Probability sampling requires that a researcher know the entire extent of the population and can contact them, while non-probability sampling is used when a researcher cannot estimate the chance (probability) of a respondent being included in the sample. Probability sampling is often subdivided into cluster sampling and simple, systematic, and stratified random sampling (Burns et al 2008, Berg & Lune 2012). For the purposes of this research, a non-probability design was employed since as Arlene Fink (2003d) has suggested, non-probability sampling methodology is appropriate in three situations: surveys of specific groups, hard to identify groups, and pilot studies.

The four most common non-probability sampling techniques used in social science are convenience, purposive, snowball, and quota sampling (Berg & Lune 2012). Snowball sampling relies on the interconnectedness of respondents. Once one informant is located, they can provide contact information for further individuals appropriate to the study. In many ways this type of sampling is thus similar to both convenience and purposive sampling. Snowball sampling is often associated with research focusing on sensitive topics, deviance, or other hard to access target populations (Berg & Lune 2012).

Due to the interconnectedness of the target group, this technique will also be employed during the interview process.

Surveys, as a static and fixed instrument, are useful for the collection and comparison of answers. These are compiled and grouped such that respondents can be categorized, and answers aggregated to form overall perspectives and trends. The interview instrument is by design more nuanced and can bring about unforeseen issues and perspectives. Interviews allow the community to provide solicited and unsolicited input which will help to clarify some issues and can provide context to complex issues and can be used in a targeted approach to contact hard to reach participants.

Survey Development- Interviews

Interviews are a structured or purposeful conversation between two people (Oishi 2003) and are designed to elicit a great deal of information from a few individuals. The operative wording of this idea is found within the term purposeful. An interview is not just a conversation with someone. It is a directed research action with the express intent of extracting information relevant to the research question being investigated. This methodology typically relies on great amounts of details (data) from few respondents and is less of a burden on respondents (Bowling 2005).

Interviews for social science research can be divided into standardized, semi-standardized, and unstructured formats, which in turn can be either quantitative or qualitative in respect to the type of data that is being sought out. The semi-standardized format falls somewhere in-between the other two styles with generally structured questions that tend towards being predetermined, but greater flexibility is allowed in the

language used and clarifications can be sought and given. Follow-up questions and digressions are almost expected (Berg & Lune 2012).

Part of the issue with skillful/ artful interviewing is knowing how, when, and why to ask certain questions. The wording matters. Interestingly, an area of agreement with most authors is the avoidance of 'why' questions, as it has been found to make some respondents defensive (Oishi 2003, Berg & Lune 2012). For this research interviews were conducted via telephone and on-line virtual meeting platforms (Google Meet and Microsoft Teams) using a semi-standardized survey instrument this allowed for follow-up questions and deviations to better understand the issues, especially those potentially not previously considered.

Interview participants were identified through literature searches and direct inquiry to various agencies and user groups. State and Provincial policy makers and high-level agency officials were sought and contacted via e-mail to solicit a time for potential interviews and request additional participation. Following the interview, snowball sampling was used to ask the participant who they felt I should discuss the issues with. In nearly every case an additional one to three names and contact information was gleaned for future interview participation. These people were contacted, and the cycle continued.

Interviews were recorded using a digital audio recorder (Sony IC recorder). Upon initiating the interview, the informant was given the informed consent information per USM-IRB Protocol (IRB Protocol Number 22-749) policy. At the termination of the interview the conversation was downloaded to a laptop computer and transcribed into text (using Microsoft Word) by listening to the audio files at 0.25 - 0.3x speed (using Sound Organizer, version 1.5.0.10210) or the downloaded data was outsourced to a third-party

transcription service (datalyst.com). Following either method, once the audio file was transcribed into text it was reviewed for accuracy by following the text file word by word while listening to the audio files. If any discrepancies were found edits were made to the text and the process repeated. These data were used to garner major themes and ideas out of the interviews and relevant quotes that help to elucidate those ideas.

Data Management and Analysis

Data analysis is very variable within self-administered survey instruments as many questions can be analyzed in multiple ways. Simple questions such as those requiring a bimodal response (i.e., yes or no) are correspondingly very simple to analyze. On the opposite end of the spectrum are complex open-ended questions which require the use of textual analysis to provide context to the language used. Although computer software is available to assist in textual analysis, it can be difficult to ensure proper and detailed analysis (Berg & Lune 2012) and was therefore not used with these data.

Data analysis was completed on a question-by-question basis dependent upon the type of question and the type and form of data collected. In general, data was reviewed in an effort to identify themes, trends, and data ranges by looking for the highs and lows and means in the data. More pointedly, what is the most common, least common, and average response to various questions? From these data themes or trends were identified upon which to base conclusions. Textual analysis is considered throughout the data since the majority of the questions have at least some aspect of open-ended response choices (often an ‘other’ category). From the results, data, graphs, charts, and tables are generated to visually represent and display the data.

The data will be analyzed for major themes and ideas useful in addressing the research questions and assessing the validity of the hypotheses. Each interview will be reviewed for concepts that related to fisheries management and its effects on the focal species. Major aspects of intergovernmental cooperation, history, ecology, and policy are the central focal points of this analysis. General themes will be extracted, not only pertinent to the focal species, but also (and more importantly) to themes providing information about the government policy and coordination and thus the necessary context for how the two focal governments manage the transient natural resources.

Dissertation Organizational Structure

The organizational structure of the balance of the dissertation will be as follows: the second chapter presents a comprehensive and detailed review of the extant literature on the topic and explains how the dissertation builds on (and adds to) that literature. The third chapter is a more detailed discussion of the methodologies employed during data collection and the subsequent data analysis. Chapter four is the presentation of evidence (e.g., results of the research). The entirety of the survey results are presented as well as the major themes and findings which were identified from the interviews. Chapter five is an analysis of the evidence presented in chapter four. Finally, chapter six culminates in the conclusions. It discusses the three hypotheses, the meaning and importance of the evidence collected, and how the research has answered the research question.

CHAPTER II – LITERATURE REVIEW

Introduction

Fisheries management is a deep field with a breadth of knowledge and a long history of scholarship. This has led to ample resources and knowledge about a broad range of subjects. The literature is vast. In order to pare down this topic and add meaningfully to the extant literature, this dissertation research is limited to two focal and representative species (figure 1), the Lake Trout (*Salvelinus namaycush*) and the Atlantic Cod (*Gadus morhua*). Both of these species are apex predators in their respective ecosystems and have had actively managed commercial fisheries associated with them for generations. They are well-studied ecologically and thus have an extensive history of management policies and actions taken over time. This will allow a review of what has happened, what is happening, and what should be undertaken to manage these fisheries with past, present, and future policies and regulations.

Fisheries have been utilized, exploited, and managed for millennia. When human populations were small, fish were abundant, and it was unlikely that any amount of fishing pressure could significantly alter fish stocks. Even so, many cultures from across the globe had established fisheries management rules and regulations to prevent mismanagement and overuse (Donda 2018, Utomo 2010, Silvans and Valbo-Jørgensen 2007, Poepoe et al 2007, Johannes 1997). However, as Reverend Thomas Malthus pointed out in the 18th century, the growth of human populations was bound to outweigh the productive capacity of the available resources (i.e., food supply) (Pauly 1990). Two

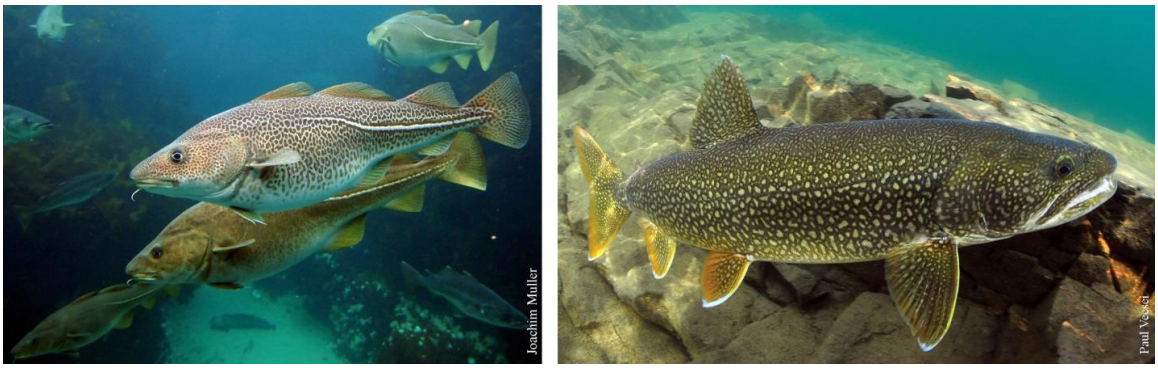

Figure 1. Atlantic Cod (left) are ocean schooling fishes with a distinctive chin barbel[1] *and triple dorsal fins, both clearly evident in the image.*
Lake trout (right) are freshwater fishes that lead solitary lives, but like cod come together to spawn in large aggregations in the same place year after year making them vulnerable to fishing pressure.

centuries later, David Pimentael and colleagues (1997) came to the same conclusions, as have many other researchers (Ritson 2020, Crist and Cafaro 2012, Friedlander et al 2008, Hogan 1992). As resources are overused and become scarce, competition and conflict emerges. This historically led to behavior changes (reduction in fishing, fishing alternate species, etc.) or to fishery collapses. The traditional knowledge of fisheries managers, the limitations of fishing tackle, and the small scale of the artisanal fisheries prevented systemic abuse and overexploitation of fishery resources. In our modern world we are still trying to identify a balance between resource use and preservation. Traditional practices and prohibitions took species ecology and life histories into account and rules were locally enforced. Modern fisheries managers, politicians, law enforcement, fishermen, scientists, and stakeholders have enacted laws, regulations, and treaties to curtail overfishing, regulate the use of new gear types, fishing methods, and industrial scale fishing yet they are only recently starting to understand the need to incorporate life

[1] A barbel is a sensory organ primarily used to help locate food. They are thin whisker-like projections that respond to touch and chemicals (taste). Widely distributed among fish families, they are typically found in groups that search for food in murky waters where visual cues are less useful.

history of a species into its management, and recognizing that not all fisheries can be managed the same.

The literature review is presented in six sections. The first, natural resources, focuses on use and management. The second, aquaculture, focuses on the development of fisheries as a captive resource. The third, ecology, focuses on the understanding of the life histories of the focal species. The fourth, fisheries management, discusses how these resources are utilized for human use. The fifth, tragedy of the commons, international relations, and policy, looks at the politics of resource use. The sixth and final section, environmental agreements and cooperation looks at the history of co-management actions between the focal nations. The chapter ends with an explanation of how this dissertation builds on adds to the existing literature.

Natural Resources

Natural resources are one of the hallmarks of a civilization's ability to not only maintain its level of development, but also to progress. States cannot maintain the status quo or progress without resources. Exactly what those requisite resources are is wholly dependent on the time and place in history under consideration. During World War II (1941-1945), for example, the manufacturing might of the United States allowed the Allies to turn the tide of war against the Axis powers through the capacity to continually produce the resources of war due to large stores of natural resources; iron to make steel, coal to fire the plants, labor to build the products, and wheat to feed the workers. Some resources have, and will, always be needed regardless of what is happening geopolitically across the world. While some natural resources are fixed and static- oil and gas reserves,

forests, and minerals, others of course do not remain fixed to a location. Air resources, many water resources[2], and many biological resources[3] can move independently of national and international boundaries, dramatically complicating their sustainable management.

The fundamental requisite resources which span the earth, cut across eras, and cross boundaries are food, clothing, and shelter. These are the basic necessities of life. While clothing and shelter are dependent upon the geographic region one settles and potentially less dependent upon natural resources, food production is dependent upon the geographic region and is usually heavily reliant upon other available natural resources. From the hunter-gatherer roots of humanity's ancestors, most societies developed and progressed into agrarian and semi-nomadic cultures, and domesticated plants and animals based upon the prevailing species available in the region (Diamond 1999). From bananas, coconuts, sugar cane, and spice in the tropics to wheat, apples, and berries in more temperate climes, the foodstuffs early people decided to grow came from the regions in which they lived. This was true of the plants and animals they chose to domesticate; from llamas in the Andes, dogs in Europe, cattle in India, sheep in the Middle East, horses in the Caucus Mountains, to pigeons in the Mediterranean, camels in Arabia, and yak in the Himalayas (Vigne 2011, Diamond 2002, Clutton-Brock 1999, Zeuner 1963). Note that all these animal examples of long domesticated species are mammals and birds.

[2] Water resources can be both static and dynamic. Many rivers flow hundreds of miles and thus may span multiple national borders and coastal waters of course move globally. However, some rivers and many lakes can be held within the confines of one national boundary (though due to the global water cycle all water technically moves globally).

[3] Biological resources can be fixed to a relative location within national boundaries (e.g., forests, small non-migratory wildlife, etc.) or may span many nations being carried by ocean currents or through species specific migratory patterns (e.g., many ocean fishes, migratory birds, insects, etc.).

What of other animals? Sir Francis Galton (1865), cousin of the famed Charles Darwin, wrote extensively on the domestication of animals and their future prospects. He said, "it would appear that every wild animal has had its chance of being domesticated," going on to suggest about those species not domesticated, "As civilization extends they are doomed to be gradually destroyed off the face of the earth as useless consumers of cultivated produce." Galton, of course, was talking about humans having already domesticated all the so called "useful" animals and protecting their crops from other herbivores— specifically those not previously domesticated as food stuffs themselves. Thus, the concept that species which had not provided people with a commodity were doomed to become extinct. More than a century later, Paul Greenburg stated it such: "...humanity is trying to master in one way or another, either through the management of a wild system, through the domestication and farming of individual species, or through the outright substitution of one species for another." (Greenburg 2010, 11).

There are few other animal taxa which have brought about so much human effort to selectively breed for desirable traits as the mammals and birds. Fish are the most speciose, numerous, and widely distributed group of vertebrate[4] animals on Earth, yet very few fish have been domesticated over the course of human history, especially in contrast to birds and mammals more broadly. The most notable exceptions are, of course, aquaculture efforts (farm-raised) for salmon(s) and Tilapia, though both these are mere fractions of the domestication scale of other taxa. So, despite millennia of human history, generations of domestication effort, and the fact that fish are, and have been the

[4] Insects and several other invertebrate taxa are significantly more speciose, numerous, and widely distributed than fish, but few invertebrates have been desirable as potential domesticates, though recent efforts to domesticate shrimps and some fly larvae have met with some success.

predominate protein source for most human populations— even today, fish are predominantly collected from the wild. They are among the world's last wild foods, representing a return to humanity's hunter-gather roots. Thus, in the modern and increasingly connected and globalized world one is forced to ask the questions, "Who owns the fish?" and "How do we manage natural resources that move of their own free will?"

In the modern world of domesticated plants and animals, fish are humanity's last wild food animal[5], and are actively sought and chased around the globe. "We eat more fish every year, not just collectively but on a per capita basis, pausing only (and only briefly) when evidence surfaces of the risk of industrial contaminants in our seafood supply. Under the umbrella of the collective acts of denial, individual and corporate rights, national prejudices, and environmental activism have been cobbled together into something government officials like to call "ocean policy." In fact, there is no "ocean policy" as such, at least none that looks at wild and domesticated fish as two components of a common future" (Greenburg 2010, 13). This is not a new phenomenon. Peoples across the globe have been chasing these resources for millennia. Yet, as the human population has expanded, the demand for food has increased and the area available to fishermen has dwindled. Fish consumption in recent years has significantly risen along with global demand. The United States ranks as the number one importer of seafood worldwide, which is reflected in rising consumption (figure 2). According to the Food

[5] Of course, fish are not the only wild food animal in any region or culture today, but relative to consumption volumes, is by far the most important to the human diet across the globe. Wild game and "bush meat" are also taken in considerable quantities in some parts of the globe and can comprise the bulk of the protein in the diet in some places and times of year.

and Agriculture Organization of the United Nations (2016), “Overall, world supply of fish for human consumption has kept ahead of population growth over the past five decades, growing at an average annual rate of 3.2 percent in the period 1961–2013, compared with 1.6 percent for world population growth.” These levels, however, are not in line with the United Nations Convention on the Law of the Sea (UNCLOS) treaty in producing the maximum *sustainable* yield of marine resources, but rather the maximum yield. This has led to fishing down the food chain and replacing once sought-after fish with the by-catch of past decades.

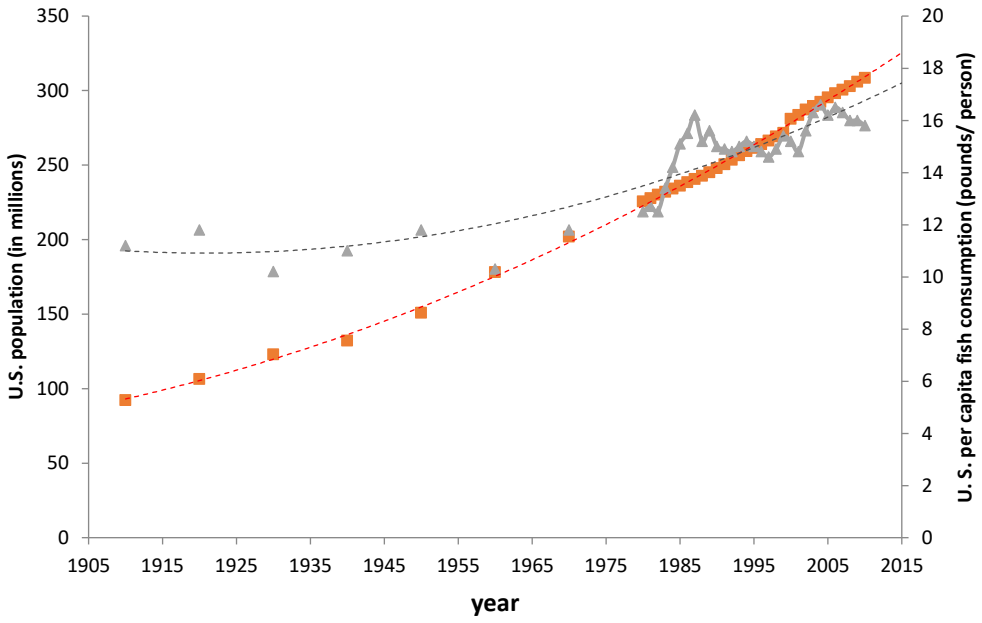

Figure 2. Graph of the population of the United States and the consumption of fish for the past century.
Grey triangles represent per capita fish consumption in pounds and the orange squares indicate the U.S. population. Until the 1980s data was collected every decade. Data collection ended in 2013. Trendlines correspond to each color and are 2nd order polynomial regressions. Source: NOAA-NMFS (2013).

Several examples have become synonymous with this idea such as the long-lived Patagonian Toothfish and the Orange Roughy. Both of these species were considered

unwanted by-catch[6] for decades while salmon and cod were actively targeted by fishing fleets. After the stocks of more prized fish began to dwindle, these previously unwanted species then became the actively sought species. However, the lucrative American market (and to a lesser extent the European market) would not accept the unpalatable sounding Patagonian Toothfish, Slimehead, or Goosefish, which in part was why it they were by-catch (figure 3). So, in 1977, fisherman Lee Lantz had the idea to change the name that Patagonian Toothfish (*Dissostichus eleginoides*) was marketed under to Chilean sea bass (Knecht 2007, Persad 2015). In just a few decades Chilean sea bass (which is not taxonomically speaking a bass, nor does it exclusively live in and around Chile) had become highly overfished. While catching premium prices, the fish reproduced too slowly to keep up with demand. Legal fisherman and poachers alike watched as the fisheries collapsed, leaving fisherman to find a new species to fish.

This is not an isolated incident, year after year the state of the international fisheries is published by the FAO and other organizations, and it has for decades foretold the reduction in fish stocks worldwide and the total collapse in some fisheries. As David Fahrenthold (2009) says, "Some of those worst-hit were fish that have been renamed to make them more marketable. For threatened animals on land, a more attractive name might be a blessing. But for these creatures -- slimeheads, goosefish, rock crabs,

[6] By-catch is a fishing industry euphemism for unwanted and incidental take of less economically important fish species. These fish can be huge volumes of the total take and in many instances can outnumber the desired target species. The catches are typically dumped onto the deck of the vessel and the by-catch is sorted out from the intended species. By-catch is then pushed overboard and most of the fish (and other taxa) do not survive.

Figure 3. Previously unwanted by-catch species which were made economically viable by rebranding and renaming.
A) Goosefish, also known as Monkfish ((*Lophius* spp.), B) Patagonian Toothfish, also known as Chilean Sea Bass (*Dissostichus eleginoides*), C) Slimehead, also known as Orange Roughy (*Hoplostethus atlanticus*).

Patagonian toothfish, whore's eggs -- it was a curse." Slimehead is the standard common name for *Hoplostethus atlanticus*, which most non-scientists know as Orange Roughy. Goosefish (*Lophius* spp.) is better known as monk fish, whore's eggs are an old term for Sea urchin roe (eggs), and Mahi-Mahi is the Hawaiian word for and now standard name for what was once known as Dolphinfish or simply Dolphin (*Coryphaena hippurus*).

All this fishing down the food web (figure 4) has significant repercussions, not just to the availability of fish, or the economic viability of fishermen and coastal fishing communities, but to the ecological integrity of the ocean. With fish humans tend to eat predators, "prey" species often taste to "fishy", yet they eat prey in terrestrial ecosystems and thus compete with other predators. By fishing down the food web, we remove the apex predators one at a time down the line. This affects the reproductive rates and capacity of other fish and non-targeted organisms which in turn has far-reaching affects further down the chain, and on and on.

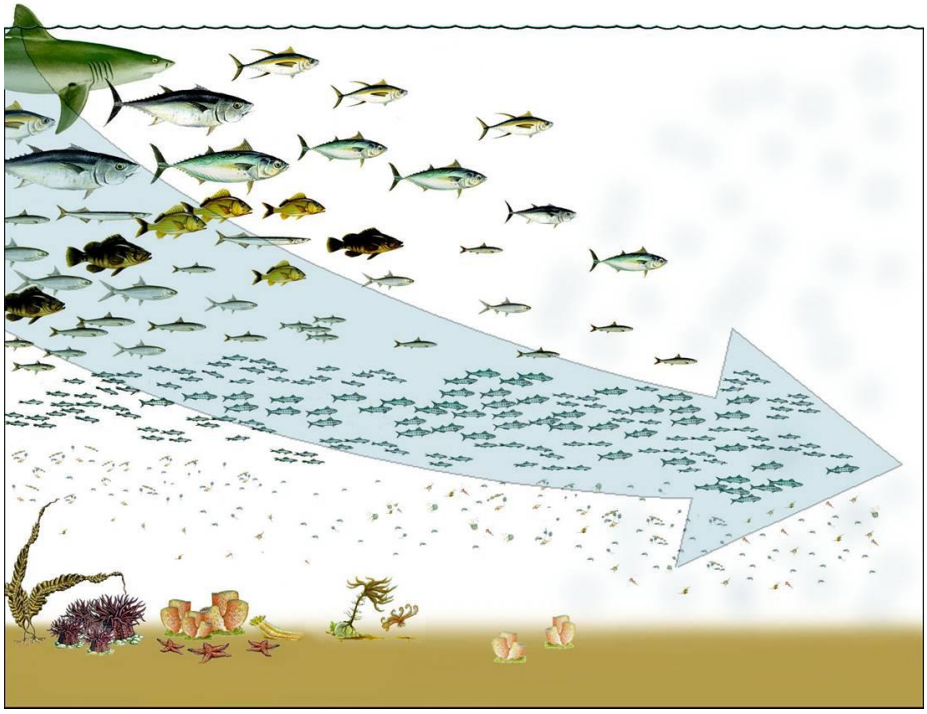

Figure 4. The painting "Fishing down the food web, a North Sea perspective" by Hans Hillewaert graphically represents the idea put forth by Daniel Pauly and his colleagues (1998) of catching the largest and most desirable fish until they are gone and then moving down the food web to the next species in succession.

Aquaculture

One ongoing initiative that may alleviate the pressure on wild populations is aquaculture. Though fish is the world's last wild food, there are those in the industry working to change that through aquaculture or fish-farming. There are two general types of aquaculture-closed systems and open. In closed systems species are reared in ponds, pens, aquaria, or other man-made structure/enclosures and are separated and have no direct contact with wild individuals or interact in the ecosystem. The majority of freshwater fishes (such as trout and tilapia) are reared in this way as are shrimps. In open systems species are reared in the open environment, often in protected bays and estuaries and sometimes fenced or netted off, but with full water flow through the enclosures. These organisms have the potential to mix and interact with the ecosystem on many

levels and could possibly escape into the wild population. Some marine fishes (such as cod and salmon) are raised in this way as are algae and many shellfish. In the consumer market aquaculture is often referred to as farming of aquatic resources.

Rearing aquatic organisms is not a new 20th century phenomenon. Ancient Hawaiians were involved in the practice through the use of coastal fishponds (Costa-Pierce 1987, Kikuchi 1976). These were not domesticated species, but rather coastal fishes which were trapped in man-made enclosures and artificially fed at some level to provide a ready supply of food. The domestication of fishes has not occurred as it has with other taxa humans farm and raise. In fact, many of the fish currently in use are, in fact, very poor choices for potential for domestication. Many of the fish which have had attempts to develop them as aquaculture species were chosen due to their economic value and taste (such as salmon and cod) rather than selecting for species which are the best suited for this type of husbandry (Greenburg 2010). Thus, attempts have been made at aquaculture and farming on both focal species, yet the domestication of these top predators has remained elusive. They are still wild foods, and each has considerable cultural histories of commercial fishing, stock fluctuations, and significant ecological roles in their respective ecosystems. Those in the field have begun to learn from their mistakes and new species more suited to aquaculture are being developed. Tilapia (actually the common name for dozens of African cichlids from the genera *Oreochromis*, *Saratherodon*, and *Tilapia*) and Swai, or Iridescent shark (*Pangasianodon hypophthalmus*)— - an Asian catfish— have met with some success in the past decade as has integrated multi-trophic aquaculture where multiple species are raised in aquaculture

simultaneously more closely mimicking a simple complete ecosystem. (Greenburg 2010, Kautsky et al. 1997, Mungkung et al. 2013).

Domestication has long been elusive toward aquatic ecosystems first since the resources were so plentiful and easily acquired there was no real drive by human populations to invest the time and effort in domesticating marine species like there was for terrestrial species. In addition, the selection pressure for aquatic species is often significantly higher due to mortality rates of offspring being in many cases 80-90% or greater. This has led to high genetic diversity and variation in wild stocks, which is required in the natural environment and actively suppressed and culled from domesticated strains. The process of domestication is often a long and laborious process as one must select individuals with desirable traits, breed them, raise the offspring, and determine if the next generation is now more desirable than the original strain. This takes time, generations in fact. However, recent advances in genetic engineering have led to the ability to select for traits at a molecular level and incorporate these gene manipulations into the parent strain or offspring, even incorporating the genetic material of other taxa to derive some unique trait like growth rate, size, or disease resistance. Even if one steps back from overt genetic manipulation, humans have the capacity to artificially manipulate breeding stocks of fish. One such example is the Donaldson strain of Chinook Salmon (*Oncorhynchus tshawytscha*), which were bred in a facility near Seattle from a multitude of salmon strains that in nature would never have met or bred. Once bred, these same Pacific fish were then stocked into Lake Ontario several thousand miles from their native range. This type of activity has led some, like Paul Greenburg to note that "...humanity is trying to master [the environment] in one way or another, either through the management

of a wild system, through the domestication and farming of individual species, or through the outright substitution of one species for another." (Greenburg 201, 11).

Generations have forgone industrial scale aquaculture, instead choosing to simply extract wild resources from the environment. Many have seen potential problems with the rise in aquaculture efforts. Paul Greenburg has asserted that "Fish farming in its first incarnations is almost always a privatization of a public resource- a mad-dash grab for ocean farming sites that previously belonged to no one." (Greenburg 2010, 49). Others have raised concerns about environmental degradation, issues arising from genetically modified organisms (GMOs), antibiotic use, escape of domesticated strains into the environment, the resources used to feed domesticated fish (i.e., the wild collection of feeder fish), fish waste, disease, cost to market, use of closed systems, genetic parsing (i.e. reducing gene pool), choice of species, mixed species practices/ polyculture or integrated multi-trophic aquaculture (IMTAs), habitat destruction (such as the damming of rivers), non-native fish species (i.e., stocking fish outside their natural range), pollution, and the lack of laws, regulations, and oversight of the industry (Greenburg 2010, Idyll 1973, Asche et al. 1999, Hill 2011, Bartley and Hallerman 1995, Martinez 2009, Ling et al 2007, Aerni 2004, Buschmann et al. 2009).

The reduction in the Atlantic Cod stocks have led to fishing down the food web. The world population likes the taste of cod. So as Atlantic stocks plummeted to commercial extinction, the industry shifted to the Pacific. Efforts shifted to 'look-a-likes'. On the market today many products, once exclusively made of Atlantic 'cod', are being replaced by other species but still sold as 'cod'. Pacific Cod (*Gadus macrocephalus*), Whiting (*Merlangius merlangus*), Haddock (*Melanogrammus aeglefinus*), Pacific

Tomcod (*Microgadus proximus*), Alaska Pollack (*Theragra chalcogramma*), Atlantic Pollock (*Pollachius pollachius*), Coley (*Pollachius virens*), and a multitude of others are all marketed and sold as 'cod'. 'Cod' for centuries meant Atlantic Cod, but now it has been replaced with any number of species in the cod family (Gadidae). The multitude of fish going into products only exacerbates the IUU fishing and other fraudulent practices and products, not to mention driving poaching and black markets.

Humans are, and have long been, a primary consumer of fish. In many states, especially those in Oceania and in the developing world, fish may be the primary and sometimes the only source of protein (Charlton et al. 2016, WHO 2016, FAO 2016). Additionally, fish are known to be a healthy animal protein option (FAO 2016, WHO 2016). In other nations it is a primary economic driver. Worldwide, in 2018 (the most recent global data available), an estimated 179 million tons of fish (worth around $401 billion) were collected, with 82 million tons coming from aquaculture facilities (FAO 2022). In 2014 there were an estimated 4.6 million fishing vessels and over 200 countries reported exports and imports of fisheries products, with worldwide exports amounting to $148 billion, representing less than half the value of what was collected just four years later and up from $8 billion in 1976 (FAO 2016). This exponentially increasing take of fish is not sustainable. According to Greenburg (2010), "With wild fish we have chosen, time after time, to ignore the fundamental limits the laws of nature place on ecosystems and have consistently removed more fish than can be replaced by natural processes." (Greenburg 2010, 13). That is to say, we remove fish faster than they can reproduce, leading to global overfishing and reductions in fish stocks.

Ecology

Life on Earth began in the sea. From the suspected humble origins of life in Earth's oceans, a vast array of species has radiated across the planet, filling nearly every available niche. There are currently about 1.9 million described species (Pimm et al. 2014, Chapman 2009). However, this is thought to be just a fraction of the total. Current estimates of the number of species that cohabit the planet earth with humans varies widely, from Costello and colleagues (2013) estimating 5 million ± 3 million to Chapman (2009) who sets that number at over 11 million, to Raven and Yeates (2007) who suggest there are 5-6 million insects alone. Mora et al. (2011) estimates the number to be around 6.5 million on land (the vast majority invertebrates- mostly insects) and 2.2 million in the world's oceans. Regardless of whose numbers you choose, early humans had a wealth of options for sustenance and subsequently domestication.

The majority of animals are spineless invertebrates, making up 99% of known animal life. Representing just 1% or less of animal life are the vertebrates, the taxonomic group most people are familiar with[7]. Within the vertebrates, the clear winner- in terms of global dominance by area occupied and species diversity, are the fishes, with more than 27,000 described species already known to science and with potentially up to 8,000 yet to be discovered (Eschmeyer et al. 2016). With all this diversity and global distribution, it is little wonder that fish has been one of the staple foods in the human diet. Within North America, Atlantic Cod and Lake Trout have been among the staples for millennia.

[7] The main vertebrate groups are Mammals, Birds, Fish, Reptiles, and Amphibians.

Lake Trout range across North America (figure 5) where they are found in cold, oxygen-rich waters. They are large freshwater members of the Salmonidae reaching lengths of 130 cm and weights of up to 46 kg. This large fish family includes salmon, trout, char, and whitefishes. All members of the family spawn in freshwater but some, like the salmon, are anadromous and live part of their lives in the open ocean and return to freshwater to breed. Others, like most trout[8], live their whole lives in freshwater- land-locked in large lakes, or in rivers and streams. All are predatory and feed on smaller fishes, crustaceans, and insects. Lake trout, in fact, have been called the 'wolves of the Great Lakes'. They are a top apex predator in this large and complex ecosystem.

Trout have existed for millennia. They saw the emergence and then disappearance of dinosaurs and persisted through numerous ice ages. In their more recent past (the past several thousand years), they have been fished by humans. Several Native American tribes even based their annual movements around prime fishing opportunities (Cochrane 2009). Since the arrival of Europeans to North America the populations have fluctuated widely. Modern threats include overfishing (from recreational, tribal, and commercial fishing), pollution, competition for food and resources from invasive species, introduced diseases, introduced predators, introduction of Sea Lamprey, habitat destruction, genetic manipulations, disappearance of breeding stocks, and decreased genetic and phenotypic

[8] One must be careful with common names and generalities. Trout is the common name typically given to fishes of the family Salmonidae, mostly in the genera *Salvelinus, Oncorhynchus,* and *Salmo*. Yet other species are sometimes also given this moniker as well, despite having other more commonly used names. One can find reference to at least two Coral 'Trout' in the South Pacific. One is *Cephalopholis miniata* and the other *Plectropomus leopardus*. However, both of these fish are more accurately, and commonly, known as the Coral grouper and the Leopard grouper (family Serranidae). Additionally, Brown Trout (*Salmo trutta*) and Rainbow Trout (*Oncorhynchus mykiss*) both have land locked as well as anadromous strains which are known respectively, as Sea trout and Steelhead.

diversity (Hansen et al. 2016, GLFC 2016, GLEAM 2016a, Muir et al. 2014, GCRP 2014).

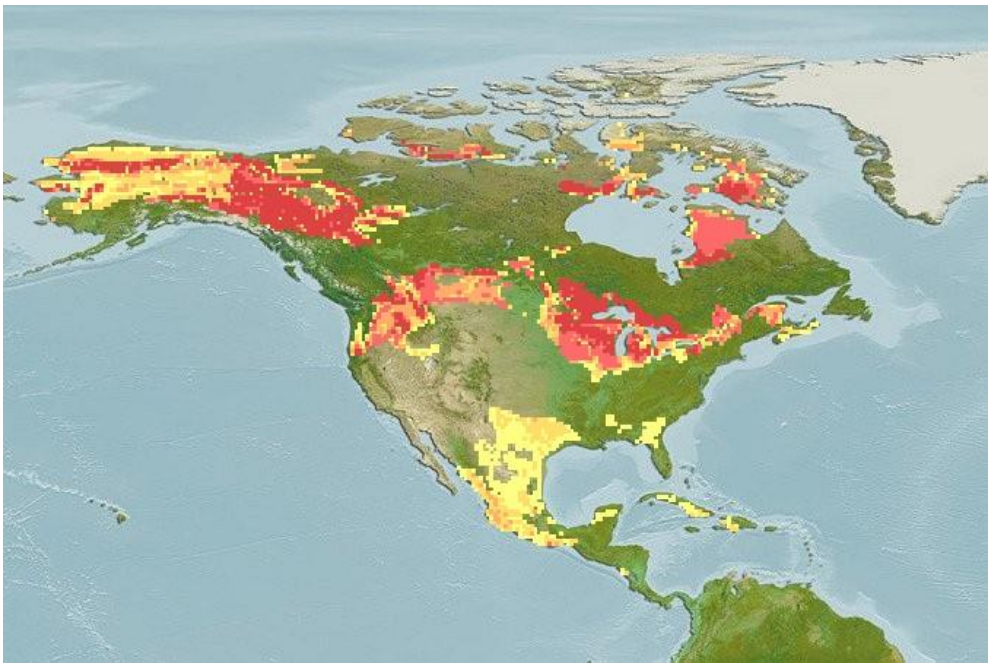

Figure 5. Current distribution of Lake Trout (Salvelinus namaycush) in North America. Red areas indicate extant populations, yellow areas indicate areas where lake trout may occur. Source: www.fishbase.org. In some places, like Yellowstone Lake and parts of Scandinavia, they are now considered an invasive species (NPS 2016).

Lake Trout are solitary as adults, but come together in large aggregations to spawn, typically in the same gravelly areas year after year. Females lay between 300 - 4,000 eggs dependent upon the size of the individual (larger females produce more and larger eggs). While they do move to spawning areas for breeding, they are not generally considered a migratory species. The young fish hatch, disperse, grow, and eventually return to spawn in 6-7 years, and typically live around 25 years, though there are documented cases of individuals exceeding 60 years.

Over the eons of evolution and development the Lake Trout has differentiated into several visually distinct sympatric morphs. Recognized for more than a century (figure 6), these variations on the Lake trout occur in a variety of micro-niches within the lakes and may represent adaptive radiation and speciation at its early stages (Agassiz and Cabot 1850, Roosevelt 1865, Goodier 1981, Baillie et al. 2016, Hansen et al. 2016). Sadly, due to the variety of threats which have arisen over the past two centuries, many of this original morphological diversity and variation has been lost.

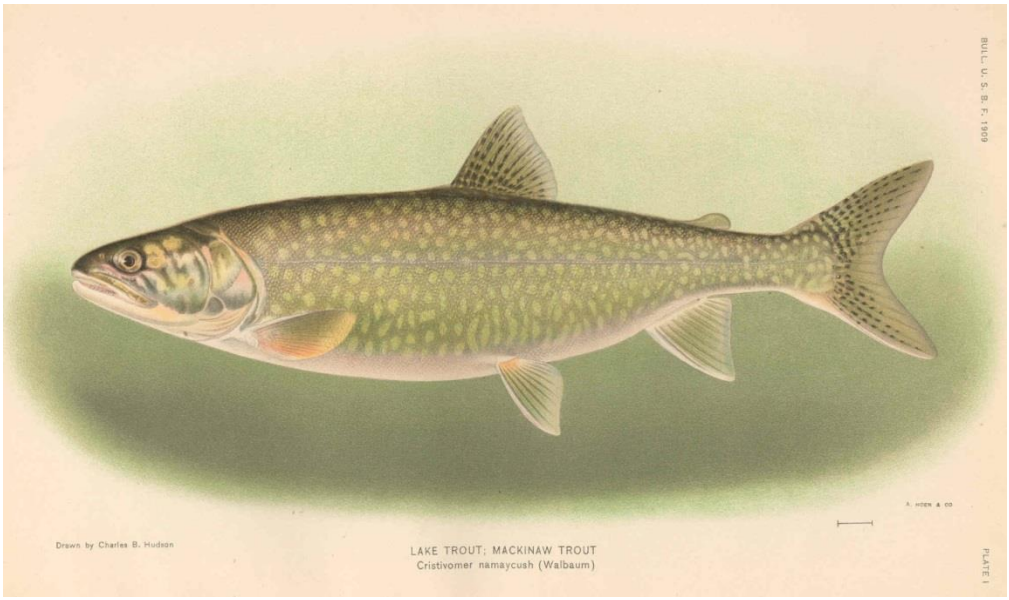

Figure 6. 1909 Lake Trout painting
by Charles Hudson from the Bulletin of the U.S. Bureau of Fisheries. At this time in history Lake Trout were an important fishery and economic driver for the development of the Great Lakes states.

Within the Great Lakes basin there are still four primary morphotypes of Lake trout (figure 7). These fish exhibit differences not only in appearance but also in life history. Variations in habitat use, breeding season, depth, and behavior help to explain and keep the populations segregated over though they coexist in the same overall ecosystem (Hansen et al. 2016). Additional morphotypes occur across the species range

throughout northern North America. These differences have allowed Lake trout to survive and thrive through many natural calamities, but in the past century, there has been a significant loss of genetic and phenotypic diversity (Muir et al. 2014). Recognizing this dramatic loss of variability, fishery managers have attempted to restore lake trout stocks through the use of artificial hatchery propagation, changes in fisheries regulations, and controlling introduced species effects (Hansen et al. 2016).

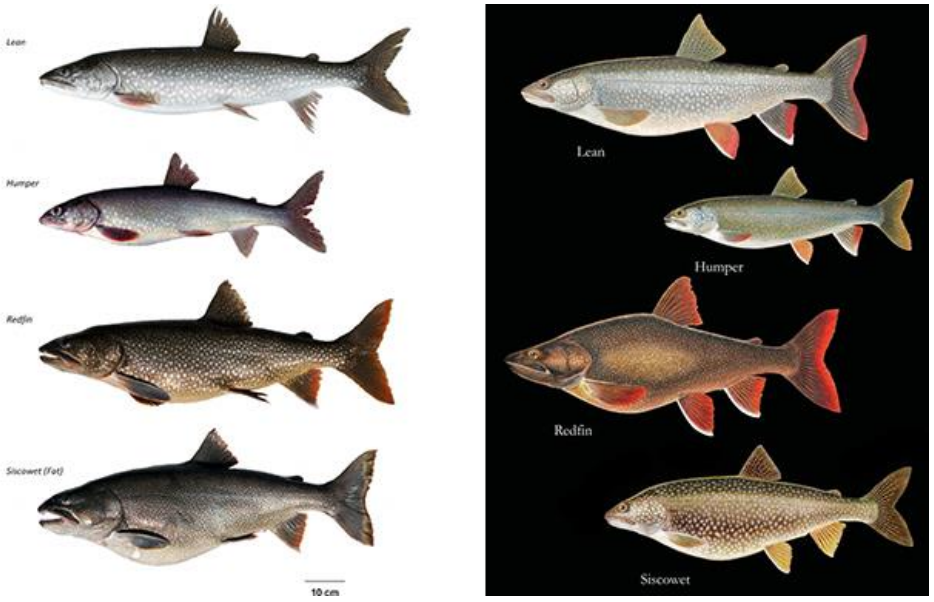

Figure 7. The four primary morphotypes of Lake Trout still extant in the Laurentian Great Lakes ecosystem.
The image on the left are photographs of fish (Hansen et al. 2016) and the image on the right is an idealized artist rendering of these same four morphotypes (Muir et al. 2014).

Despite these many threats and the mitigation measures currently and previously being undertaken, the decline and disappearance of the variety of Lake Trout morphotypes has been predominantly due to just a few causes, predominantly habitat destruction, overfishing, and the introduction of Sea Lamprey (*Petromyzon marinus*). Sea Lampreys are an ancient jawless fish remaining relatively unchanged for the past 340

million years. They are a parasite, and using their sucker-like mouth and tongue, they rasp a hole through the skin and scales of their prey and feed on bodily fluids (figure 8). International and interstate shipping in the early 1800s depended heavily on man-made canals and locks. It was the opening of these artificial structures which allowed the Sea lamprey to gain access to the interior of North America from its native Atlantic Ocean habitat. By 1830 Sea Lampreys were in the Laurentian Great Lakes. However, Niagara Falls acted as a natural barrier to their movement, effectively halting their spread to Lake Ontario. The opening of the Welland Canal[9] in 1829, and specifically its modification in 1919 allowed the Sea lamprey to gain access to Lake Erie in 1921 (GLFC 2000, Fuller et al. 2016). Once past Niagara Falls, the sea lamprey spread quickly to all the Great Lakes, finally appearing in Lake Superior by 1940.

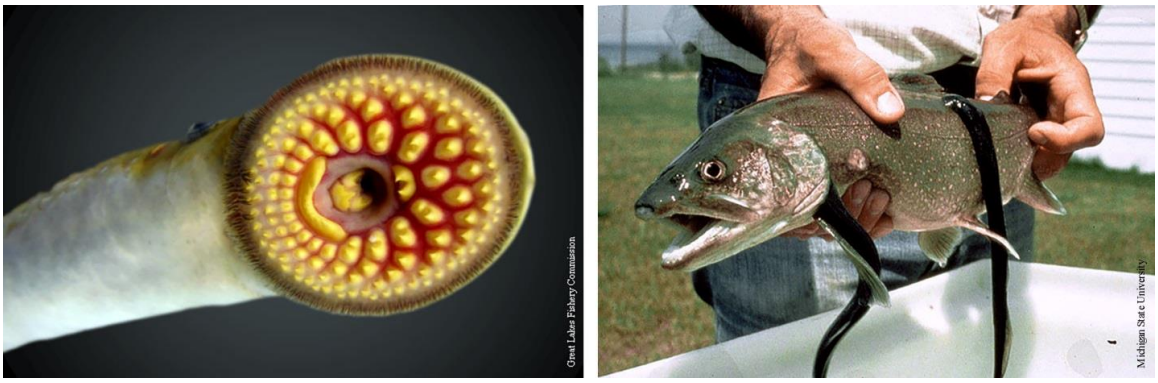

Figure 8. Ventral view of Sea Lamprey mouth used to rasp through the body wall of other fishes (left) and pair of Sea Lampreys attached to a Lake Trout (right).

Prior to the invasion of the Sea Lamprey, the combined commercial fisheries catches out of the Great Lakes were 15 million pounds/year, but by the 1960s that annual

[9] The Welland Canal is a shipping canal in Ontario, Canada that artificially links Lakes Ontario and Erie. Opened in 1829, the canal allows ships to bypass Niagara Falls so that ships can move through the St. Lawrence seaway from the Atlantic Ocean through to all the Great Lakes.

catch number had dropped to 300,000 pounds, just 2% of the previous years (GLFC 2016). Lake trout, Lake Whitefish, and Ciscoes—the mainstays of the Great Lakes commercial fishing industry—were decimated by the non-native lamprey[10]. Those fish not killed outright often succumbed to secondary infections and disease from the lamprey attack wounds (GLFC 2016).

Beginning in the 1958, the governments of the United States and Canada began implementing a control program for sea lamprey. This $20 million/year program is a very successful partnership and according to the Great Lakes Fishery Commission, "Sea lampreys must be controlled to maintain and improve the fishery as we know it and to protect the integrity of the ecosystem. The good news is they can be controlled! The Great Lakes Fishery Commission, pursuant to the Convention on Great Lakes Fisheries, delivers sea lamprey control in partnership with the U.S. Fish and Wildlife Service, Fisheries and Oceans Canada, and the U.S. Army Corps of Engineers." (GLFC 2016b). What is used are lampricides—poisons specifically developed to kill larval lampreys, on an ecosystem scale in order to remove and control this noxious invader and protect the $7-9 billion Great Lakes fishery (MSU 2015, GLFC 2016b). This toxicant has been very effective in reducing the population of the Sea Lamprey in the Great Lakes. However, it also has been very effective in killing the native lamprey species as well. In recent years the collateral damage to native species has been taken into account in the lamprey control

[10] Sea Lamprey (*Petromyzon marinus*) are non-native in the Great Lakes, but they are not the only lamprey species. There are four lamprey species native to the Great Lakes and its tributaries and streams- the Northern Brook Lamprey (*Ichthyomyzon fossor*), the American Brook Lamprey (*Lethenteron appendix*), the Chestnut Lamprey (*Ichthyomyzon castaneus*), and the Silver Lamprey (*Ichthyomyzon unicuspis*). Two are also parasitic like the Sea Lamprey but having co-evolved with the other native species rarely cause the death of the host. The other two are non-predatory of fishes as adults and therefore not natural threats to other Great Lakes fish species (Stackpoole 1997).

program and accordingly they have "…refined our control efforts to minimize our impact on native lampreys" (Moen 2002).

While the Sea Lamprey was a major cause of the 1950s collapse of the Great Lakes fisheries, it was certainly not the only cause. Recreational fishing, combined with unsustainable commercial fishing, had already severely depressed fish populations for decades. Years of overfishing and Sea Lampreys were major causes of the collapse, but these were not the only causes.

Atlantic Cod could be found historically across a large swath of the northern Atlantic Ocean (figure 9). Wide-ranging and migratory, huge schools numbering in the millions could be found in the deep waters of the coastal shelves in North America and Europe. Atlantic Cod are members of the marine fish family Gadidae, which is known for Cod (or codfishes), Haddock, Pollock, and Whiting.

All members of the family are active predators. Atlantic cod are known to be especially voracious and formerly occupied the ecological role of apex predator in many places on the coastal continental shelves of Europe and North America. According to Kenneth Frank and his colleagues (2005), removing top predators from the ecosystem can cause cascading effects resulting in a complete restructuring of the food web. Cod are a classic omnivorous predator and are known to swallow practically anything that will fit in their mouths. However, the diet consists mostly of invertebrates and small fishes (Fahay et al. 1999). Deblois and Rose (1996) found that fish leading the schools (known as scouts) fed more heavily on fish and those toward the rear of the school fed more on invertebrates.

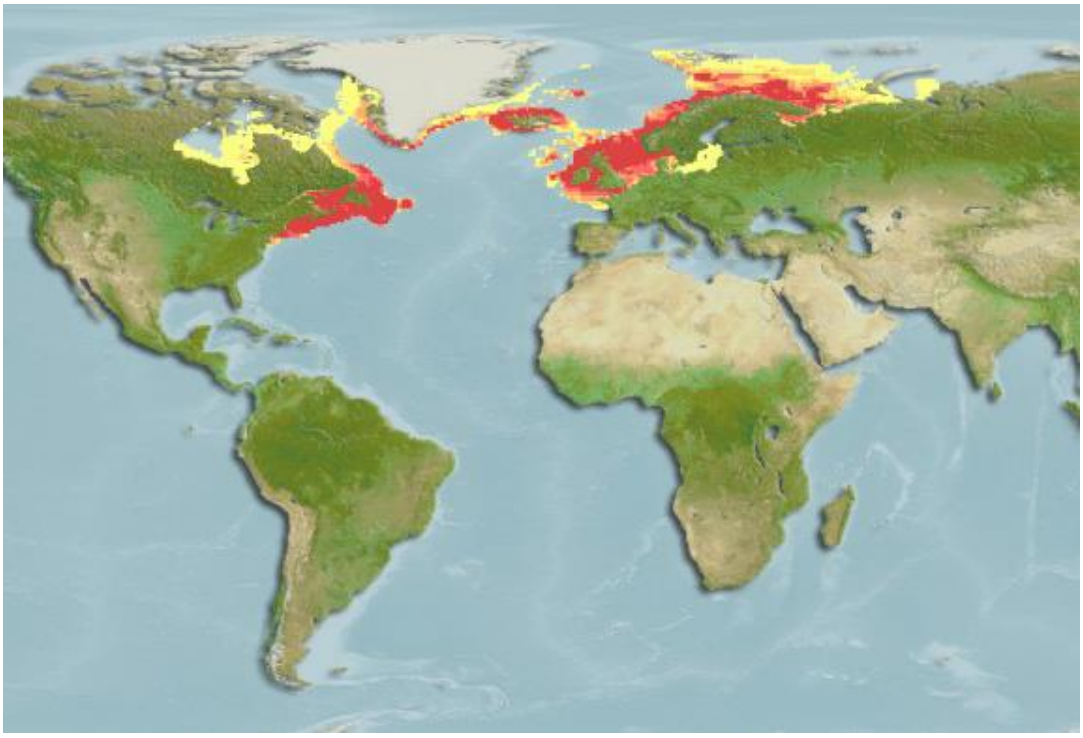

Figure 9. Current distribution of Atlantic cod (Gadus morhua) in the Atlantic Ocean.
Red areas indicate extant populations, yellow areas indicate areas where Atlantic cod may occur. Source: www.fishbase.org.

This type of generalist predator diet, along with their migratory nature, large size, and schooling behavior, meant that they dominated the food web and kept species in balance. In some places where cod have been overfished, the food web has been so altered that cod have been unable to reclaim their top predator role and have not rebounded despite long-standing moratoriums on the fishery (Hutchings 2000, Hutchings 2001, Hutchings and Reynolds 2004, Bundy and Fanning 2005, Shelton et al. 2006, Crockett 2012). Adult Atlantic Cod are found on or near the bottom between 40-130 m near to rocky slopes and ledges. Typically, like many fish, the juveniles are found in slightly different habitats. Young cod tend to linger near spawning areas and disperse into deeper, colder, more saline water as they age and grow (Tremblay and Sinclair 1985). A schooling species, Atlantic Cod live typically live 20 years.

All members of the Gadidae are marine fish which exemplify the reproductive strategy known as broadcast spawning. In fishes following this reproductive strategy millions of eggs are released at a time producing so many eggs at once that egg predators quickly become satiated, allowing the remainder of the eggs the chance at fertilization and subsequent larval development. As with most fish species, fecundity is directly correlated spawning-stock biomass, e.g., the larger and older the fish, the more eggs they produce and the higher the quality (Marshall et al 1998, Hutchings and Myers 1993, May 1967). In the case of Atlantic Cod, a single 34 kg adult female can produce nine million eggs, a 5 kg female while still prolific, produces only 2.5 million (Kjesbu et al 1992). Given that Atlantic Cod have been recorded at 200 cm in length and up to 96 kg, the potential for huge volumes of eggs is profound (up to 20 million eggs/female).
Having been fished for millennia, Atlantic Cod had survived fishing pressures placed upon them until relatively recently. Technological advances (e.g., improved fishing tackle, industrial factory ships) led to catastrophic overfishing- specifically unsustainable fishing practices of catches over the maximum sustainable yield (MSY) and poaching also known as illegal, unreported, and unregulated (IUU) fishing. Habitat destruction and degradation (predominantly from historic trawling) has also caused significant changes to the ecosystem. This has led to dramatic reductions in the cod population which translated into trophic cascades and a complete restructuring of the food web, with little to no rebound in the population numbers, despite long-standing moratoriums (figure 10). As Kurlansky (1997) noted, “Canadian cod was not yet biologically extinct, but it was commercially extinct – so rare that it could no longer be considered commercially viable.” The dramatic drop in population led to the eventual listing by the International

Union for the Conservation of Nature (IUCN) to list Atlantic Cod as a threatened species in 1996 (Sobel 1996).

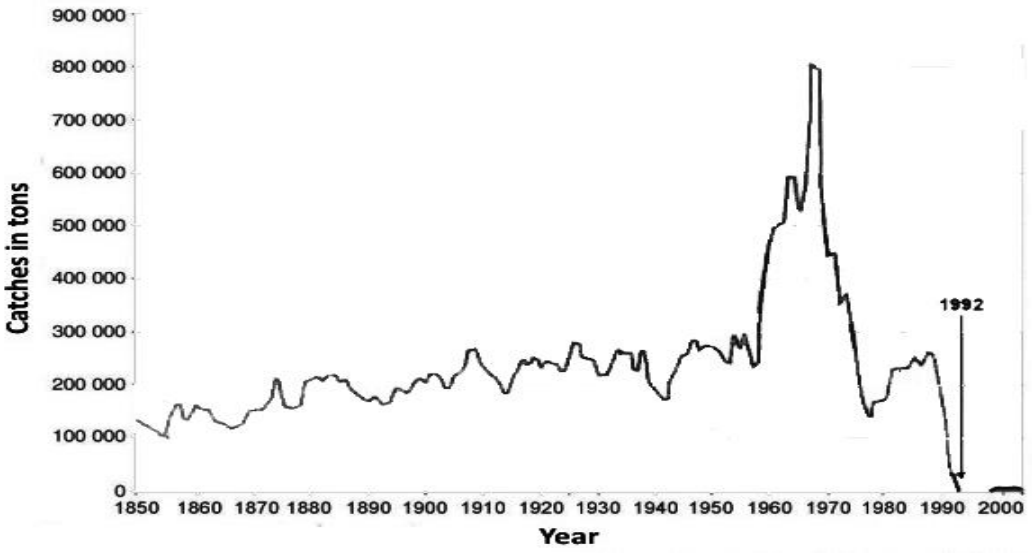

Figure 10. Catch values (in thousands of tons) of Atlantic Cod from 1850 through to 2005 demonstrating the near total collapse of the Atlantic cod population (noted as the year 1992). Source: Millennium Ecosystem Assessment.

Part of what is driving the lack of recovery is the long-term changes taking place in the genetics of the population. Atlantic Cod are smaller than they were in 1750s (Kenchington and Kenchington 1993). People want the biggest fish. New regulations exacerbate the old problems of trophy fishing. Bigger is better. This is especially true of large fishes where fecundity increases exponentially with size. These are the most reproductively useful fish. And the most sought by fisherman. Given this selective fishing pressure, studies are showing genetic changes in the population including smaller sizes and earlier maturation (Beacham 1983, Smith 1994) as the species tries to cope with the

removal of large reproductive individuals. Exacerbated by low population levels, these drive genetic pressures (and changes) even faster.

Fisheries Management

Fisheries management is defined as, “the process that creates and enforces the rules that are needed to prevent overfishing and help overfished stocks rebound.” (Thorpe and Turekian 2001). It can be seen as a response to the ‘tragedy of the commons’. It requires that government set-up, maintain, and enforce regulations meant to limit access and take of species which are collectively available in order to prevent wasteful overfishing (Wilson and McCay 2001). Societies have enacted laws, regulations, policies, international treaties, and best practices to ensure the sustainability of these collective goods. Fisheries management programs set-up the total allowable catch (TAC) by determining catch per unit effort (CPUE) and establishing a maximum sustainable yield (MSY)- a value meant to ensure maximum fish landings from year to year without reducing the base stock population. Sustainable levels require that recruitment (breeding, stocking, migrations, immigrations) must exceed extractions (die-offs, predation, fishing, emigrations).

Throughout time nations have sought to extract the maximum natural resources available to them. This is easily demonstrated with above ground resources like forests and wildlife and below ground resources like minerals. Underwater resources (e.g., fish) however tend to be out of sight, widely distributed, highly variable both spatially and temporally, and often present dramatic variation in life histories and ecology.

Historically, nations have sought to extract the maximum catches of fish available and thus seek to extract to (and often beyond) their MSYs. However, with fish that move across internal boundaries, this is one population and the MSY is not independent to each state in the international system. If each such state seeks to extract the MSY independent of one another, then that MSY is not the same value, and each is then extracting above the MSY driving down and overusing the resource. Fish that move across national boundaries thus require cooperation among nations to prevent overfishing with each nation only extracting a subset TAC of the available MSY. Combined, the fisheries of Canada and the United States are the largest in the world and cover an area of almost 18 million km2 of both marine and freshwater. Thus, huge area must be managed under coordinated fisheries management programs to allow for the maximum allowable fishing and simultaneously combating illegal, unregulated, and unreported fishing (i.e., poaching and bycatch).

Fishing pressure is a fundamental driver of fisheries management programs. This reduction in the population must be accounted for if programs are to be successful. Anthropomorphic and natural elements must also be considered including pollution, habitat change, Climate Change, invasive species, completion, die-offs, migrations, and numerous other considerations. The fisheries management of Lake Trout and Atlantic cod is understandably complex having to incorporate ecology, biology, politics, culture, and economics.

Competition from invasive and non-native fishes has played a role in the decline of Lake Trout. The intentional introduction of Pacific basin and European non-native species such as Chinook Salmon (*Oncorhynchus tshawytscha*), Coho Salmon

(*Oncorhynchus kisutch*), Rainbow Trout (*Oncorhynchus mykiss*), and Brown Trout (*Salmo trutta*) all had negative effects on the native fish populations. These fish, along with the native Lake Trout, all exist within the same ecological niche. They have nearly identical life history needs. They live in the same habitat, feed on the same diet, and spawn in similar places. The introduction of these species to the Great Lakes caused significant competition and pressure on already declining and depressed native lake trout populations.

These non-native salmonids were first introduced to the Great Lakes over 150 years ago, though it was only the rainbow trout, native to the Pacific Ocean that was able to establish a self-sustaining breeding population (GLEAM 2016a). Then, with the 1950s collapse of the lake trout commercial fisheries and the introduction of invasive Alewife (*Alosa pseudoharengus*) and Rainbow Smelt (*Osmerus mordax*), other introduction and reintroductions efforts were established. In fact, it was the control of these invasive mid-water species that prompted the introduction of the Chinook and Coho Salmon as natural control measures (GLEAM 2016a).

The stocking of these non-native[11] species has continued for years and in high volumes (table 1). The total stocking volume for the period 2000-2009 was almost 19.5 million non-native fish, all of which directly compete with the native lake trout for resources like food and spawning areas. Additionally, they cause direct mortality by feeding on young fish, may provide vectors for disease and parasites, and may disperse

[11] Atlantic salmon are/were native to Lake Ontario. This once land-locked population was wiped out by overfishing and habitat degradation and is considered extinct by the Ontario Ministry of Resources (Edwards 2006). They were last seen in 1898. A population from the Atlantic Ocean was reintroduced in 1972 and stocking efforts continue today, though the original genetically distinct population is now gone (MDNR 2016, Edwards 2006). So, these ocean reintroductions are somewhat native to the lakes.

these pathogens and parasites across the lakes (GLEAM 2016a). These non-native competitors are not entirely bad for Lake trout or the Great Lakes. The alewife and smelt control has been effective and their suppression does aid in the recovery of other native species. Additionally, the economic benefits from the recreational fisheries associated with these non-native species provide funds to continue conservation and recovery efforts.

Table 1 . Mean annual non-native fish stocking into the Great Lakes (2000- 2009).
Table derived from (GLEAM 2016a). Superscripts identify species origin: 1 indicates an Atlantic species, 2 a European species, and 3 are Pacific species. Source: Great Lakes Fish Stocking Database (FWS/GLFC 2010).

Non-native species	L. Superior	L. Huron	L. Michigan	L. Erie	L. Ontario
Atlantic Salmon[1]	0	35,000	0	0	0
Brown Trout[2]	179,000	220,000	1,500,000	60,000	600,000
Chinook Salmon[3]	835,000	2,300,000	3,700,000	0	1,900,000
Coho Salmon[3]	25,000	0	2,300,000	42,000	360,000
Rainbow Trout[3]	859,000	450,000	1,800,000	1,400,000	880,000
TOTAL	1,898,000	3,005,000	9,300,000	1,502,000	3,740,000

The stocking efforts are not just for non-native species. Both Lake and Brook Trout (*Salvelinus fontinalis*) have active programs at fish hatcheries to restock the Great Lakes (table 2). In the same time period, 2000-2009, just over nine million native[12] trout were stocked into the Great Lakes. All four morphotypes of Lake Trout and several

[12] Splake (*Salvelinus namaycush* X *Salvelinus fontinalis*) are a hatchery hybrid cross between two native species. They are derived from a pairing of a male Brook Trout and a female Lake Trout. While potentially possible to have this crossing in nature it would be exceedingly rare and while they are reproductively viable, they rarely breed in the wild and are perpetuated in the environment through stocking (Sowards 1959, Kerr 2000).

strains of Brook Trout are actively managed and stocked in an effort to maintain and increase these native species. The question is should we continue to stock the non-native species which compete with our native fish, fish that were highly valuable as a commercial fishery until multiple human perturbations including our overuse caused their crash. While all these native strains are currently managed, there is no way of knowing what genetics have been lost with the extirpations of other morphotypes and strains. Lake Trout are a cold-water species. The effects of Climate Change are also impending stressors which may affect the populations for centuries to come (GCRP 2014).

Table 2 . Mean annual native fish stocking into the Great Lakes (2000- 2009).*
Table derived from (GLEAM 2016b). 1 see footnote 11 above, 2 Splake are a hatchery hybrid, see footnote 9. Source: Great Lakes Fish Stocking Database (FWS/GLFC 2010).

Native Species	L. Superior	L. Huron	L. Michigan	L. Erie	L. Ontario
Atlantic Salmon[1]	0	0	0	0	230,000
Brook Trout	280,000	0	25,000	11,000	0
Lake Sturgeon	2,200	0	7,800	0	0
Lake Trout	960,000	3,600,000	2,800,000	230,000	780,000
Muskellunge	0	0	8,900	0	0
Splake[2]	200,000	32,000	100,000	0	0
Walleye	9,700,000	1,100,000	2,300,000	260,000	86,000
Yellow Perch	140,000	0	0	300,000	0
TOTAL	11,282,200	4,732,000	5,241,700	801,000	1,096,000

Atlantic Cod are arguably one of the most heavily fished species in history. Fishing for this species on an industrial, commercial scale can be traced back to at least 800 AD and has formed the basis of several economies in the past (figure 11), including

the rise of the United States in the world economy (Kurlansky 1997). Paul Greenburg in talking about the cod industry has said "Cod, a white, flaky-fleshed animal that once congregated in astronomical numbers around the slopes of the continental shelves many miles offshore, heralded the era of industrial fishing, an era where mammoth factory ships were created to match cod's seemingly irrepressible abundance and turn its easily processed flesh into a cheap commoner's staple." (Greenburg 2010, 10). Recent technological advances in the past century to fishing tackle and the invention of the industrial factory ship led to catastrophic overfishing and eventual moratoriums of the commercial cod fishing industry in the North Atlantic. Modern threats to Atlantic Cod thus include a myriad of factors including habitat destruction and degradation (mostly from previous trawling practices), overfishing and unsustainable fishing practices such as fishing well over the maximum sustainable yield, poaching and illegal, unreported and unregulated (IUU) fishing, and trophic cascades.

Figure 11. Historic advertisements for Atlantic Cod from the Gloucester, MA area.
Images from Procter Brothers (1876).

Overfishing of Cod stocks caught people by surprise. After all, the bounty of the sea is limitless, or so people have thought since the 18th century- right up until the cod fishery collapsed. Thomas Huxley (1883) famously discussed the issue of the inexhaustible nature of marine fisheries (and cod specifically) by stating:

> Are there any sea fisheries which are exhaustible, and, if so, are the circumstances of the case such that they can be efficiently protected? I believe that it may be affirmed with confidence that, in relation to our present modes of fishing, a number of the most important sea fisheries, such as the cod fishery, the herring fishery, and the mackerel fishery, are inexhaustible. And I base this conviction on two grounds, first, that the multitude of these fishes is so inconceivably great that the number we catch is relatively insignificant; and, secondly, that the magnitude of the destructive agencies at work upon them is so prodigious, that the destruction effected by the fisherman cannot sensibly increase the deathrate… I believe, then, that the cod fishery, the herring fishery, the pilchard fishery, the mackerel fishery, and probably all the great sea-fisheries, are inexhaustible; that is to say that nothing we do seriously affects the number of fish. And any attempt to regulate these fisheries seems consequently, form the nature of the case, to be useless.

Huxley, however, made one important caveat to this statement. He referred to the inability to exhaust these marine resources *at that time*, and with *currently available technology*. Huxley had no way of envisioning factory ships, monofilament fishing line, or the exploding world population.

As populations have grown so has the fishing pressure on worldwide stocks. The cod fishery off the coast of North America has long been a highly prized economic commodity. There is evidence to suggest that the Spanish and Icelandic fleets have been sailing to the new world for centuries to capitalize on this resource (Kurlansky 1997). These lucrative North America cod fisheries fueled the early United States and Canada. As both of these nations grew and prospered, there slowly became a realization that other nations were also tapping into these vast natural resources. The extension of exclusive economic zones was driven in part to protect these and other offshore fisheries. However, the ocean is a large place and enforcing regulations of exclusive use of resources is difficult.

Equally difficult is the assessment and measurement of fish populations (i.e., stock assessments). These problems multiply with species that migrate across international borders or into international waters. Questions of What methods are being used to monitor? How is biomass estimated? When is the data collected? Where is the data collected? (e.g., spawning grounds vs. open ocean). What life stage is being examined? (eggs, larvae, juveniles, adults, post-spawning, pre-spawning). Even something as simple as, how the fish is measured (total length, fork length, standard length), can affect stock assessments.

In stock assessments of Lake Trout and Atlantic Cod that move across political boundaries- data transferability from one agency (or State) to another, natural fluctuations in catches from year to year, and enactment of new international laws or changes in multilateral and bilateral agreements between nations can alter assessments and predictions.

Illegal, unreported, and unregulated (IUU) fishing is a scourge on the world's oceans. IUU fishing undermines any policies and efforts to sustainably manage fishery resources. IUU fishing and fraudulent seafood products distort market prices and can undersell legal products from law-abiding fisherman (NOAA-NMFS 2016). Recent international efforts seek to reduce the threat of IUU fishing and Atlantic cod are one of the priority species.

IUU fishing and indeed overfishing in general has for centuries driven the population genetics of the Atlantic Cod. Following the complete collapse of the NW cod fishery steps have been taken to implement new regulations and re-open the fishery. The stocks were so low that any amount of fishing pressure precludes a recovery. Cod are migratory, but still segregated into discrete spawning populations. Historically, some of these areas have been harder fished than others and some have shown little to no recovery. According to the National Marine Fisheries Service, reproductive cod in the Gulf of Maine population make up just 3-4% of the population and they have said, "Unfortunately the news is not good. The new analysis presents a grim picture for the potential recovery of this iconic fish stock." (Frady 2014).

Recently, fishery managers have found a slight improvement in the stock assessments for the Northwestern stocks of Atlantic Cod (Berke 2022), which after decades of low numbers and failures to rebound are significant. However, according to the most recent stock assessments (2021) based on the fisheries rebuilding and recovery plans for the Gulf of Maine and the Georges Bank stocks, they are still overfished and below the target biomass levels (NOAA-NMFS 2022a).

As Daniel Pauly and his colleagues (2009, 1998) have eloquently stated, “fish down the food web”— the concept that fisheries, faced with declining catches of previously harvested species, switch to invertebrates and smaller (previously undesirable) fish to maintain the same (unsustainable) level of fisheries catches.

The reductions in the Atlantic Cod stocks have led to fishing down the food web. The world population likes the taste of cod. So as Atlantic stocks plummeted to commercial extinction, the industry shifted to the Pacific. Efforts shifted to ‘look-a-likes’. On the market today many products, once exclusively made of Atlantic ‘cod’, are being replaced by other species but still sold as ‘cod’. Pacific Cod (Gadus macrocephalus), Whiting (*Merlangius merlangus*), Haddock (*Melanogrammus aeglefinus*), Pacific tomcod (*Microgadus proximus*), Alaska Pollack (*Theragra chalcogramma*), Atlantic Pollock (*Pollachius pollachius*), Coley (*Pollachius virens*), and a multitude of others are all marketed and sold as ‘cod’. ‘Cod’ for centuries meant Atlantic Cod, but now it has been replaced with any number of species in the cod family (Gadidae). The multitude of fish going into products only exacerbates the IUU fishing.

Tragedy of the Commons, International Relations, and Policy

The tragedy of the commons is a theory postulated by Garrett Hardin (1968). In it he contends that individuals [or for my research purposes individual states] that act rationally and independently from one another will act in their own self-interest and generally contrary to the long-term best interests of the greater group by removing a publicly held (common) resource for their own gain at the expense of all others. Hardin’s

work was informed by that of Lloyd (1883) who theorized that individuals with access to a shared resource act in their own self-interest and then deplete the resource for all.

Given that all actors tend to act rationally and, in an effort to maximize their own utility, as postulated by Adam Smith in 1776 (Smith 2004), then everyone will each act to maximize their take of the common resource, thereby overusing the common resource in an unsustainable manner. This concept is somewhat contrary to the Smith's theory of the 'invisible hand' (Smith 2004, Olsen 1993), where the individuals' action of maximizing their own utility may inadvertently benefit society by mistake—even more so than if they set out to take actions to benefit society. Maximizing one's individual pursuits will unintentionally benefit all despite being of primarily individual aims. It is that logic which in part leads to the tragedy of the commons. It works when the population is small enough that the common resource is not overly taxed or depleted, but once society or a population grows to the point that they are eating into the capital (to use an economics framework) by their collective individual actions, then the common resource is bound to eventually disappear and collapse. Individuals cannot all act as if their actions do not directly affect others.

This is directly applicable to transnational fisheries issues. Each state seeks to fish to the MSY- the maximum sustainable yield. In other words, each state wants to extract as many fish as possible from the common resource stock on an annual basis. However, if this fish stock is one population that is utilized by more than one nation, (i.e., a population that moves across international boundaries) then the MSY is not independent. The MSY stays the same, but the states each share a portion of it. Problems develop when each nation seeks to extract their MSY catches (maximize their individual utility) from

the common resource without regard to how that is affecting the group overall. When each state seeks to extract the MSY in a given year independent of one another, then that MSY is not the same value and each then is extracting above the MSY driving down the common resource for all and overusing the resource. It is not sustainable. Fisheries can and do replenish themselves, but only if the stocks are removed at sustainable levels- meaning that recruitment (breeding, stocking, migrations, immigrations) must be higher than extractions (die-offs, predation, fishing, emigrations). Kratz and Block (2013) have suggested the answer is new regulations, individual transferable quotas (i.e., central regulation of the population and distributed sanctioned use- permits), and privatization of ocean regions.

Often in North America, the minority use of the resource by fishermen and their individual needs is seen as a more important voice than the majority. While the greater society loses out if the common goods are removed, these fisherman benefit. The logic of collective action put forth by Mancur Olsen (1965) may help explain part of this. In this seminal work Olsen argues that the concentrated action of a few may be able to trump the majority since the larger a group gets, the harder it is to organize and reach a consensus action. The large groups, in this case the societies at large in Canada and the United States, may not want to see the common goods overused, but as a whole have a hard time coalescing into actions or policies. Additionally, there is a 'head-in-the-sand' mentality that often prevents action on seemingly insurmountable environmental policy issues. In relation to global Climate Change, Irina Feygina and her colleagues have argued that "these responses are linked to the motivational tendency to defend and justify the societal status quo in the face of the threat posed by environmental problems" (Feygina et al

2010, 326). It is hypothesized here that this same issue of system justification holds true for fisheries management issues as well.

Wilen et al. (2012) contend that marine resource uses are an "interplay between biology, market forces, and governing institutions." They explain that fisherman are not inherently over-exploiting resources intentionally, but rather are acting in their own self-interest and 'scrambling' for resources and wastefully competing with each other because they lack secure access to the resources into the future. They only have ownership of the goods when they are in their possession. Market forces and secure access to the resources then drive overfishing and by-catch.

Of course, to avoid these issues, societies have enacted laws, regulations, policies, international treaties, and best practices to ensure the sustainability of collective goods. These legal frameworks are enacted by governing institutions and are created at the highest levels. This 'top-down' management is highly effective in creating the guiding principle of action and has blanket authority to enact regulations, yet enforcement and community adherence is less effective. It can become a 'carrot versus a stick' concern. People follow regulations and rules not because of a greater ethical and metaphysical sense of right versus wrong (that varies considerably among individuals, cultures, and groups), but rather because of fear of consequence. Indeed, Wiedemann and her colleagues (2011), found that carrots (i.e., incentives) do increase cooperation, sticks (i.e., consequences) are more effective in maintaining the cooperative use of public goods. With this in mind, this research will focus on how the governments of the United States and Canada are able to overcome issues of collective action and avoid the tragedy of the commons in fisheries management with species that move across the border.

During the colonial era much of the world's political economy was driven by dependence. The relationship between many nations was not cooperative, but oppressive as it was being affected by external factors and forces. During the past several decades as economies and nations became linked through globalization, interdependence (essentially mutual dependence) began to become the norm for many nations' interactions. Complex interdependence as put forth by Keohane and Nye (1977), following on from the work of Buell (1925) and Cooper (1968), postulates that in international relations the fate of states is inevitably and completely linked to one another. Effective fishing management, and indeed any bilateral agreement, requires that parties cooperate with one another. With most nations this sets up the basis for this complex interdependence.

According to Nye (1987), in his review of the relevant literature on neo-liberal institutionalism, complex interdependence has been considered the opposite of realism. The example of the relationship between Canada and the United States is often cited as the (neoliberal) example as their relationship is built on shared values, beliefs, and security and neither nation feels threatened by the other (Braddon 2012). Classical realists' postulate that states always seek increases in relative power, and this is not the case here. However, it is understood that this system breaks down under developing world conditions and both classical realism and neorealism seems to explain international relations better. While advanced developed nations tend toward cooperation and the use of international institutions and multinational corporations which require cooperation among nations, this is generally not the case for developing world states.

Following the end World War II in 1945 and through much of the Cold War from 1945-1991, U.S. foreign policy followed with the reasoning of Hans Morgenthau, based

in large part on his seminal book on classical realism, Politics Among Nations (1948). In that work he argued for realism, and that individuals and the states they lead must work in the national interest. Following his reasoning, while personal opinions help to develop one's character, these cannot factor into decisions intended towards maximizing the national interest. Federal employees, ambassadors, and policy makers thus represent the state and not themselves, this Morgenthau premise has permeated government service for decades and may have real consequences for implementation of fisheries management practices. Real conflict and alterations may persist when one is acting in what they believe is the national interest rather than personal opinions. Issues presented by scientists may be treated as opinion rather than facts, and thus discounted in the national interest.

Contrasting the work of Morgenthau is seminal neo-realist theorist Kenneth Waltz (1979), who argued that international politics are based on anarchy and functionally undifferentiated state actors. He postulates that states are only distinguished by the capabilities they possess. He felt that states fundamentally pursue security above all else, a situation commonly observed during the Cold War. This narrow focus of priorities leads to a lack of cooperation and mistrust even with allied neighbors. This may have thus factored into some of the policies and treaties with which fisheries are managed.

Fisheries management between states is ultimately a collective action issue. Olsen (1965) argued that the larger a group gets, the harder it is to organize and reach a consensus action. Centuries ago, when there were only a handful of fishing vessels, it was easy to cooperate (or even avoid entirely) other fishermen utilizing the common resources. As states grew their relative footprints across the fisheries grew and as we see

today there is a huge overlap in fishermen and fisheries and thus the need to coordinate actions. Yet it is still only a subset of society (fishermen) that are directly interacting with the resources. Even though societies at large may not want to see the common goods overused, they are only indirectly involved and as such have a hard time coalescing interests and concerns into actions/policies. Additionally, many in the greater society commonly develop a 'head-in-the-sand' mentality that often prevents action on seemingly insurmountable environmental policy issues. From these issues we can therefore understand how the concentrated action of a few may be able to trump the views of the majority, which can thus lead to overuse of the resources, IUU fishing, and other fisheries management breakdowns.

Environmental Agreements & Cooperation

Canada and the Unites States share a vast, largely unregulated border. This is especially true in the marine environment offshore context, where it is unusual for fishermen to interact with others (including law enforcement, border control, coast guard, and immigration). This is possible because there are long-standing treaties in place that regulate the intergovernmental relations, trade, border control, etc. and the two countries have interacted in highly collaborative and peaceful ways. It is rare for these nations to need the use of international institution interventions. They demonstrate why there is a need to incorporate international institutions, inter-governmental organizations (IGOs), and non-governmental organizations (NGOs) to help facilitate multilateral cooperation on natural resource management for commodities (i.e., fishes). Even so, there has been limited success demonstrated by treaties and especially their enforcement leading to the

continued decline of some fisheries stocks that cross the boundaries (Atlantic Cod) and not in others (Lake Trout).

Exploitation of marine resources is the biggest threat[13] to most fish species. Understanding this potential threat to their food security and other maritime uses, countries in the 20th century began to expand their sovereign maritime borders, from what was initially (dating back to the 17th century) 4.8 kilometers (3 nm) from shore, out to 371 km (200 nm) (figure 12) and have exclusive rights to manage the natural resources found within (Alcock and Hoel 2006). This marine area has come to be known as the exclusive economic zone (EEZ) and was codified in the 1970s and 1980s by the United Nations Convention on the Law of the Sea (UNCLOS)[14]. Part V, Article 61 of UNCLOS states, "2. The coastal State, taking into account the best scientific evidence available to it, shall ensure through proper conservation and management measures that the maintenance of the living resources in the exclusive economic zone is not endangered by over-exploitation. As appropriate, the coastal State and competent international organizations, whether subregional, regional or global, shall cooperate to this end." (United Nations 2016, underline added for emphasis by author).

[13] This statement is hard to quantify or validate. There are many threats to marine resources and arguments could be (and have been) made that habitat degradation, Climate Change, pollution, ocean acidification, etc. are the biggest threats to marine species. This is indeed the case for some species. Ocean acidification and Climate Change for example are likely the biggest drivers in the decline of Coral Reefs and their associated flora and fauna. However, in terms of direct threats to fishes, exploitation, or resource extraction (i.e., fishing) is the main driver of change.

[14] UNCLOS is actually a series of three UN conferences which concluded in 1982. The final meeting, UNCLOS III, replaced four 1958 international treaties (developed after the first UNCLOS conference in 1956), but did not go into effect until 1994. As of 2016 there are 167 signatory countries to UNCLOS.

Figure 12. The eastern portions of the Exclusive Economic Zones (EEZ)[15] of the United States and Canada.
The purple-blue color representing American areas and the light blue representing Canadian areas. Map created by the author, GIS data from ESRI and MarineRegions.org.

Such efforts were not created by the international community devoted to a metaphysical conservation ethic, but as a way of maintaining food security and continued fishing internally, while simultaneously excluding outside fishing fleets. Part V, Article 61 of UNCLOS goes on to mandate that "3. Such measures shall also be designed to maintain or restore populations of harvested species at levels which can produce the maximum sustainable yield, as qualified by relevant environmental and economic factors, including the economic needs of coastal fishing communities and the special

[15] Typically, Exclusive Economic Zones are designated along coastal areas of continents based on recognized national borders and extend 321 km (200 miles) offshore. The Great Lakes region would be encompassed within this range for either country. By treaty, the lakes which lie across the international border were divided down the center of the lakes.

requirements of developing States, and taking into account fishing patterns, the interdependence of stocks and any generally recommended international minimum standards, whether subregional, regional or global." and in Part V, Article 62, which states in part, "4. Nationals of other States fishing in the exclusive economic zone shall comply with the conservation measures and with the other terms and conditions established in the laws and regulations of the coastal State…" (United Nations 2016, underline added for emphasis by author). UNCLOS thus established a legal framework for regulating the use of the world´s oceans, required cooperation among nations, sustainably fisheries, and working toward resource improvements (Burke 1994, Alcock and Hoel 2006).

As international boundaries have appeared (and grown), so, too, have international regulations based in large part on fishing rights, states are forced to examine fisheries stocks under their jurisdiction. But these resources, which nations are trying to zealously hoard and exclusively use, tend to move; in particular, they swim past the national boundaries—those imaginary lines established on two dimensional maps. How can we manage these vital resources which are zealously sought, and jealously guarded, across multiple jurisdictions? How can one avoid the tragedy of the commons if they are not collectively managed? Fish move across international boundaries, or as David Butler (personal communication) once noted, "Fish do not have loyalty to a nation state; fish do not fly a flag". Ecologist Garret Hardin (1968) noted that "…natural selection favors the forces of psychological denial. The individual benefits as an individual from his ability to deny the truth even though society as a whole, of which he is a part, suffers." (Hardin 1968, 1244). Over four decades later, Paul Greenburg in his book Four Fish noted that,

"With wild fish we have chosen, time after time, to ignore the fundamental limits the laws of nature place on ecosystems and have consistently removed more fish than can be replaced by natural processes." (Greenburg 2010, 13).

Bilateral and multilateral cooperation have had a prominent place in international relations for centuries and as such, there is a breadth of literature on the subject. Cooperation helps states to arrive at mutually beneficial agreements though not without a great deal of work and coordination. Ultimately, each state is working to maximize its own benefits in a neo-Smithian manner. Kinne (2013) has theorized that bilateral agreements beget further agreements as partners begin to trust and understand their counterparts. These mutual agreements are often based on trade, and therefore each party has a vested interest in maintaining these relationships. This leads to decreased conflicts and according to Polachek (1997) this is why we see less conflict between democracies that trade with each other than non-trading partners and even less that non-democratic non-trading partners.

Environmental agreements can often be the most challenging to develop, as there are so many shifting variables and a high degree of complexity and unknowns. Despite these challenges, fisheries agreements which seek to maximize yields while avoiding the tragedy of the commons are understandably complex and numerous. According to the Fisheries Department of the Food and Agriculture Organization (FAO) of the United Nations (1999), bilateral agreements comprise 91 percent of the worldwide fisheries agreements between states. These agreements include standard formal language and requirements including ratification dates, signatories, and relevant publications as well as substantive language detailing types of ships, fishing methods, tackle used, quotas,

dispute resolution, species involved, and types of technical cooperation and monitoring. These substantive aspects are especially important in fisheries management as it can be very difficult to measure fish populations (i.e., stock assessments). As Ørebech (2013) points out, the problems multiply with species that migrate across international borders or into international waters. What methods are being used to monitor? How is biomass estimated? Even things as seemingly simple as how the fish is measured (total length, fork length, standard length) can have dramatic differences in the final data (FAO 1974). When is the data collected? Where is the data collected (e.g., spawning grounds vs. open ocean) and what life stage is being examined (eggs, larvae, juveniles, adults, post-spawning, pre-spawning) also have dramatic consequences to the data and the transferability from one agency (or state) to another.

"It is common knowledge that when coastal states and high seas fishing states exploit straddling and shared fish stocks, this uncoordinated harvesting practice easily overexploits the population and, in the long run, depletes the stock." (Hardin 1968). While this statement may seem obvious, it even says it is 'common knowledge," many states have refused to cooperate with other countries to regulate and manage fisheries. Publications from the turn of the century (Hjort 1914) describe the same issues that nations are facing today, detailing the natural fluctuations in catches from year to year, and the apparent decline in some fisheries. This has led to large declines in worldwide fisheries stocks and predicated the enactment of international laws and the increase in multilateral and bilateral agreements between nations (Carroz and Savini 1979, Carroz and Savini 1978, Kim 2018).

With the rise of international institutions many States have ratified treaties and protections through third party oversight. These international institutions are considered neutral parties which can serve as arbitrators in the case a dispute or conflict arises, or one or more parties feel that the other is not meeting its agreement responsibilities. The rise in international arbitration has also solidified the idea of '*jurisdiction ratione personae*'- whereby only States which are party to an agreement or treaty can benefit from the arbitration process (Ørebech 2013). This has aided States abilities to fend off illegal use of resources and forced parties into more formal agreements.

The cooperative relationship between the United States and Canada is well understood. The use of bilateral agreements, treaties, and intergovernmental working groups between these two nations has made them an example on the cooperative management of fisheries resources. The basis of fisheries management within each respective nation is predicated on federal laws. In the United States the primary law governing fisheries management in federal waters is the Magnuson–Stevens Fishery Conservation and Management Act (NOAA-NMFS 2017). In Canada the primary federal law is the Canadian Fisheries Act 2019 (FOC 2019).

The Magnuson-Stevens Fishery Conservation and Management Act (MSA) was originally developed, codified, and enacted as the Fishery Conservation and Management Act of 1976. The impetus for its creation was to remove access to foreign fishing fleets to U.S. fisheries resources[16]. Since its adoption, the act has been amended several times in response to intense fishing pressures, first in 1996 with the Sustainable Fisheries Act to

[16] Also in 1976, Canada, like the United States, wanted to remove foreign fishing pressure on their fisheries resources and declared their exclusive economic zone off limits to non-Canadian fishing fleets.

improve the long-term viability of fisheries, and then in 2007 with the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act to develop controls on the U.S. fishing fleet.

The MSA established eight regional fishery management councils. These councils are comprised of state fisheries managers as well as appointed representatives from the local fishing industry. The councils develop fishery management plans, which are then approved and implemented by the federal government (specifically the National Marine Fisheries Service). The intention is that this management methodology promotes transparency, accountability, and cooperation between stakeholders at all levels of government (local, state, and federal) resulting in sustainable fisheries managed with the best available science which is fair and equitable to all parties.

While sustainability is the founding intention of the MSA, it does, however, have provisions which are antithetical to this goal. One such item is that 'fishing down the food chain' is seemingly encouraged by "promoting development of commercial fisheries and markets for underutilized species of the northwest Atlantic Ocean," through "developing alternative fishing opportunities for participants in the New England groundfish fishery, providing technical support and assistance to United States fishermen and fish processors to improve the value-added processing of underutilized species, and to make participation in fisheries for underutilized species of the northwest Atlantic Ocean economically viable…" (NOAA-NMFS 2007, underline added by the author).

Canadian fisheries have long been afforded legal protections and active management with the passage of the original Fisheries Act (FA) in 1868. This remained unchallenged or altered until 2012 when amendments significantly removed many

protections to the fisheries resources. Following widespread discontent with the changes made to the Fisheries Act in 2012 another amendment was developed and implemented in 2019. According to Fisheries and Ocean Canada the new act: "reinstates lost protections by providing comprehensive protection for all fish and fish habitat; restores the previous prohibition against the harmful alteration, disruption or destruction of fish habitat; … recognizes that decisions can be guided by principles of sustainability, precaution and ecosystem management; promotes restoration of degraded habitat and rebuilding of depleted fish stocks; … creates new fisheries management tools to enhance the protection of fish and ecosystems; strengthens marine refuges to ensure the long-term protection of biodiversity; helps ensure that the economic benefits of fishing remain with the license holders and their community…" (FOC 2021).

The focus of the Fisheries Act now requires that the federal government of Canada must manage fisheries stock at 'sustainable levels', and further that it must develop and implement plans for restoring fish stocks. However, it prescribes this as the maintenance of 'major fish stocks listed in regulation' that are depleted allowing for interpretation of the need to manage all fish.

Federal government oversight (e.g., laws and regulations) a top-down approach has been used for centuries as a means to manage fisheries. The MSA in the United States and the FA in Canada are the preeminent examples. Within fisheries management, traditionally a 'hard science', there has been a shift towards utilizing more social science approaches as fisheries managers realize that managing natural resources is as much about managing people as it is the resources themselves. 'Participative governance', the co-management of resources between agencies (i.e., government) and stakeholders has

also increased in recent years as government funding has decreased and the value of stakeholder engagement and assistance has become more valued (Symes 2006). A stakeholder group that has been gaining particular sway in resource management is large corporations. Corporations, especially large multinational corporations, often have stakes in local, regional, and national politics, acting directly as lobbyists and indirectly in implementing resource management actions directed by governments (Falkner 2003). Another newer implementation of an older (e.g., community or locally led) bottom-up approach has recently been increasing in relevance, fishery improvement projects.

Fishery improvement projects (FIPs) are based on cooperation and engagement using the vested interests, resources, and expertise of multiple stakeholders to have direct voices directly in decisions, policymaking and the management of local and regional fisheries (Cannon et al. 2018). FIPs are essentially a form of participative governance to reduce environmental impacts, restore stocks, and promote sustainability in some of the most previously impacted fisheries. FIPs are notable for their diversity and ability to work across fishery types and locations. As a collaboration of multiple stakeholders, they can be led by industry, non-governmental organizations (NGOs), or government agencies (Crona et al. 2019). The role of FIPs is to serve as a template for improved fisheries management. This is done by providing a strategic plan, developed collaboratively among the various stakeholders, for actions that can lead to changes in policies, best practices, and implementation. According to Crona et al. (2019) the most common way this is achieved is through dialogues with policy stakeholders, data collection,

educational efforts directed at fishermen, rules for limiting fishing access, increasing compliance, mandating gear changes[17], and observer and traceability programs.

A notable FIP in Canadian waters is the Atlantic Groundfish Council (AGC). This industry based FIP is composed of Canadian offshore fishery companies- supported by the Sustainable Fisheries Partnership, which targets Atlantic Cod. The goal of the FIP is to create an action plan to restore Atlantic Cod stocks and habitat to a level in which the industry can receive Marine Stewardship Council (MSC) certification that the fishery meets sustainability requirements (FisheryProgress.org, 2022).

Much has been discussed to this point referencing sustainability. The sustainable use of marine resources, specifically fisheries is codified in numerous bilateral and multinational agreements and laws. However, as Hoel and colleagues (2005) have suggested, there is increasing concern about the long-term conservation of fisheries species and what constitutes sustainable fisheries. Despite many efforts scientifically, culturally, legally, and politically, there are multiple interpretations and perceptions of what constitutes 'sustainability' in fisheries. Hilborn et al. (2015) have argued pp that the definition of sustainability in fisheries is, "the ability to sustain goods and services to human society, with social and economic factors to be considered along with environmental impacts." The result has been that various stakeholders define sustainability using differing metrics, which are based on their perception(s) of the most

[17] 'Gear' in the fisheries management parlance refers to the fishing tackle used to catch fish. Gear types can be categorized broadly as bottom longlines, bottom trawls, buoy gear, dredges, fish aggregating devices, gillnets, green sticks, hook and line, mid-water trawls, pelagic longlines, pound nets, purse seines, skimmer trawls, and traps/pots. Typically, fishermen use a specific gear type to target specific fishes and while effective, some gear is less 'targeted' than others and can lead to bycatch- the capture of non-target fish (NOAA-NMFS 2022b).

relevant criteria. This ultimately creates confusion and controversy as each user group questions the legitimacy, value, and viability of the methods used by another.

In response to the problem, the industry has moved toward sustainability standards. Fishery managers, the public and, the fishing industry recognized that assessing sustainability and having all the various parties recognize the legitimacy of the results requires a holistic approach beyond the simple direction of fishery agencies since it is transparency that builds trust, which is increasingly important for the fisheries to continue to operate (Fleming et al. 2020). The legitimacy of sustainability standards has long been of concern (Haack and Rasche 2021). It is functionally required by standard setters to create simple and low requirements so that they will be accepted and adopted (at least initially), allowing for cognitive legitimacy (i.e., belief that the system can work), but yet the standards also need to ensure results to acquire moral legitimacy (i.e., public acceptance, industry and agency buy-in) (Fleming et al. 2020).

The result has been the establishment of the Marine Stewardship Council (MSC). This non-profit NGO has come to be recognized as the primary standard setter for marine seafood sustainability in North America. MSC certification is applied to fish (and other seafood) from fisheries that have been independently assessed to meet the MSC Fisheries Standard not only to the effects on wild fish populations but also to their habitat (MSC 2022). The MSC was launched in 1999. In the ensuing two decades they have grown from the initial adoption phase to developing standards which seek to to adhere to global best practices as they have emerged and evolved and ensuring that fishermen meet or exceed these standards. The MSC regularly engages with multiple stakeholders to maintain buy-in, legitimacy, and meet expectations for the fishing industry, regulatory

agencies, and the public. While many fisheries have indeed improved, others (like the Atlantic Cod fishery) have struggled to maintain performance and indeed have regularly required significant improvements (Agnew et al. 2014).

Nearly two decades ago Alcock and Hoel (2006) suggested "…that fisheries managers could benefit from political science insights." This assessment was made in reference to the problems within the EEZ framework, failures in maintaining sustainable fisheries (e.g., the complete collapse of the Atlantic Cod fishery), and the regular acts of 20th century piracy- IUU fishing (Harris 1998). From these issues came the 1992 United Nations Conference on Environment and Development (UNCED), which had been mandated by the general assembly to alleviate these problems. Following several years of talks, the UN Fish Stock Agreement (UNFSA) was released in 1995. The major factor to the UNFSA was the adoption of a precautionary approach to fisheries, improvements to regional cooperation in fisheries management, plans to implement better enforcement, and mandatory dispute resolution (Balton 1996).

Contributions of the Dissertation to the Existing Relevant Literature

As this chapter demonstrates, there is a vast collection of research on the subjects of this dissertation. How this dissertation differs is in its focus on interdisciplinary research. The ecology of Lake Trout, for example, is a well understood topic, as is the political economy of cod fisheries, the impact of invasive species, or the management of collective resources. This dissertation builds on many of the previously identified factors involved in managing resources that move across borders and synthesizes all these disparate fields of study into one cohesive interdisciplinary approach. No one field has

been able to demonstrate a full and conclusive causality to the differences seen in managing fisheries. Through this research I hope to show that the interdisciplinary approach will fill in critical gaps in knowledge and understanding, so that future researchers and stakeholders will be able to better understand the reasons that the outcomes in fisheries management have not been uniform.

CHAPTER III – METHODOLOGY

A fundamental question in any social science research design is whether the data to be collected is qualitative, quantitative, or a combination of the two. It has been argued that "*quality* is essential to the nature of things." (Dabbs 1982, emphasis in original). A qualitative analytical approach focuses on the 'what, when, where, why, and how' of relationships between one or more independent variables and a dependent variable, while a quantitative one specifies numerically the effects of the former on the latter. Due to the type of the data to be collected, the topic at hand to be understood, and the nature of collecting data directly from people, this research design will predominantly be focused on qualitative information. It will rely on three major data collection methodologies, which will synergistically combined to present a robust answer to each of the research questions. The methods to be employed are a literature review (content analysis), survey, and interviews. This technique, known as triangulation, or convergent validation, allows the researcher to garner overlapping data collection techniques to arrive at a more robust answer to the research question (Berg & Lune 2012, Denzin 1978, Campbell & Fiske 1959).

Methods of Data Collection

Literature Review/ Content Analysis

In order to understand the breadth of any topic and be able to add to the current knowledge of the subject, one must first be well-versed in what is known and has been studied and learned on that topic to date. This is accomplished through an exhaustive search of the literature available on the subject. With a topic (fisheries management) that

spans centuries, academic disciplines, and national borders, the researcher must narrow the scope of the task. Well-focused research questions (articulated earlier in the dissertation) can help to define the type of information needed in order to fully understand the topic, the work previously undertaken, and the gaps that may exist. The literature review covers a broad array of the published data on the topic and spans the scientific literature, government documents and reports, international treaties, books, and historical accounts and essays. However, the intersection of Political Science and Fisheries policy is a surprisingly vast topic, with hundreds of thousands to millions of published journal articles in the pool of relevant literature.

The topic can be narrowed by utilizing appropriate keyword searches. Starting with the search terms “fisheries management”, results come in nearly 3 million potential articles. Similarly, “fisheries policy”, yields over 2.5 million articles. Adding terms to limit the scope of the search and results to “transnational boundaries fishing Canada United States “, still yields over 45,000 articles (table 3).

Instrument Development- Surveys

According to Arlene Fink, “A survey is a system for collecting information from or about people to describe, compare, or explain their knowledge, attitudes, and behavior” (Fink 2003a, 1). Fink (2003a) goes on to suggest that surveys have seven functional components: objectives for the research, study design, preparation of a reliable and valid instrument, administering the survey, data management, data analysis, and reporting results. Survey objectives are simply a way of articulating what type of information you are trying to gather information about. These objectives will inform the

rest of one's research, from study design and question formation to analysis of the resultant data. Surveys always have to have a research objective, and by simply changing the sentence structure regarding what the research goal is, a researcher can alter the focus of research. The objective(s) can, and are, formulated based on a specific research question or hypothesis.

Table 3 Literature review search terms and their results.

Search terms	Results (in millions)
fisheries management	2.94
fisheries policy	2.53
transnational boundaries	1.48
Atlantic Cod	0.622
Lake Trout	0.597
Canada and the United States fishing	0.546
fisheries politics	0.533
cultural politics fisheries management	0.384
fishing exclusive economic zone	0.162
Canada and the United States fishing cooperation	0.158
Canada cod fishing	0.111
transnational fisheries	0.0916
transnational boundaries fishing Canada United States	0.0459

Before a survey questionnaire can be developed, the researcher must first clarify the objectives of the survey, review the literature, and research the subject matter. In this

way a survey instrument can be developed to obtain an insight into the characteristics of the target population. Since the focus of this work is fisheries management across international boundary lines; an initial look into the commercial fishing industry was made with an online search engine (www.google.com) with the keywords “commercial fisheries survey questionnaire.” Over 5.75 million results were returned. Numerous scholarly articles regarding the use of survey questionnaires were returned with the results, as well as examples of surveys which had been, and are currently used, in the United States and abroad.

The self-administered survey questionnaire methodology is applicable and is undertaken in this industry with great frequency to help inform managers and policy makers how best to manage the resources of the region. Based on this simple metric, it can be seen that surveys within the fishing industry are used with some regularity. In fact, they have been used for decades as a primary data collection methodology in order to garner a wide variety of information. Almost 90 years ago, researchers from what was then the Bureau of Fisheries (now the U.S. National Marine Fisheries Service), in speaking about the usefulness of survey data for fisheries management said, “I have learned early in my work on the Great Lakes that a very important part of any survey or investigation of the commercial fisheries of a region is the careful assimilation and correlation of the views and opinions of the commercial fishermen of that region.” (Van Oosten 1934, 107).

The online self-administered questionnaire methodology was used for this study. While this method relies on informants completing questions themselves and thus tends to be the most burdensome to respondents (Bowling 2005), it was the most expeditious

way to garner the largest pool of participant opinion as possible from multiple stakeholder groups relevant to the topic. This was done using computer assisted surveying, through the use of e-mail solicitation.

It is often difficult and impractical, if not impossible, to administer a self-administered questionnaire to all of a given population (Burns et al 2008, Rubenfeld 2004). Therefore a subset, or sample, of the target population (the sample frame) is usually surveyed rather than trying to census the entire population. Since the sample frame should represent the larger group, various sampling methodologies have been derived to accommodate different types of data that may be collected. Sampling can be based on a randomized (probability) or deliberate (non-probability) design (Burns et al. 2008, Aday & Cornelius 2006). Probability sampling requires that a researcher know the entire extent of the population and can contact them, while non-probability sampling is used when a researcher cannot estimate the chance (probability) of a respondent being included in the sample. For the purposes of this research a non-probability design was used, since as Fink (2003d) suggests it is useful for data collection for surveys of specific and hard to identify groups.

There are a variety of non-probability sampling techniques. The four most commonly used in social science research are convenience, purposive, snowball, and quota sampling (Berg & Lune 2012). With this study, given the projected target population, purposive sampling and snowball sampling techniques were utilized. In purposive sampling individuals are selected based on the researcher's knowledge and expertise so that they meet specific set of criteria. Due to the nature of the selection process this type of research does not allow for extrapolation to a wide audience. While

the data cannot be generalized, the results can still be very robust and useful, but not representational. Snowball sampling relies on the interconnectedness of respondents. Once one informant is located, they can provide contact information for further individuals appropriate to the study. In many ways this type of sampling is thus similar to both convenience and purposive sampling. Snowball sampling is often associated with research focusing on sensitive topics, deviance, or other hard to access target populations (Berg & Lune 2012). Due to the interconnectedness of the target group, this technique will also be employed during the interview process.

Concurrent with the identification of a sampling frame and methodology the researcher needs to identify the target population and the eligibility criteria. The target population for this research included fishermen, fisheries managers, fish biologists and ecologists, diplomats, and government employees from the United States and Canada.

For this dissertation research, there were many sub-populations to target ranging from the general public (i.e., fishermen) too difficult to access elites (i.e., high ranking government officials). Potential survey participants were identified by reviewing potential organizational groups such as specific government agencies and user groups. Government agency employees were ruled out as survey respondents due to the difficult nature of targeting that group with research surveys. In order to survey government employees, a lengthy and onerous process, it requires the approval of the Office of Management and Budget (in the United States) and Public Services and Procurement Canada (in Canada). Given this difficulty, it was determined that they would best be reached through direct contact for more the more in-depth interview process and that many of the potential respondents with information pertinent to the investigation could be

reached through other professional organization affiliations. Contact was thus made with several professional organizations, including the American Society of Ichthyologists and Herpetologists, American Fisheries Society, Canadian Aquatic Resources Section, Trout Unlimited, Cape Cod Commercial Fishermen Alliance, Fisheries Council of Canada, Great Lakes Fishery Commission, and the New England Fishery Management Council.

Survey Question Development

All questions were reviewed by the dissertation committee and the IRB and received approval. The questions were categorized into five functional groupings: general, scientific/technical, political, economic, and cultural. Given the length of the survey, questions were all simple closed responses presented as binary, Likert scale, multiple choice, or the selection of multiple options. In this way survey respondents could be asked similar questions in order to discern differences between the target Nations and taxa.

Typically, the use of vague qualifiers and jargon is to be avoided in self-administered surveys as the respondents cannot ask clarifying questions. This can, in turn, lead to difficulty in data analysis and the interpretation of responses. However, due to the nature of this topic and the target population, there will often be jargon used. This is because the sciences, and especially government agencies, tend to heavily rely on technical terms, jargon, and acronyms. The target population will be familiar with, and tend to use these terms, as they are industry standards. MSY, CPUE, Salmonid, and fecundity may be jargon to the layperson, but they are standard speech within the North

American fisheries community at all levels, from fishermen to managers to policy makers.

"A reliable survey instrument is consistent; a valid one is accurate." (Fink 2003a, 47). Reliability therefore relates to the notion that if you repeatedly use the instrument, you expect to get similar (consistent) data. Poorly worded open-ended questions can, for example, contribute to poor instrument reliability. "Reliable data come from consistent responses over time and between and among observers and respondents." (Fink 2003b, 5). Validity refers to the idea that your survey instrument is collecting data as it was intended in order to answer the research objectives. Again, poorly worded questions or response choices can contribute to an invalid instrument; one that does not measure (or collect data) on what it was intended to.

Pilot (Beta) testing

Pilot testing, in this context, is the systematic pretesting of a survey instrument with a small group of respondents to ensure that any errors in the instrument are found and resolved prior to the full implementation and administration of the instrument for data collection. Litwin (2003) suggests that pilot testing serves three main functions: identification of errors in the survey, identification of areas in the instrument that may need to be redesigned, and providing predictions of possible problems that may be encountered. Pilot testing helps to support the creation of an internally valid instrument. Collection of a large sample size from a random group of respondents helps to ensure external validity. Beta-testing is very valuable in allowing the researcher to gain insights into how potential respondents would perceive the survey questions. Additionally, while

waiting for colleagues and reviewers to perform the beta-testing it allows the researcher to gain some 'distance' from the questions in order to review them with renewed scrutiny (Beers 2005). Questions and/or responses may be changed as the direct result of beta-testers comments and others may be changed by the researcher in order to make them more focused to address the research question. Questions were beta tested with fishermen and fisheries managers known to the researcher from outside the scope of this research (i.e., Pacific biologists, Salmon fishermen). From these questions, the final approvals were granted for the survey instruments.

Instrument Development- Interviews

Interviews are a structured or purposeful conversation between two people (Oishi 2003) and are designed to elicit a great deal of information from a few individuals. The operative wording of this idea is found within the term purposeful. An interview is not just a conversation with someone. It is a directed research action with the express intent of extracting information relevant to the research question being investigated. This methodology typically relies on great amounts of details (data) from few respondents and is less of a burden on respondents (Bowling 2005). "Qualitative studies usually have research questions that require description of how phenomena are experienced rather than measurement of aspects of experience" (Oishi 2003, 9). One of the best ways to get at this description is through speaking directly with an individual.

The process (methods) of interviewing can be reduced to the foundational elements of who, what, when, where, and how. Each of these subdivisions gives a unique yet overlapping perspective of the rationales for this type of data collection. The question

of why is a fundamental one with a broad answer that ultimately reflects the answer to nearly all science; to get answers to research questions. To attempt to narrow this focus Sabine Oishi articulated that, “The purpose of qualitative interviewing is to describe and interpret experience, not to test hypotheses, find statistical differences between groups, or describe what proportion holds a certain belief” (Oishi 2003, 173). So, the question of why revolves around the ability to use informants to gain insights, facts, stories, and gather opinions (Berg & Lune 2102).

The nature of interviews yields data, which is both broad and voluminous, but concurrently specific and detailed. Therefore small ‘n’ values are expected and why they can still provide valuable insights into a particular target population. Part of this decision is based on the needed n-value and if this is to be a large representational sample as is often the focus in quantitative interview projects versus a small-n study where a targeted subsample is needed. Small-n interviews are more often conducted with hard-to-reach populations such as policy officials and biologists with specific knowledge bases.

To gather data for this research, the interview technique most useful was determined to be the semi-structured instrument. This type was used to ensure that major themes and questions are included with each interview (created during the development of the on-line survey and based on a subset of major topic questions), while also allowing for additional information gathering from informants that may have ideas and opinions not considered by the researcher, but which can subsequently be included due to their relevancy. The interview instrument was developed as a reference for the interviewer so that the informant could be guided towards the type of information needed and then allowed to discuss the issues, they felt were most relevant. At any time the researcher felt

that the topic was becoming too tangential, the questions from the instrument were used in moving back on topic. Follow-up questions and digressions are almost expected (Berg & Lune 2012). This type of interview can utilize mixed method, quantitative, or qualitative data, depending on what information is needed for the research.

Individuals were sought for interviews based on their presumed knowledge in the area of interest based on geography and vocational position (predominantly academia and governmental agencies). In addition to searching for potential informants through broad email inquiries to previously identified governmental agencies and academic institutions the researcher also used personal government and academic contacts to help identify key participants. This was especially useful in identifying and locating contact information from 'elites' such diplomats, senior government officials, and academic researchers and fisheries managers known to have investigated similar areas in the field (i.e., Great Lakes and Atlantic Coast states/provinces) (table 4). Once interviews were conducted, a final question was posed to informants asking for additional potential informants and contact information based on their contacts and knowledge of what information the researcher was seeking (i.e., snowball sampling). An additional source of interview participants self-identified through the final question of the online survey in which participants were asked to provide contact information if they saw an interest in discussing the research further during the interviews.

Table 4 Interview informant affiliation and nationality consulted for the present study.

Informant Group	Affiliation	Country
Fishermen	Commercial Fishing Alliance	United States
State/Provincial Fishery Managers	Michigan Department of Natural Resources	United States
	Wisconsin Department of Natural Resources	United States
	Massachusetts Division of Marine Fisheries	United States
	Ontario Ministry of Resources	Canada
Federal Fishery Managers	National Marine Fisheries Service	United States
	U.S. National Park Service	United States
	U.S. Fish & Wildlife Service	United States
	U.S. Geological Survey	United States
	Fisheries and Oceans Canada	Canada
Policy Advisors/ Diplomats	National Oceanic and Atmospheric Administration	United States
	U.S. Department of State	United States
	Consulate General of Canada to the United States, in Detroit	Canada
Academics	Dalhousie University	Canada
	Northern Michigan University	United States
Fishery Management Councilors	Fisheries Council of Canada	Canada
	New England Fishery Management Council	United States
	Great Lakes Fishery Commission	United States

Research Process

Institutional Review Boards (IRBs) were established in order to regulate research activities involving human subjects and ensure that no harm was done to these individuals, nor their privacy violated (Berg & Lune 2012, Fink 2003a). Permission for the surveys and interviews central to this dissertation was sought from and granted by The University of Southern Mississippi (USM) Institutional Review Board

(https://www.usm.edu/research/institutional-review-board) prior to the administration of the data collection instruments[18].

Further ethical considerations of this research required participants had been given informed consent. Prior to taking part in research activities, potential respondents must be made aware of the risks and benefits of participation, along with their rights. This requirement is fulfilled by either verbally informing informants, or as in the case of self-administered surveys, in writing as an informed consent clause prior to beginning the survey. This 'informed consent form' allows participants to make educated decisions about whether or not they want to participate in the research and their rights afforded to them if they do so (Fink 2003a). For the purposes of this research, informed consent in written form was the first question in the survey. Participants had to read and acknowledge the informed consent statement before the on-line survey would continue (i.e., the question could not be skipped). For interview participants, the statement was read aloud at the initiation of the interviews and a verbal acknowledgement was received. Furthermore, with the interview participants they were also informed that while the session was being recorded, no information would be personally attributed to them. Attribution was only be made to generalized title and agency when applicable. This was done in order to allow them to speak candidly.

Administering Surveys

Following the dissertation committee and IRB approvals, contact was made with the previously identified target participant organizations. On their request, copies of the

[18] USM Institutional Review Board (IRB) approval # 22-749, granted 9 May 2022. See appendix C.

IRB approval and the informed consent statement were forwarded to the organization for review. Upon approvals of the governing board (or equivalent) a link to the online survey instrument (hosted at www.surveymonkey.com) was emailed to the organization.

Amassing adequate response rates is so important to the collection of sufficient data from the target audience. Numerous ways of increasing and ensuring adequate response rates have been investigated including; follow-up mailings, graphically sophisticated surveys, use of monetary or tangible incentives, identification of larger eligible respondent pools than are needed, assuring interest in the topic by the target population, assurance of anonymity and confidentiality, and adequately assessing and administering the survey instrument at the proper reading level (Fink 2003a). It has been well documented (Burns et al 2008, Fink 2003a, Sierles 2001, Fischbacher et al 2000, Schleyer & Forrest 2000) that response rates can be increased 30-50% or more by further follow-up and reminders.

A significant concern was the appearance of legitimacy in the survey request. With the very real potential for viruses, malware, and other computed related concerns, most of the public is generally aware of the danger posed by clicking on unsolicited links in emails. As an attempt to circumvent that skepticism and increase response rates, the email soliciting survey participation from membership was sent via official organization correspondence, either in the form of an email or through publication in the society newsletter. In this way potential participants would, 1) recognize the survey link as a legitimate request, and 2) that the request itself would not get filtered out by automated spam software. In this way the request for the survey came from a trusted source and the participants would plausibly be more willing to click on the survey link.

Additionally, based in part on the work of Bourque and Fielder (2003), it was made clear in the initial survey request that the survey would take at least 15 minutes to complete given its breadth and complexity since the two most common mistakes made by researchers in developing and formatting research instruments for self-administered questionnaires are, 1) indicating that the questionnaire will "only take 5 minutes to fill out," and 2) formatting the questionnaire so as to appear as short as possible. Both of these critical errors, made even before a respondent has begun the questionnaire will actually reduce response rates in the subsequent survey efforts (Bourque & Fielder 2003).

Administering Interviews

Following the dissertation committee and IRB approvals, contact was made with the previously identified informants. An initial email was sent requesting to schedule an interview for the current research. Those individuals that responded were then consulted on schedules and a time to meet via on-line virtual meeting platform was set-up via Zoom, Google Meet, or Teams. The informant was allowed to dictate the platform of choice to ensure user familiarity and deference was given to informant needs for scheduling interview times though all were scheduled for one hour.

All informants were assured that no information would be attributable to them, and their identity masked through generalized categorized titles (e.g., U.S. Federal Fishery Manager) in this way data is not discoverable to individual since many titles are specific enough to identify a single individual. This was done to ensure that informants,

especially government officials (who are not authorized to present official agency opinions) were able to speak candidly[19] and openly.

Interviews were recorded using the online platform technologies (Google Meet, Microsoft Teams, or Zoom for Government) or using a digital audio recorder (Sony IC recorder). Upon initiating the interview, the informant was given the informed consent information per USM-IRB Protocol policy and the informant acknowledged they were being recorded and/or notes being taken[20].

Data Management & Analysis

Data entry is the process of inputting raw data (not in digital form) into a computer system and has always been one of the most laborious aspects of data management in the digital age. The utilization of the online survey platform significantly reduces the workload, as raw data never has to be manually encoded and therefore eliminates human error in the data entry process. The interview data will be set into digital form through transcription of the recorded interviews and/or entry of the session notes taken. The recordings were downloaded to a laptop computer and transcribed into text (using Microsoft Word) by listening to the audio files at 0.25 - 0.3x speed (using Sound Organizer, version 1.5.0.10210) or outsourced to a third-party transcription service. Following either method, once transcribed into text, each audio file was then

[19] Though they were reflecting individual opinions and not that of their respective government or agency, many informants found it more comfortable to present information, facts, and opinions knowing the information was not directly associated with themselves, especially when discussing agency policy matters.
[20] During several interviews technological difficulties in the on-line platform prevented the recording of the session directly. In these cases, the audio recorder was used, and in a few instances, informants requested not to be recorded.

reviewed for accuracy by following the text file word by word while listening to the audio files. If any discrepancies were found, the resulting edits made to the text, and the process repeated.

Data analysis for the survey dataset was completed on a question- by- question basis, dependent upon the type of question and the type and form of data collected. In general, data was reviewed in an effort to identify themes, trends, and data ranges. One way this was accomplished was by looking for the highs, lows, and means in the data. More pointedly, what is the most common, least common, and average response to various questions. Data was grouped by functional category (e.g., political, cultural), then by theme, and then to understand if any significant issues were identified. These more quantifiable responses were transposed into percentages to understand the relative importance and overall value placed on the theme or idea of the question. Data were then visually represented as graphs, charts, and figures for further analysis. From these, themes or trends were identified upon which to base conclusions.

Each interview was reviewed for concepts that related to fisheries management and its effects on the focal species and policies and regulations of each nation. Major aspects of intergovernmental cooperation (or lack thereof), history, ecology, and policy were the central focal points of the analysis. General themes were extracted not only pertinent to the focal species, but also themes which provided information about the government policy and coordination and thus provided context for how the two focal governments manage the transient natural resources. Themes, ideas out of the interviews, and relevant quotes were identified which help to elucidate those ideas. Following the

individual dataset reviews, they were then correlated to compare general trends in data response on the survey questionnaires to the general trend of interview responses.

Limitations of Research

It is understood that there are limitations to these datasets and the conclusions that can be drawn from them. First, given the small n-values and unknown total population, any inferences are anecdotal and not representative of any focal group or agency. It is understood that each survey respondent and interview informant was answering based on their own personal opinions on the issues. Observer bias is a potential concern in any qualitative research (Babbie 2012). Individuals all have opinions and biases. Consequently, researchers conducting interviews need to be aware of their biases and not let it influence (to an undue degree) the content or direction of the interview, since in qualitative interviews, the interviewer's interaction with the target population is part of the data. Since interviews are further augmented in the data analysis by the literature review, as well as by the survey results, this combination of interconnected steps will lessen the extent of bias in the data. Official permissions from the governments of the United States and Canada were not attained and so the survey candidate pool was reduced. This was overcome to the extent possible by specifically targeting employees from various governmental agencies. Many of these employees can be considered 'elites'. Elites, as a group, are difficult to target and schedule. There are often 'gatekeepers'— people who manage the individual's calendar and scheduling of events— that must first be sought and coordinated with or the elites' behalf. The potential for maximizing an interview was accounted for by early attempts at contact and by letting

participants (or their respective gatekeepers) choose the schedule and then completing the interview through virtual platforms. There is an unknown sample pool. The number of people engaged in the various stakeholder groups such as fishermen, fishery managers, academics focusing on the focal species are all unknowable quantities. Finally, survey reluctance, survey length, and survey response rates are all unknown quantities.

Hypothesis testing

Three hypotheses were tested in this research. These all seek to gain a better understanding of the explanatory potential of the answer to the research question, which is Why do states not have uniform outcomes in fisheries management? The first hypothesis: the failure of policymakers and practitioners to take into account the biology (the natural ecology and life histories) of species and treat all fish as the same (the independent variable) results in mismanagement of fishery stocks (the dependent variable). The second hypothesis: officials do not take stock of their actions (and those of their constituents) relative to those of their international neighbors (the independent variable), thus falling into a classic tragedy of the commons with dwindling resources (the dependent variable). The third hypothesis: — four Cs[21] are addressed at various, and often low, levels within the governmental hierarchy (the independent variable) and explains why policy makers and practitioners know overfishing is a problem yet continue

[21] The 'four Cs' are a concept developed by the researcher to explain the major points of sustainable fisheries management. They are concern, cooperation, coordination, and commitment. Concern is focused on the concept that there is a recognized problem that needs to be addressed. Cooperation relates to whether there are partnerships, collaborations, or other indications that disparate stakeholders recognize the value of working together. Coordination asks if stakeholders are working toward common goals. Commitment relates to the understanding and willingness of stakeholders to make sacrifices toward the improvement of common resources.

to have the inability or lack the political will to alter our behaviors (the dependent variable).

The hypotheses were tested by evaluation of the data collected from the survey and interview instruments. For survey testing, each question was analyzed individually to determine the most common responses and ranked according to the percentage of respondents who selected each choice. Bar graphs and pie charts were used to visually represent the data for clear analysis. The interviews were listened to again and transcribed. During the transcription process, answers to interviewer questions were tagged with themes (major categories) to which the answers relate. Each question may have up to three sub-themes, additionally tagging the answer as relating to a certain broad topic. After all interviews were completed, the major themes were identified, counted, and collated together. Significant quotes pertaining to the themes or otherwise explain the major basis for the informant response were pulled aside and segregated by the major topics.

Survey questions/responses were then sorted and categorized into bins relating to the identified major themes. In this way both interviews and survey responses were collected together into the identified major themes for further analysis. At this time questions from the survey which had inconclusive responses or to which the intent of the respondents' answers could not be identified were culled from further analysis, except to define broad perceptions. Additionally, interviews and question responses were analyzed to see if they had agreement on a subject or if they the findings of one method contradict those of the other. Interview questions were compared against survey responses to determine if additional insight can be gathered from the more nuanced responses from

interviews or if there is no way to understand the intent of the survey response. In cases where a survey response intent was unclear, the interview responses were given weighted preference. The results of the major themes were then analyzed to measure the relationships between the variables and determine if they could be used to understand the validity of the hypothesis or if they directly answered the research question.

CHAPTER IV - RESULTS

Introduction

This chapter presents the results of the field research. The field research consisted of two components the on-line self-paced and self-directed survey and the in-person (virtual) interview with subject matter experts. The objective of this chapter is to present the raw data and findings from the data collection effort. It begins by presenting the results of the on-line survey. Each question is included in the order presented in the survey and with the responses presented as text and an accompanying graph or chart. In this way data is presented in two ways to allow the reader the ability to best grasp the responses to the questions and with the questions clustered together in their original functional groupings (scientific, political, economic, and cultural). The second half of the chapter presents the summarized responses of the interview informants. These data are presented as the major findings of the informants having grouped together by the major themes discovered from the initial data.

Survey Response and Analysis

The survey was made available to potential respondents following IRB approval[22] and remained open for a period of 3 months. It was distributed to the email lists of stakeholder user groups. The size of these groups varied from several hundred to several thousand potential respondents. Exact values were not available from stakeholder user

[22] Institutional Review Board (IRB) approval was granted 9 May 2022 (see appendix C). The survey was sent to potential groups over the course of the next two to three weeks.

groups. The largest group, the Canadian Aquatic Resources Section of the American Fisheries Society has approximately 2,000 members. The total potential survey respondent pool was estimated to be approximately 4- 5,000 individuals. Survey requests were sent to potential informants from the stakeholder groups directly as a way to attempt to avoid spam folders. Follow-up requests for survey participation were sent approximately one month after the initial requests.

In total, when the survey was formally closed through the SurveyMonkey website, 80 respondents had completed the survey. Only a single question had been answered by all respondents (question 1, 100% response rate). The responses rates for the other questions ranged from 13.8%- 52.5% (figure 13). Survey fatigue did not seem to play a role, as there was no drop-off in response rate after the first question of the instrument (figure 14). The questions with the lowest response rates were 11, 14, 22, and 62.

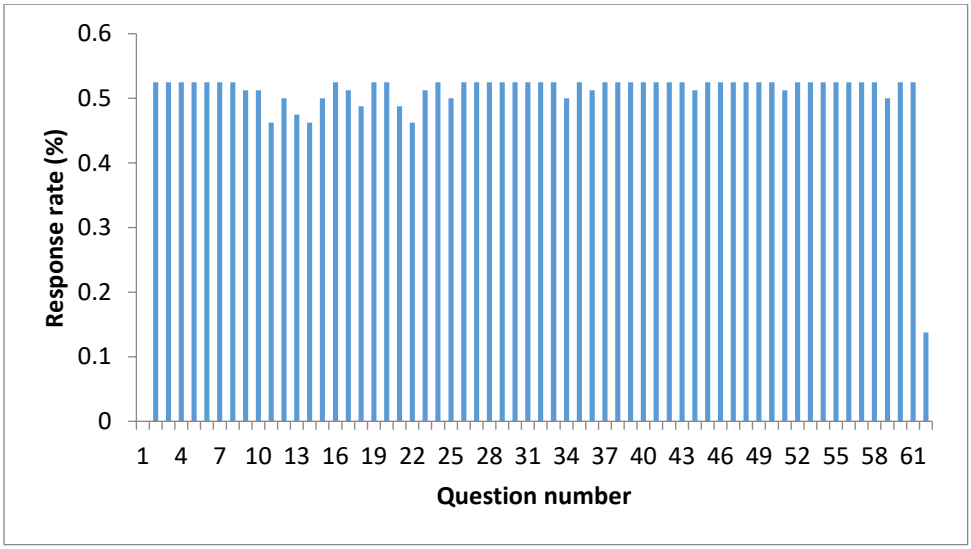

Figure 13. Respondent response rates to all survey questions.
Note that data for Question 1 has been omitted to clarify the remaining relative values. Question 1 had a 100% response rate. Source: author

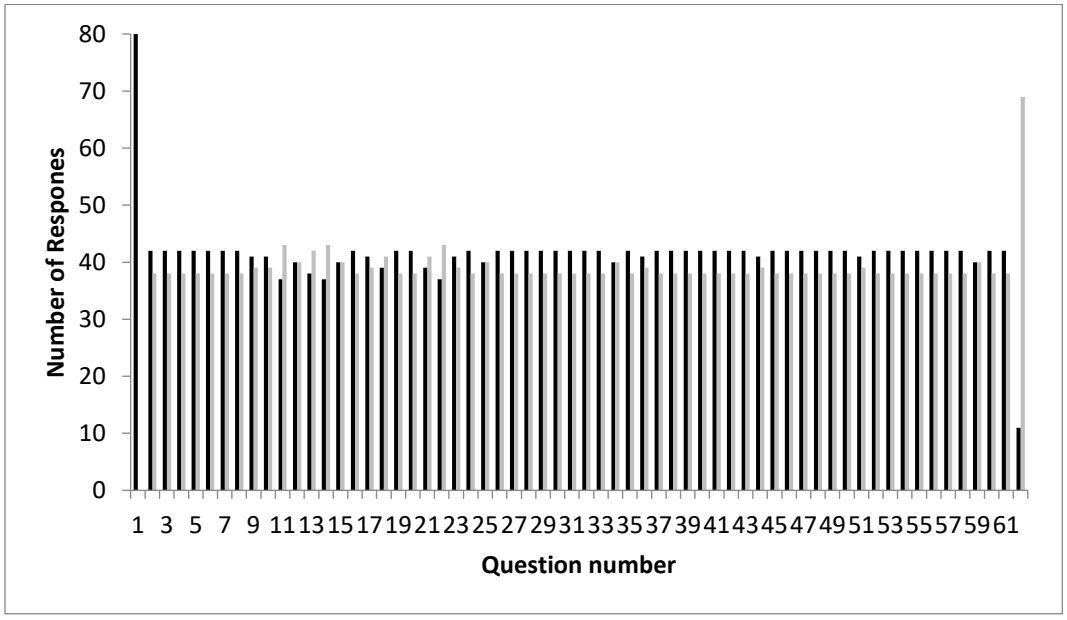

Figure 14. Respondent response rates to all survey questions including skipped questions.
Black bars represent answered questions. Grey bars represent skipped questions. Source: author

The demographic questions revealed the job category (figure 15) that survey respondents self-selected, as well as the number of years (figure 16) they had spent working in their fields. The majority (85.71%) of survey respondents identified as "biologist", "scientist", or "academic". When "regional biologist" was added to the results, the clear and overwhelming majority of survey respondents (92.85%) identified as technical experts. These questions were located at the beginning of the survey instrument and revealed a great deal about "who" had chosen to answer the survey. The survey respondents also revealed that not only were they 'technical' experts, but they had extensive knowledge and experience in the field. Nearly three- quarters of the respondents had worked for more than 15 years, and almost 60% had worked for two decades or more.

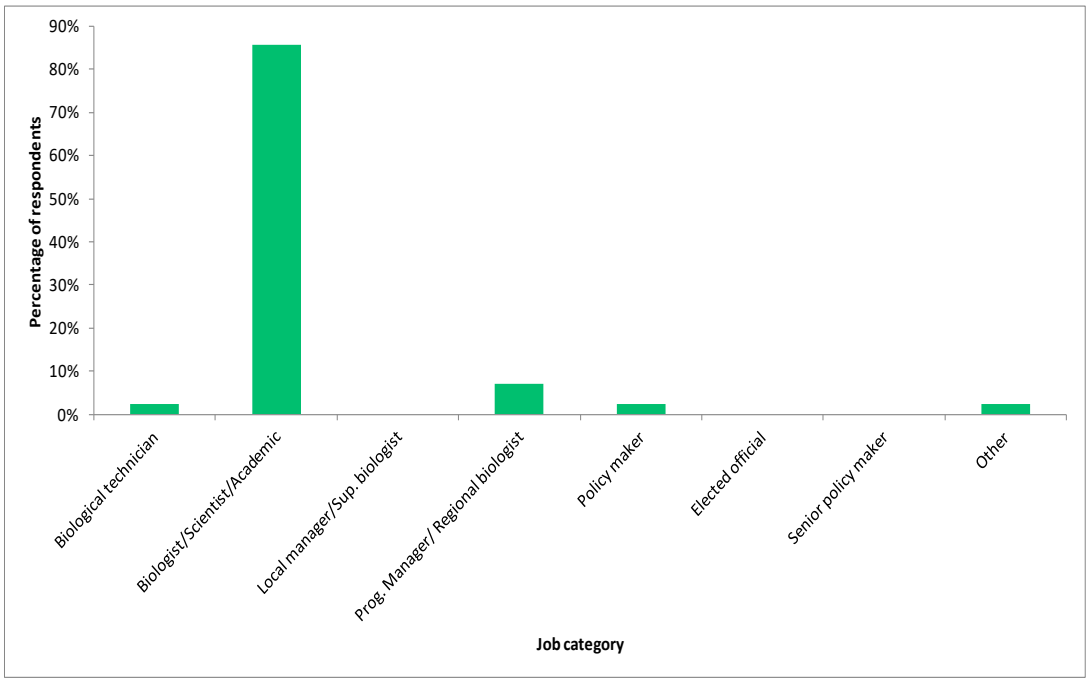

Figure 15. Job category that survey respondents self-identified.
The majority were within the "biologist" category representing more than 80% of respondents. Data from Question 2. Source: author

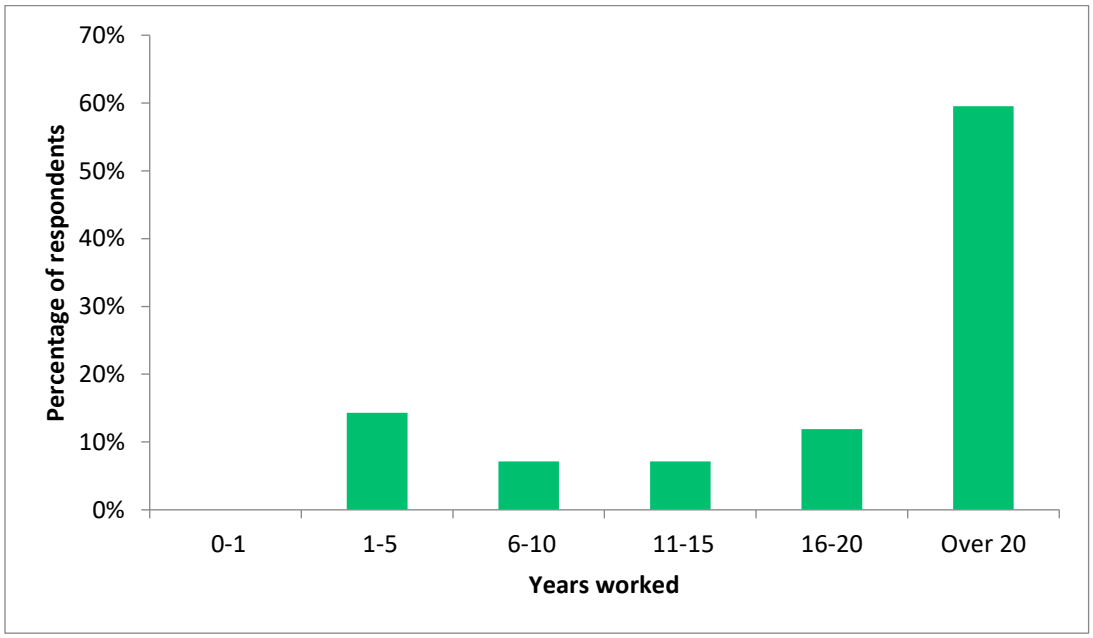

Figure 16. Years of vocational experience working in fisheries of survey respondents.
The data are clearly skewed towards more experienced professionals with 78.6% of respondents having had worked for more than a decade. Data from Question 3. Source: author

The remainder of the survey (58 questions) had been broken into four functional categories. Questions 4-25 were focused primarily on fisheries, scientific, and technical issues. Questions 26-46 focused on political issues. Questions 47-49 addressed economic issues and Questions 50-61 focused on cultural issues. Within these four functional groupings (scientific, political, economic, and cultural) there was often overlap across categories[23] and there were 21 major themes (table 5). Some themes were clearly tied to a specific functional group, but most question themes spanned more than one area. For example, questions pertaining to the theme of 'coordination' spanned the identified categories of both politics and culture.

Table 5 . Major themes identified within survey questions.

non-natives	trout	life history
major issues	habitat loss	regulations
sustainability	marine protected areas	cod
effort	fishing mode/user group impact	local economy
coordination	poaching	subsidies
stock assessments	law enforcement	quotas
management quality	policy	funding

[23] Questions were developed around the four primary categories. However, some questions could be considered 'multi-category' or belonging to another category entirely from how they were sorted. For example, Question 48, "*How much does the local economy affect fishermen in your state/province or locality?*" was developed and categorized as an 'economic' question, yet one could easily interpret this as a 'political' question as well.

The technical questions (Questions 4-25) related to science, biology, or other technical issues pertaining to fish and fisheries management. These questions did not require advanced degrees or years of vocational expertise in the field to answer, but did ask for information regarding issues that biologists and fisheries managers would be more likely to be familiar with and have opinions about. Question 4 asked respondents to rank the top three most important issues relating to the field of fisheries management out of a field of 14 choices (figure 17). Climate Change, habitat loss, and overfishing were the top choices, each having been selected by more than 50% of respondents. Invasive species was selected as a close fourth issue. Four choices (recreational fishing; employment and local economic development through fishing; political support for the fishing industry; and Economics) were selected by none.

Question 5 asked if life history was a factor in fisheries. Overwhelmingly (98%), respondents identified that life history[24] is an extremely important issue (figure 18). Question 6 asked if respondents felt that maximum sustainable yields calculated by nations considered data from outside their borders (figure 19). Only 10% felt that these calculations were considered, but over half (52%) felt that external sources of data should be used in MSY calculations. Roughly a third (38%) were unsure[25]. Question 7

[24] 'Life history' is a biological term that refers to "the pattern of survival and reproduction events during the life of an organism" (Petrik 2019). In other words, it describes the life of an organism from beginning to end, detailing such issues as diet, habitat, reproduction, and survival.

[25] MSY calculations are a very technical issue related to the field of fisheries management specifically. They are used to determine the number of fishes that can be extracted in a given year by fishermen without undue pressure or potential to remove too many (i.e., collapse the fishery). While some biologists may be aware of these calculations, it is not something that a layperson outside this area would likely be able to answer.

asked if life history was a factor in the management of fish. Two-thirds of respondents said that they did and less than one-fifth (19%) disagreed (figure 20). Question 9 asked if respondents thought North American fisheries were overfished. More than ¾ of respondents (78%) agreed that it was (figure 21). Question 8 asked the extent to which stock assessments affect the regulations surrounding fishing. Most respondents felt the effects were moderate (62%) and 81% felt the effects were low to moderate (figure 22). Less than 10% of respondents felt that stock assessments[26] had a large impact on fishery regulations.

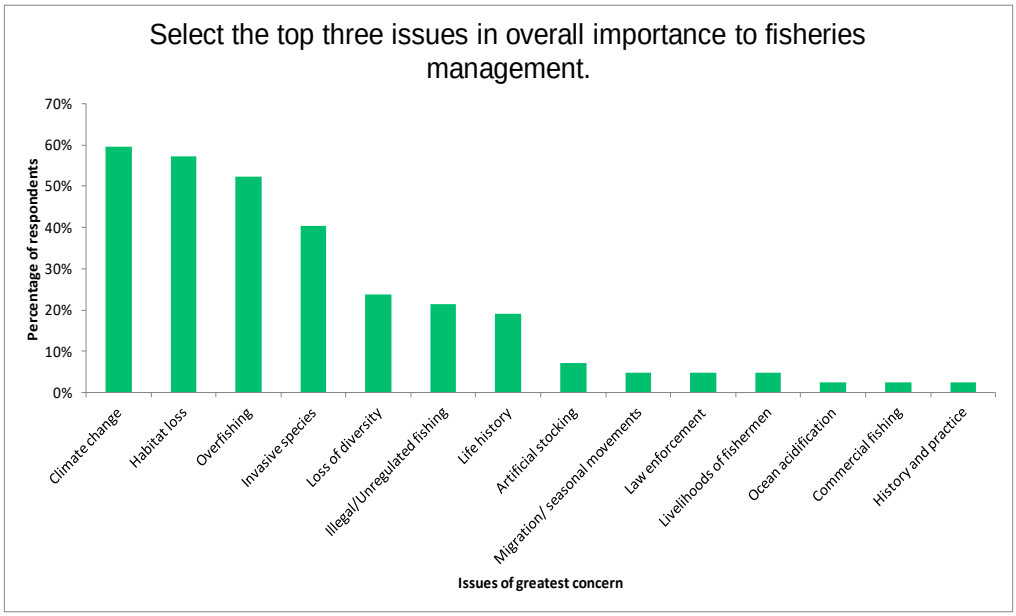

Figure 17. The most important issues effecting fisheries management ranked by survey respondents.
Note that four potential response options (recreational fishing; employment and local economic development through fishing; political support for the fishing industry; and Economics) are not listed in the graph as no respondents identified any of these as one of their top three priorities. Data from Question 4. Source: author

[26] According to NOAA, "A stock assessment is the process of collecting, analyzing, and reporting demographic information to determine changes in the abundance of fishery stocks in response to fishing and, to the extent possible, predict future trends of stock abundance" (NOAA 2012).

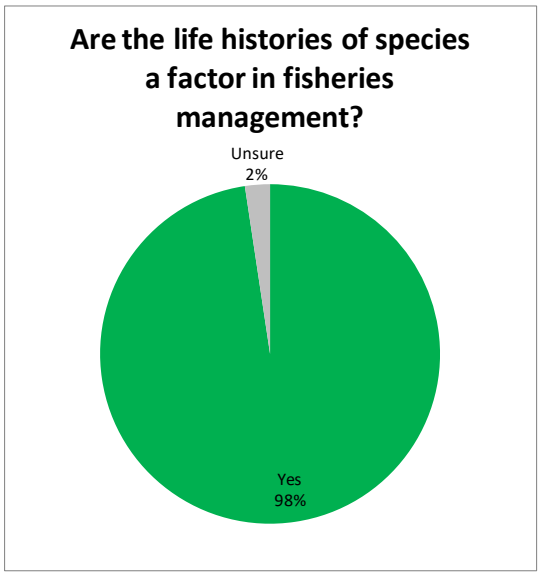

Figure 18. Life histories were clearly identified as a factor in fisheries.
Data from question 5. Source: author

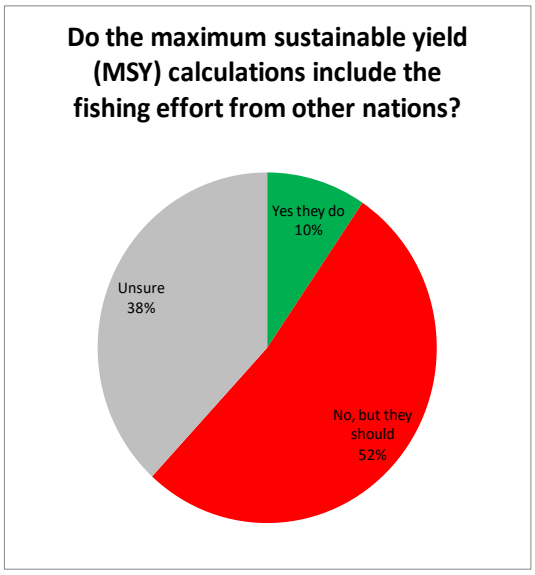

Figure 19. Perceptions of MSY calculation use by other nations.
Data from question 6. Source: author

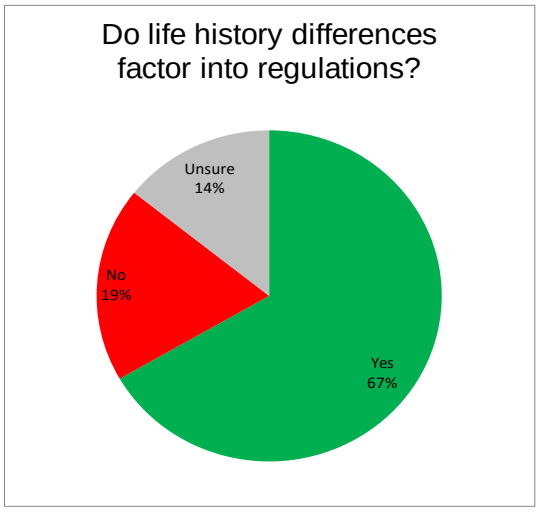

Figure 20. Perception of the use of life histories in promulgating regulations.
Data from Question 7. Source: author

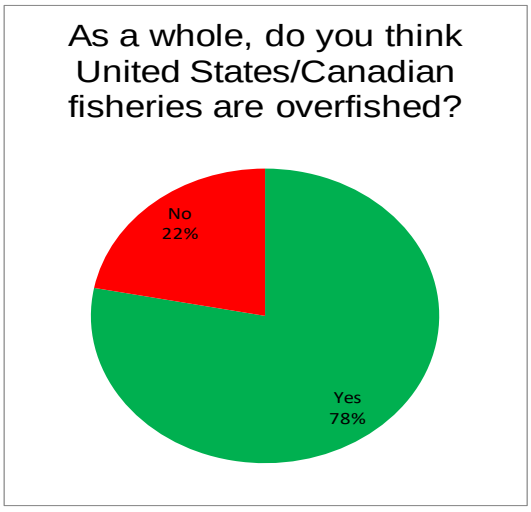

Figure 21. Perceptions of North American overfishing.
Data from Question 9. Source: author

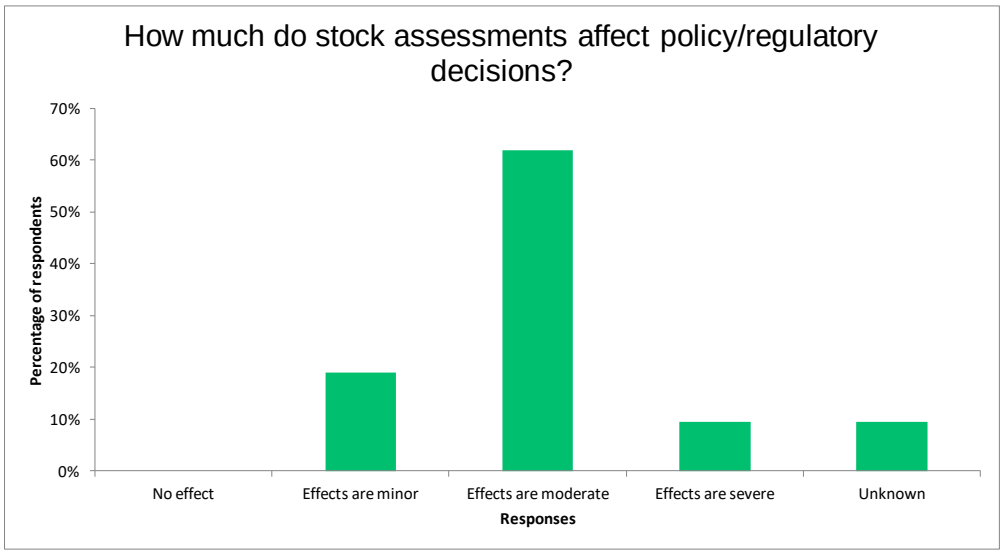

Figure 22. Stock assessment effects on policies and fisheries regulations.
Data from question 8. Source: author

Question 10 asked respondents about the quality of fisheries management from Canadian and American perspectives. The respondents were nearly equally split (44% vs. 39%) on the overall success of managing fisheries in Canada and the United Sates. Nearly half (44%) felt that both Canada and the United States are doing well in managing their fisheries with smaller portions (10% Canada only 7% U.S. only) thinking just one nation was doing well (figure 23). Question 11 asked if survey respondents felt that (Atlantic) Cod in the Atlantic region were properly managed. A clear majority (73%) felt that cod fisheries in the Atlantic were not well managed, though nearly one-fifth of respondents (19%) disagreed (figure 24). Very few individuals felt one nation, or another was singularly doing well in managing this fishery. Question 12 asked about the sustainability of the Atlantic cod fisheries. The response was clear that this is not the case with 80% suggesting that this fishery is not sustainable (figure 25).

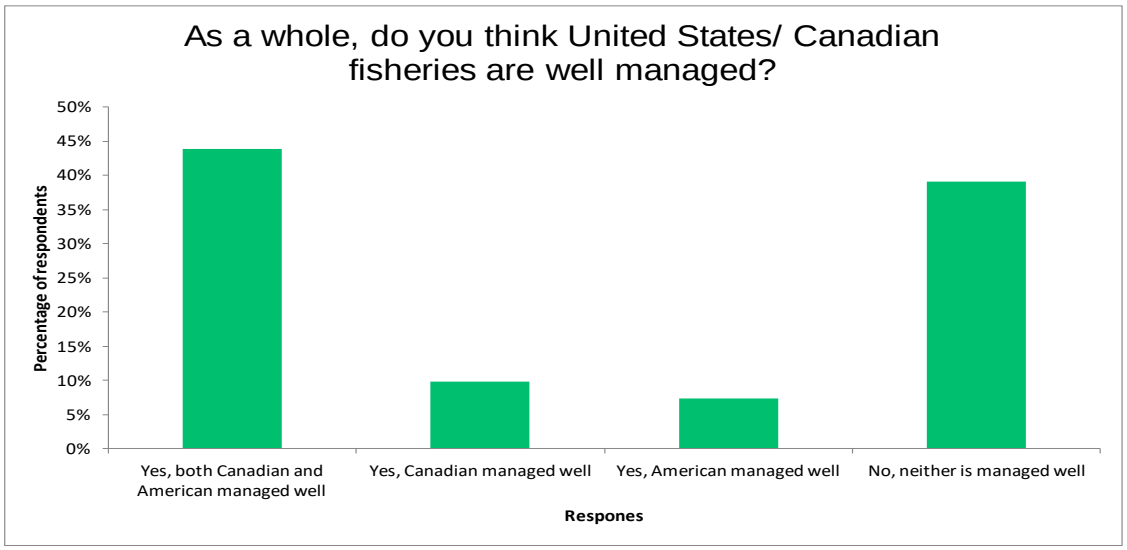

Figure 23. Stock Perspective of respondents towards the successful management of both Canadian and American fisheries management.
Data from Question 10. Source: author

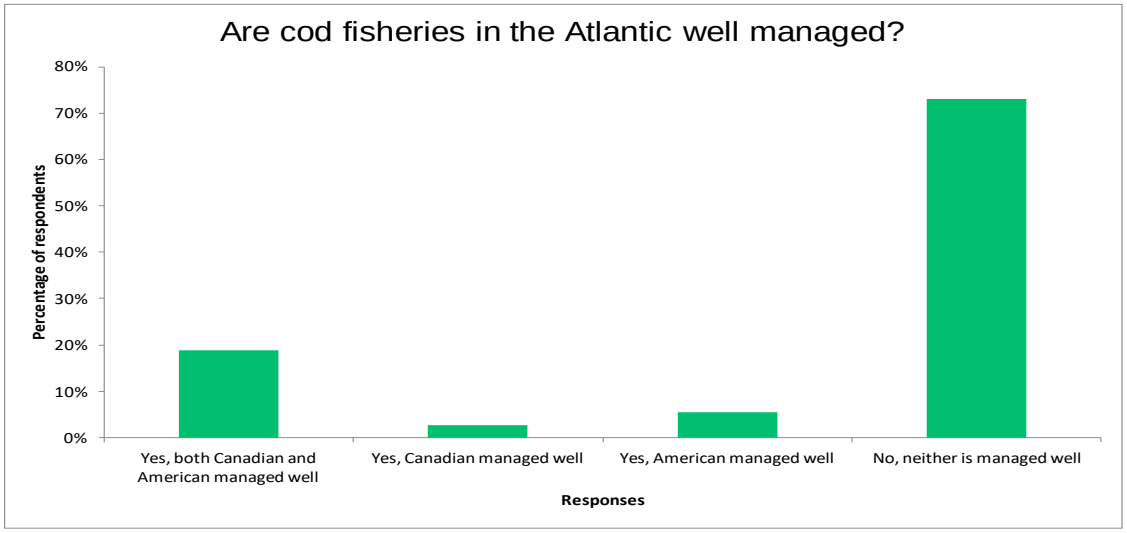

Figure 24. Survey response on the quality of management of the Atlantic cod fishery.
Data from Question 11. Source: author

Question 14 asked about the sustainability of the Great Lakes trout fisheries. The response was split with 57% suggesting that this fishery is sustainable and 43% believing that it is not (figure 26). Question 13 asked if the trout fisheries in the Great Lakes were

well managed. The response was split with 53% suggesting that this fishery is well managed and 40% believing that it is not (figure 27).

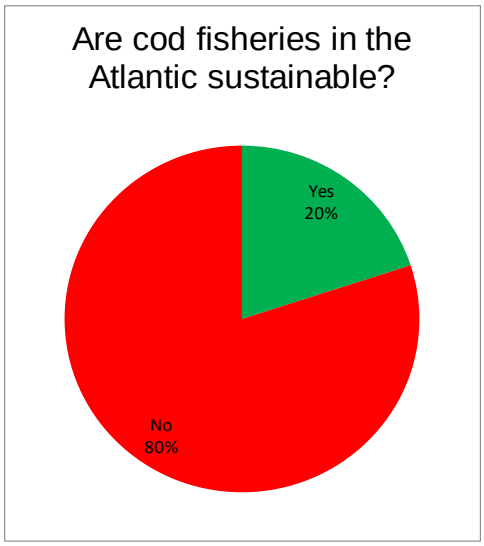

Figure 25. Sustainability of cod fisheries in the Atlantic.
Data from Question 12. Source: author

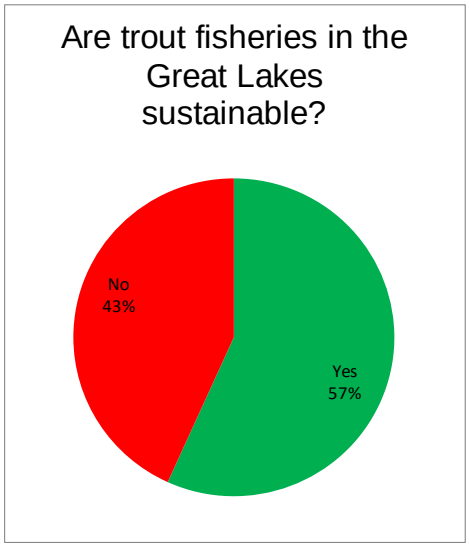

Figure 26. Sustainability of trout fisheries in the Great Lakes.
Data from Question 14. Source: author

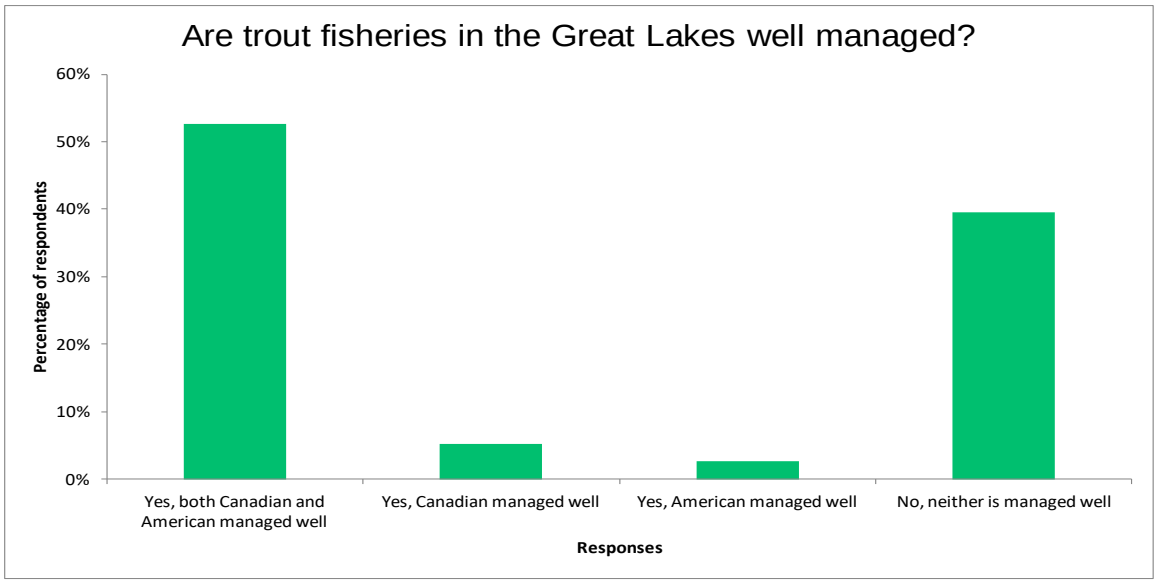

Figure 27. Sustainability of trout fisheries in the Great Lakes.
Data from Question 13. Source: author

Question 15 asked about the historic use of trawl fishing[27] and its effects on available habitat for Atlantic Cod. The majority (82%) believed that this fishing method had indeed been detrimental to the habitat and the remaining 18% were unsure (figure 28). None identified trawling as not problematic. Question 16 asked respondents if more effort should be made toward fishing for non-native species (figure 29), to which the majority (93%) agreed that more targeted fishing should be occurring for non-native fish species.

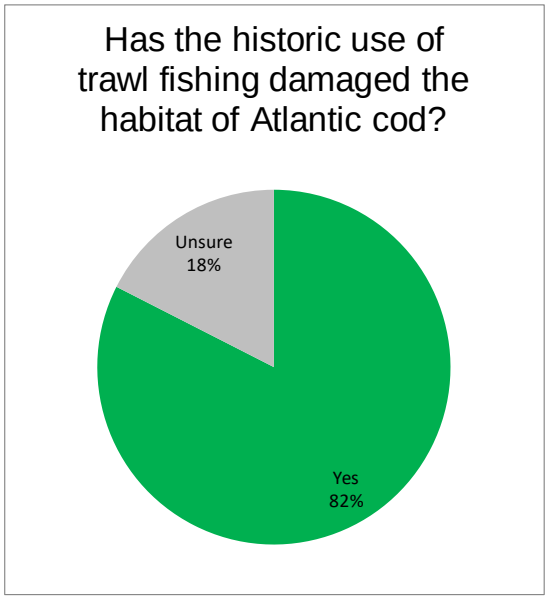

Figure 28. Trawl fishing and is damaging. effects on bottom habitat.
Data from Question 15. Source: author

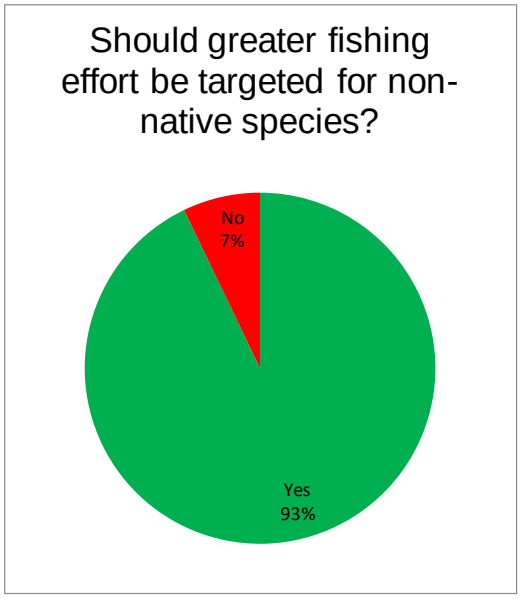

Figure 29. Perception of the need to target non-native fish with greater fishing effort.
Data from Question 16. Source: author

[27] Trawl fishing is a method of fishing in which a weighted net is dragged behind a fishing vessel. In the case of ground fisheries (i.e., fish that live at or near the bottom of the water column), the net is weighted so that the front leading-edge scraps along the bottom. This type of fishing is well documented to damage sensitive habitats.

Question 17 asked if the artificial stocking of non-native species should be allowed to continue. The clear consensus (85%) was that it should not be continued (figure 30). Similarly, Question 18 asked if the stocking of non-native fish harmed native fish. The answer was nearly unanimous with 97% agreeing that stocking non-native fish negatively affects the local fish community (figure 31). Question 19 asked about the effects of marine protected areas. Three-quarters (76%) of respondents felt that MPAs have a moderate to profound effect (figure 32).

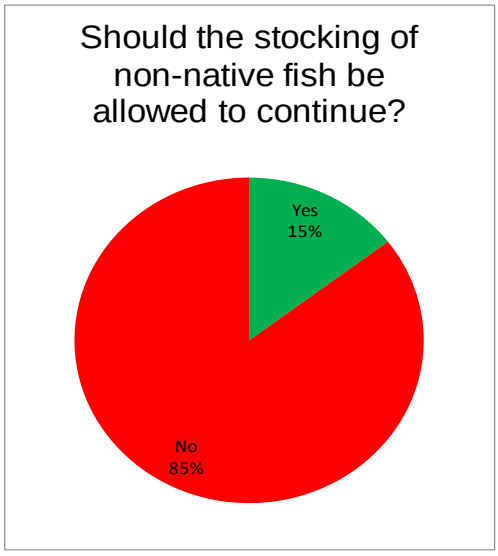

Figure 30. Perception about the continuation of stocking non-native fish.
Data from Question 17. Source: author

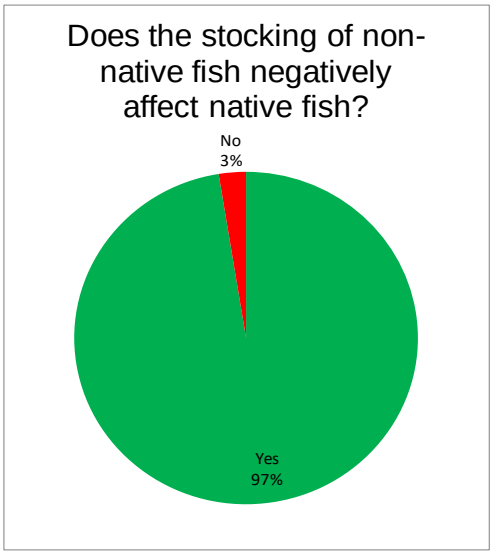

Figure 31. Perception of the harm done by stocking non-native fishes.
Data from Question 18. Source: author

Question 20 asked about the relative impact of commercial versus recreational fishing. Respondents clearly answered that commercial fishing (88%) is the greater threat to fisheries resources (figure 33). Question 21 asked simply, if Atlantic Cod were overfished. Almost everyone (95%) felt that these resources are overharvested (figure 34).

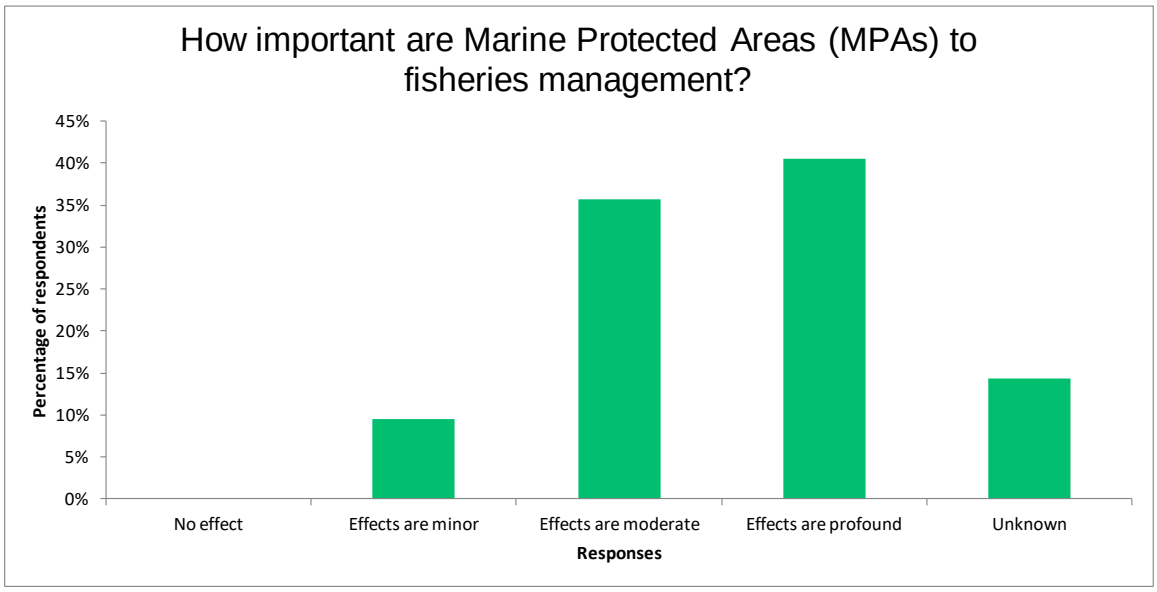

Figure 32. The importance of Marine Protected Areas (MPAs) to the successful management of fisheries resources.
Data from Question 19. Source: author

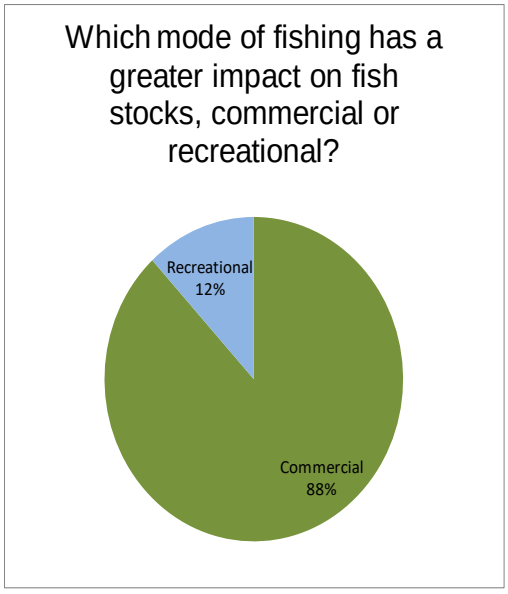

Figure 33. Relative impact of commercial fishing versus recreational fishing.
Data from Question 20. Source: author

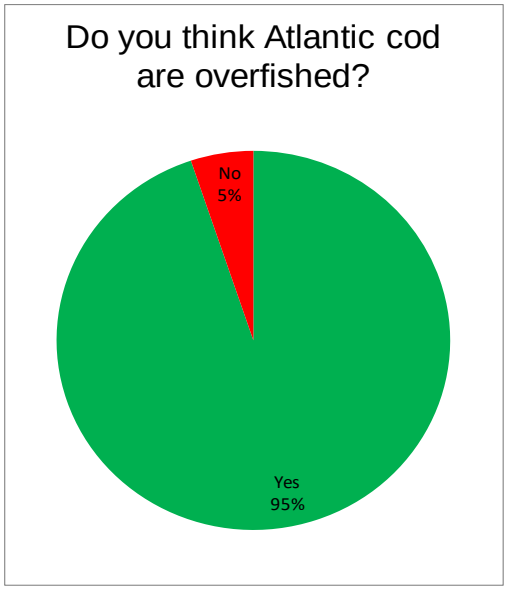

Figure 34. Perception of the state of the Atlantic Cod fishery
Data from Question 21. Source: author

Question 22 asked respondents if Lake Trout are overfished. 68% of respondents said that they were overfished (figure 35). Question 25 asked if respondents felt that speciation[28] was occurring within the Lake Trout population. There was a great deal of uncertainty related to this question with 65% responding as unsure. The remainder of respondents were split, with 22% thinking that speciation is occurring, and 13% thinking it is not (figure 36). Question 23 asked about the ability of native species to recover when faced with completion from artificially stocked non-native species. Most respondents (76%) felt that the effects were "great" or "considerable" (figure 37).

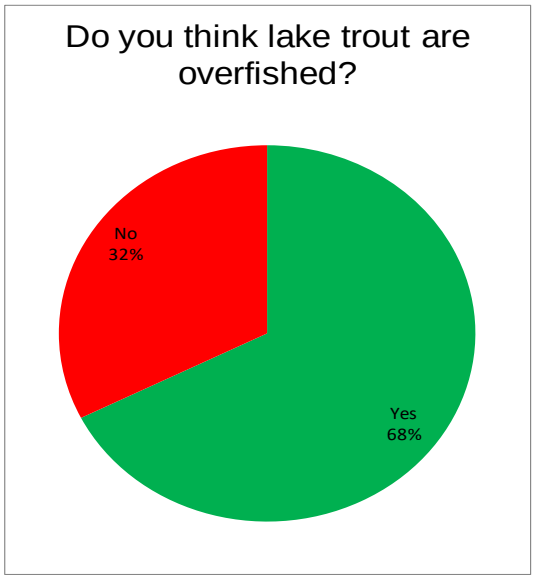

Figure 35. Perception of fishing pressure on Lake Trout.
Data from Question 22. Source: author

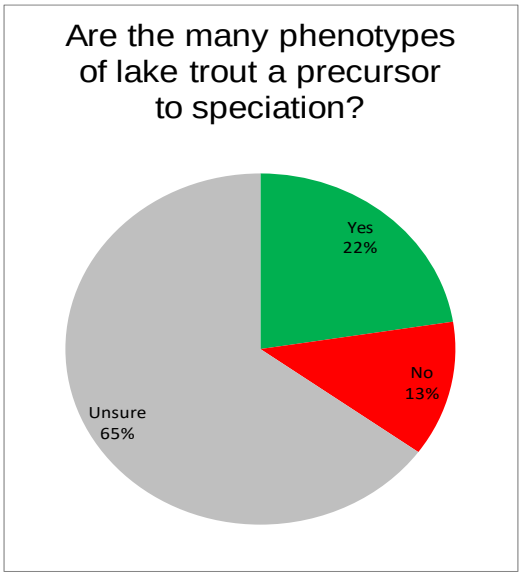

Figure 36. Perception of the likelihood of speciation occurring in Lake Trout.
Data from Question 25. Source: author

[28] This was another very technical question that is ecologically and biologically unanswerable with any degree of certainty. Speciation (as proposed by Darwin in 1859) suggests that over a period of time species which are separated from one another and thus prevented from interbreeding with begin to drift apart as they adapt to their specific environments. Since this occurs on a time scale of thousands of years with vertebrates, this is not a question which can be definitively answered. However, there are indications present in some species (such as varying body types, different spawning behaviors, etc. which may indicate this process is occurring.

Question 24 asked respondents to rank the top three issues they felt were the most important to maintaining a stable fishery. The three most important were identified as "overfishing", "habitat", and "life history/ecology" (figure 38).

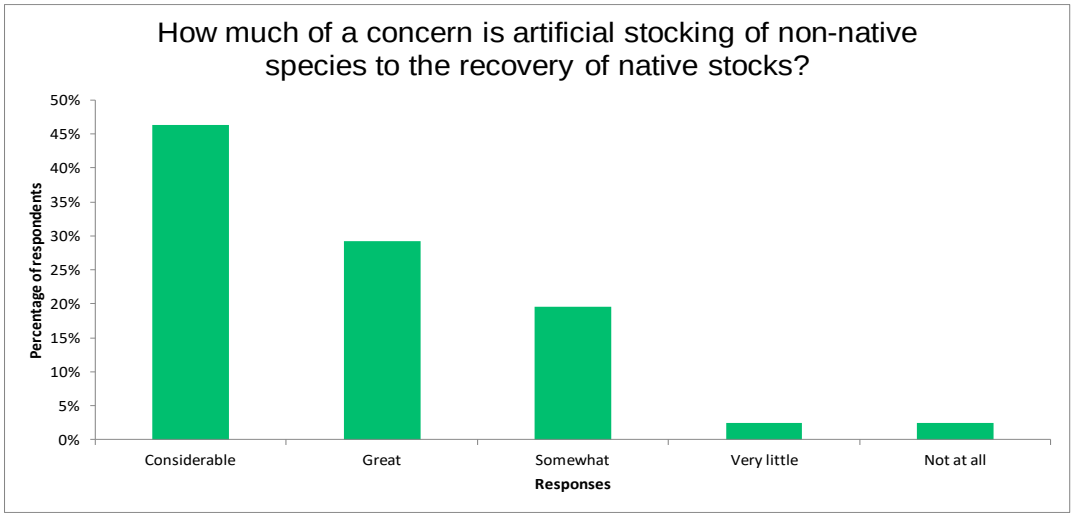

Figure 37. Perception of the effects on artificially stocking non-native species to the ability of native fish to recover to historic population levels.
Data from Question 23. Source: author

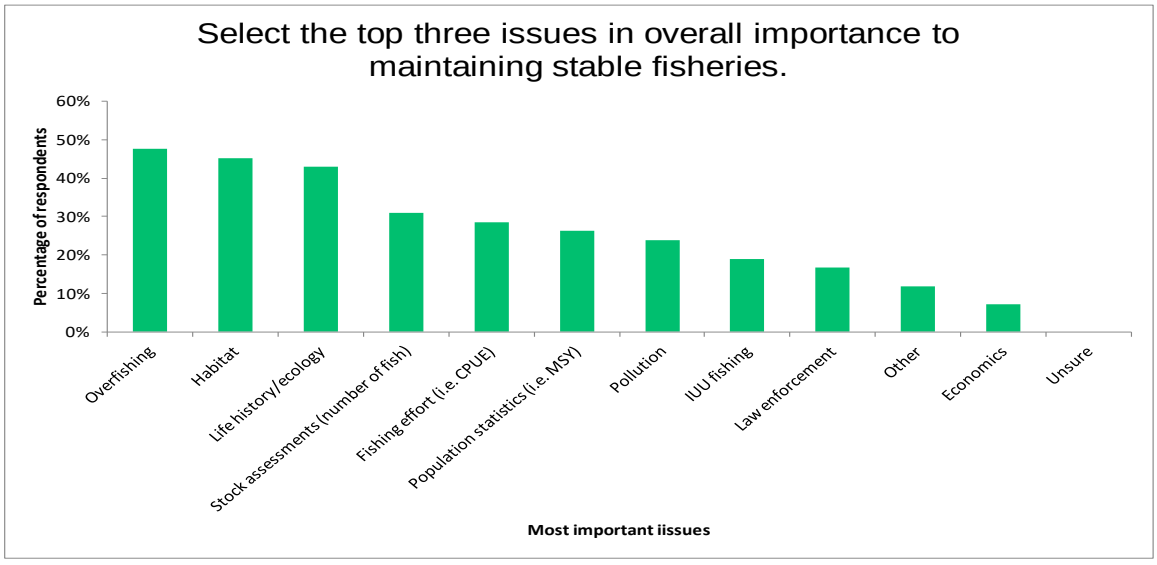

Figure 38. Ranked issues determined by respondents to be the most important to maintaining stable fisheries.
Data from Question 24. Source: author

The political questions (Questions 26-46) focused predominantly on laws, regulations, and policies. Additionally, there were questions about cross border coordination, poaching, and law enforcement. As with many of the survey instrument questions, those categorized as 'political' overlap into other categories. Question 26 asked about the perception of restrictiveness of North American fisheries laws in relation to other nations. The responses were split between affirmation (43%), uncertainty (36%), and denial (21%) (figure 39). Question 27 asked respondents if the two focal nations worked cooperatively toward common fishery management goals. Only 17% believed that this was true, 45% thought that it might be, 33% were unsure, and 5% thought they did not (figure 40). Question 28 was more specific than the question that preceded it and asked if fisheries were cooperatively managed at the state or provincial level. With this added specificity, the number of affirmative responses almost doubled (28%), yet the negative responses also increased significantly (36%) (figure 41). Question 29 asked respondents if fisheries were managed across international boundaries. The responses were similarly mixed with 43% stating that they did and 33% stating that they did not (figure 42).

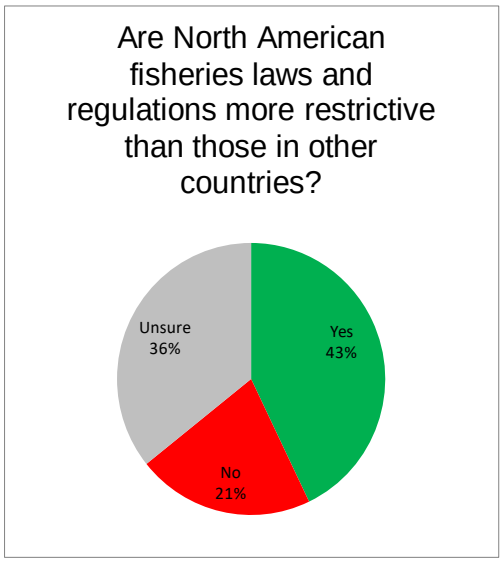

Figure 39. Perceptions of the restrictiveness of North American fisheries laws compared to other nations.
Data from Question 26. Source: author

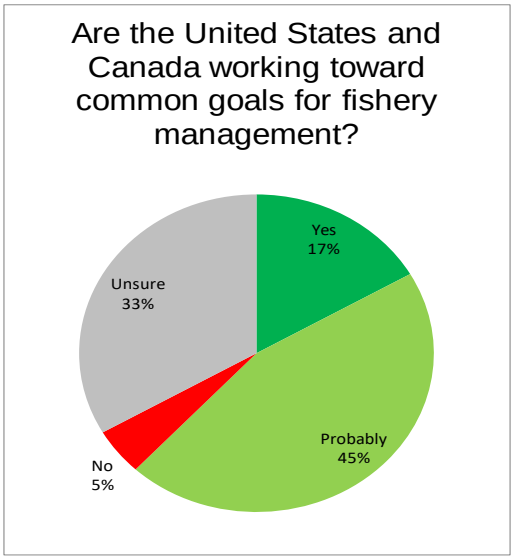

Figure 40. Respondent responses to the United States and Canada working towards common goals of fisheries management.
Data from Question 27. Source: author

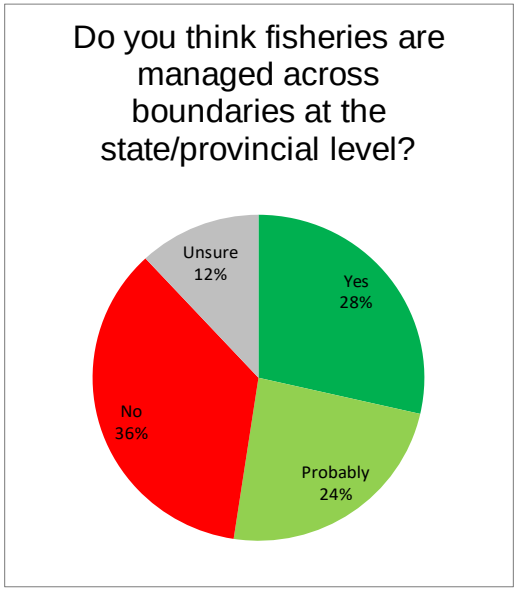

Figure 41. Cross boundary management at the state/provincial level.
Data from Question 28. Source: author

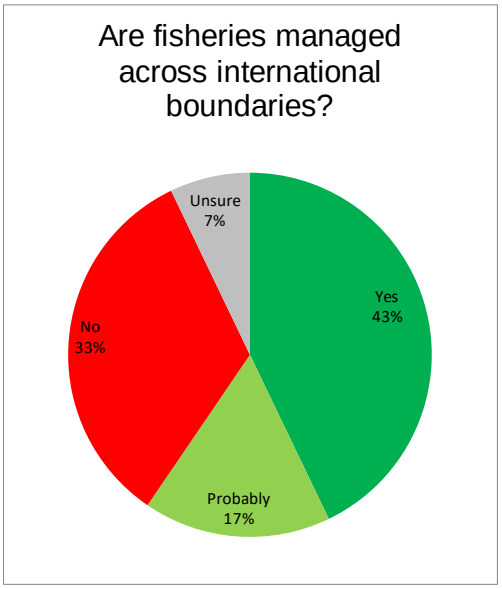

Figure 42. Responses to fisheries being managed across international boundaries.
Data from Question 29. Source: author

Question 30 asked if differences in life history of various species was taken into consideration and accounted for in fishing laws across different local jurisdictions. Approximately one third (29%) of respondents felt they did and one third felt they did not (figure 43).

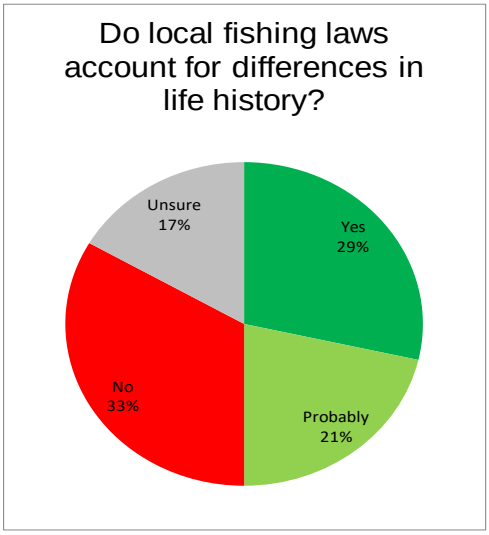

Figure 43. Perception that local laws take life history into consideration.
Data from 30. Source: author

The remaining third was unsure, though half of those felt that they local laws probably took life history into account. Question 31 asked about genetically modified fishes and if specific regulations were important to them. Half of respondents felt they were very nearly a third felt they had some importance, and only 17% felt they had little importance (figure 44).

Question 32 asked about the relative political power of various levels in creating fishing regulations. The majority of respondents (38%) felt that the state/provincial level had the most authority/influence in creating these regulations though this was closely followed by federal agencies (31%) (figure 45). The third most common group was fishermen (14%). Question 33 asked what level should be the most influential. Respondents ranked governance at the international level to be the most important (36%) followed by multi-state/ provincial regional jurisdictions (24%) (Figure 46).

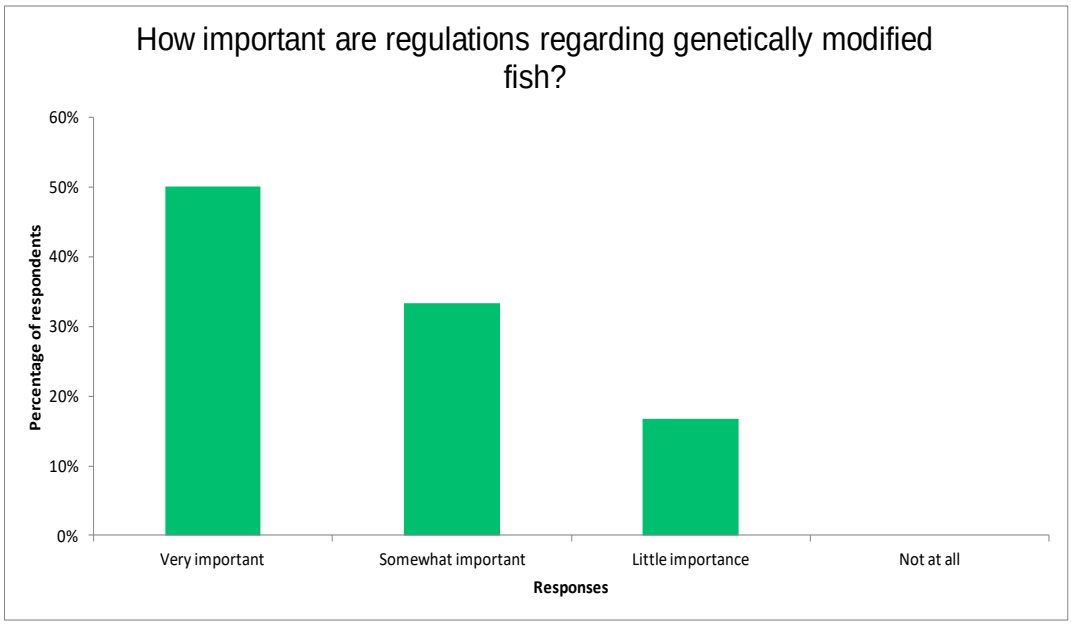

Figure 44. Perceptions of the importance of regulations pertaining to genetically modified (GMO) fish.
Data from Question 31. Source: author

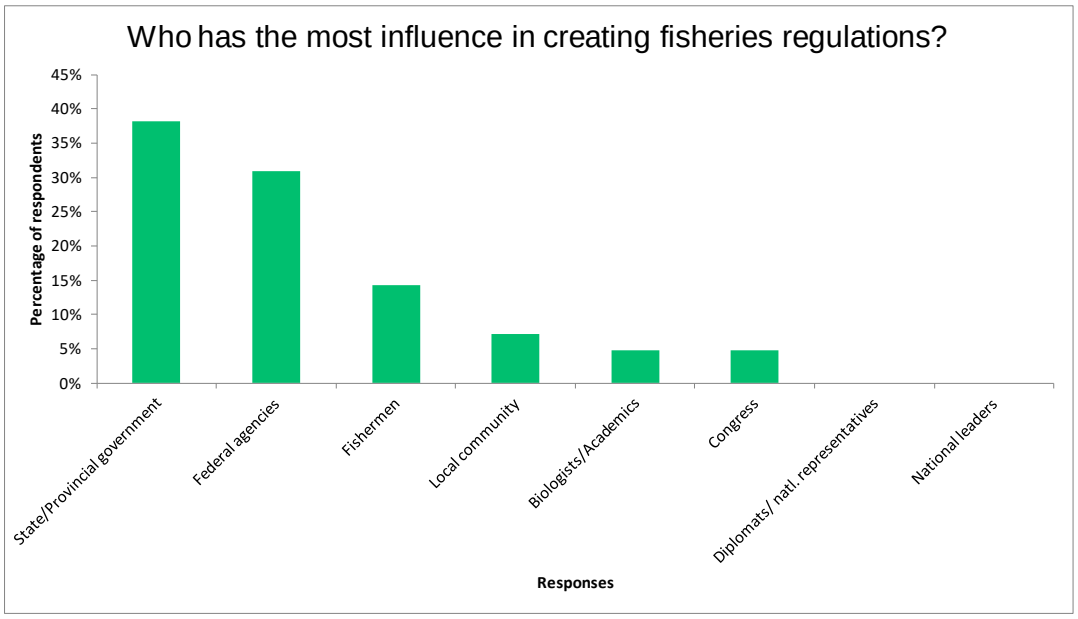

Figure 45. Ranking of perception of the moist influence in creating fishery regulations.
Data from Question 32. Source: author

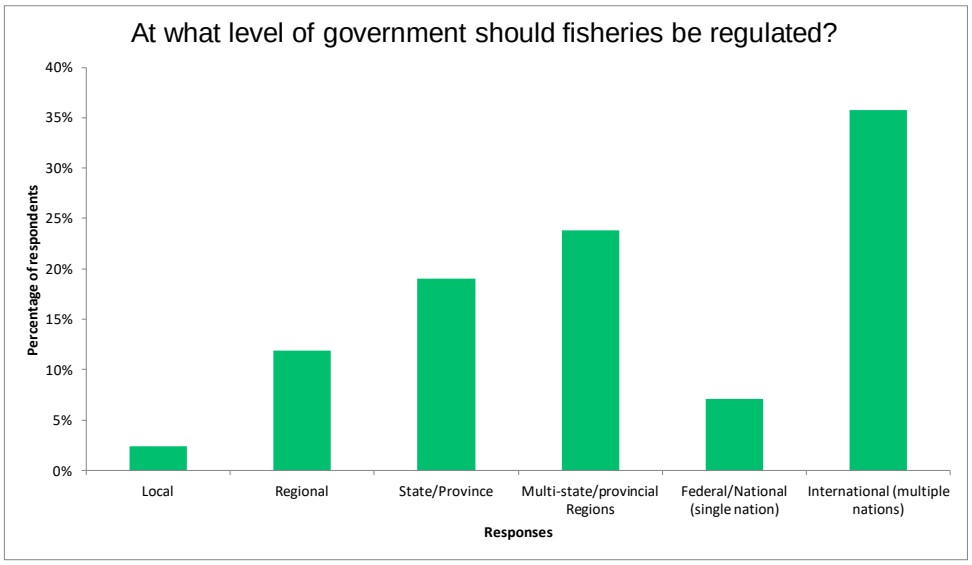

Figure 46. Level that respondents felt should have jurisdiction over fisheries.
Data from Question 33. Source: author

Question 34 asked respondents if they worked with peers across the border and 73% replied that they did indeed work with partners across borders (figure 47). Question 35 asked if catch limits took into consideration potential fishermen across the border. Only 10% said that they did, while 45% said they did not (figure 48). Question 36 asked about coordination across state or provincial boundaries. The response was evenly split at 49% yes and 51% no (figure 49). Question 37 asked if survey respondents thought that all fish were managed the same. Only 2% responded that they were, with 98% noting that they did not (figure 50). Question 39 inquired if respondents felt that the military should be used for law enforcement purposes to monitor for illegal fishing as a peacetime activity. Most (57%) felt that the military should not be used in this way (figure 51). Question 38 asked about the amount of effort the government should provide in combating poaching. More than half of responses said that the maximum consideration

should be given and 43% also agreed that some consideration should be given (figure 52).

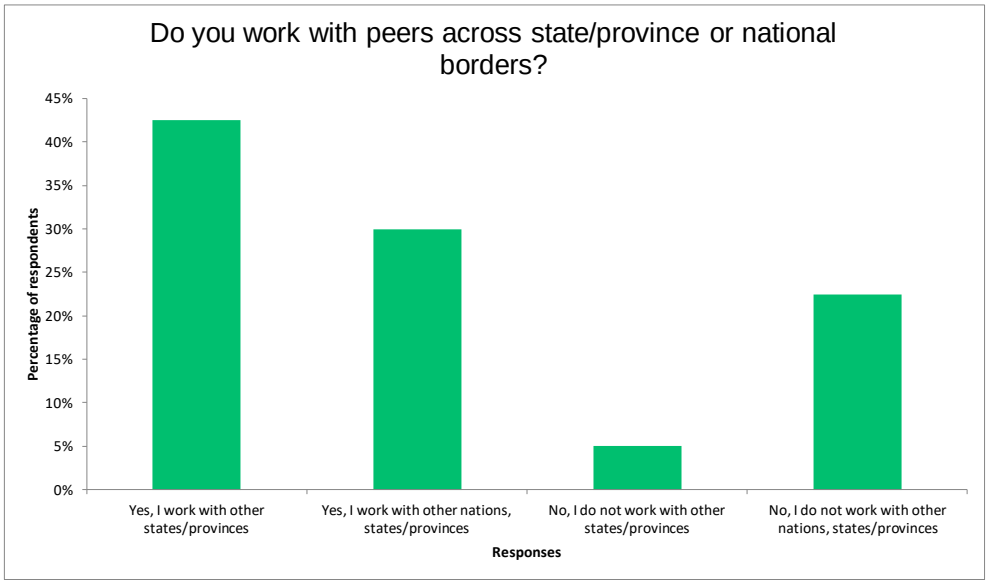

Figure 47. Responses from survey informants to working across state/provincial and national borders.
Data from Question 34. Source: author

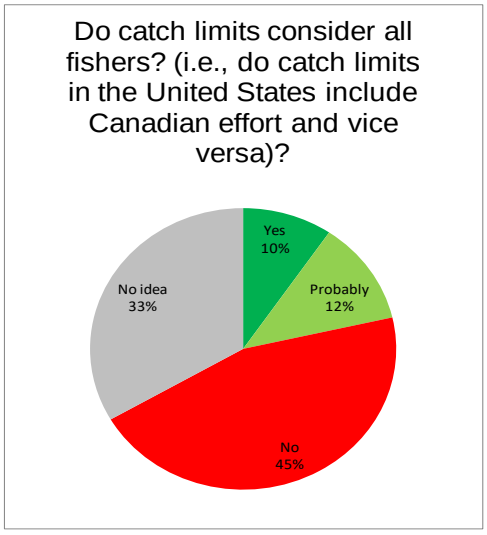

Figure 48. Catch limits being included across borders jurisdiction over fisheries.
Data from Question 35. Source: author

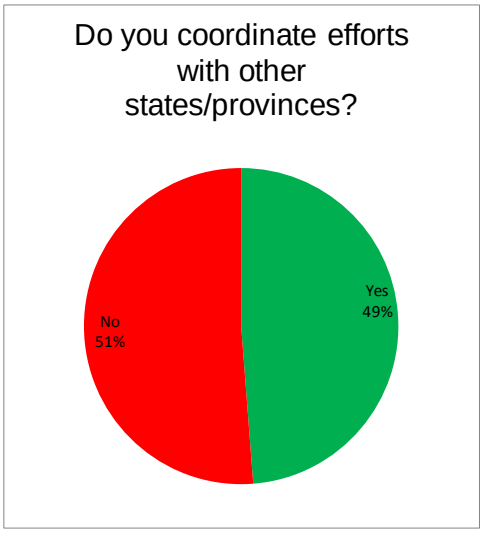

Figure 49. Respondents' coordination with other states/provinces.
Data from Question 36. Source: author

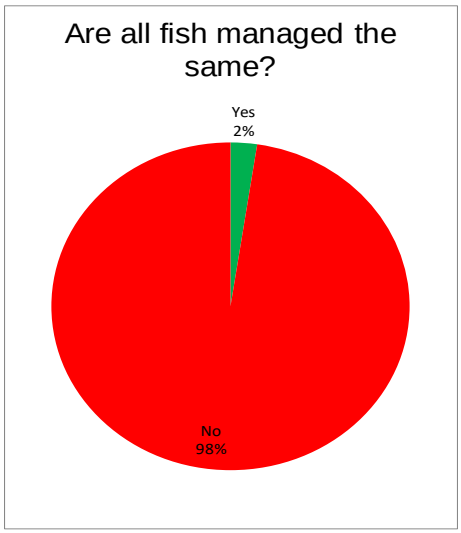

Figure 50. Survey respondent response to being asked if all fish were managed the same.
Data from Question 37. Source: author

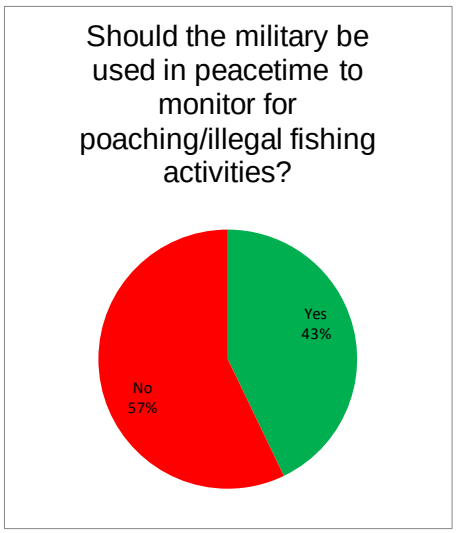

Figure 51. Response to using the military to provide peacetime monitoring for illegal fishing.
Data from Question 39. Source: author

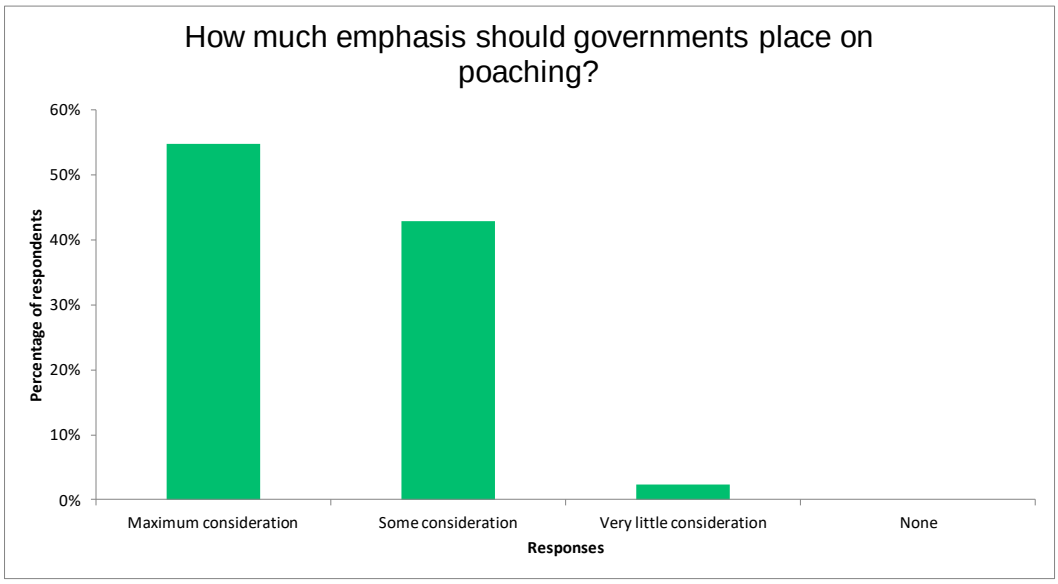

Figure 52. Amount of emphasis governments should provide towards poaching.
Data from Question 38. Source: author

Question 40 asked about the level of law enforcement for fishing regulations in their local area. Around three-quarters of respondents (76%) felt that there was some

level of enforcement occurring near them, with 14% feeling that the maximum enforcement was occurring. No one responded that enforcement actions did not occur (figure 53).

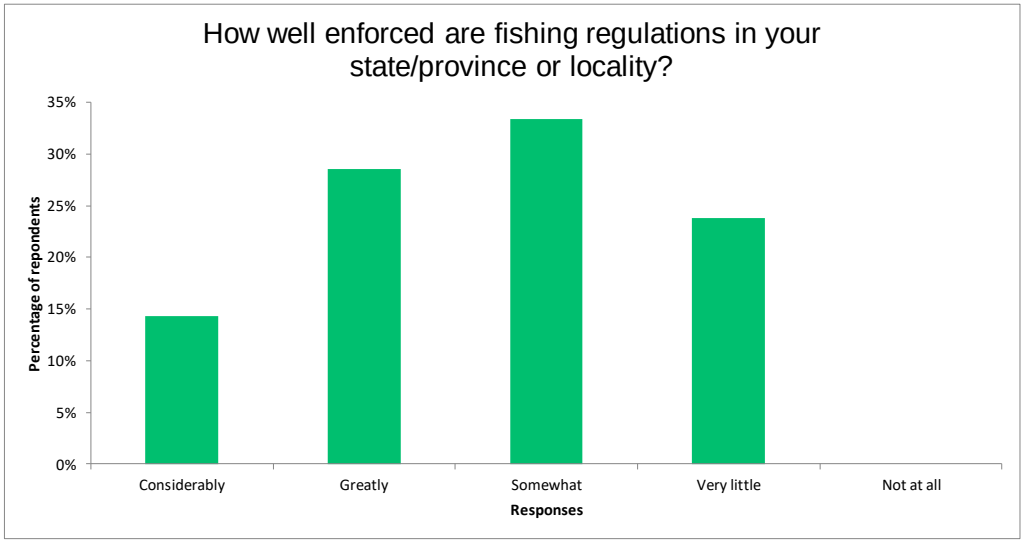

Figure 53. Perception of the amount of law enforcement occurring at the state/provincial or local level.
Data from Question 40. Source: author

Question 41 asked if respondents knew of peers working across the border in another nation, with 57% responding that they did (figure 54). Question 42 followed up and asked if they had actually worked with their peers from other nations. Almost two-thirds (62%) of informants said that they have worked directly with their peers in other countries (figure 55). Question 44 asked if respondents felt that policy makers used the best available science to make decisions and only 27% said they did (figure 56).

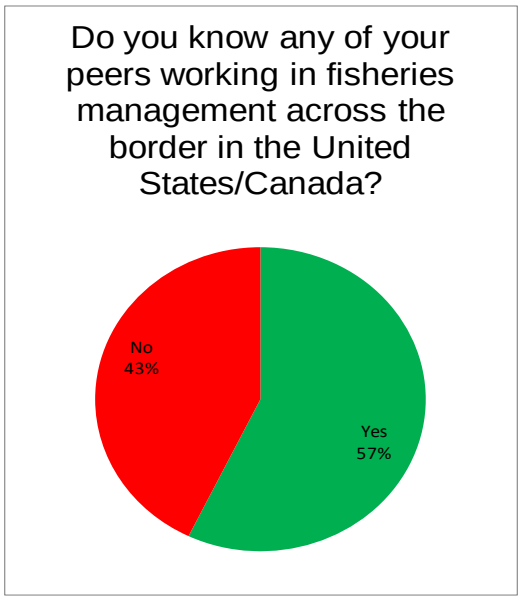

Figure 54. Inquiry about knowing of peers in other nations.
Data from Question 41. Source: author

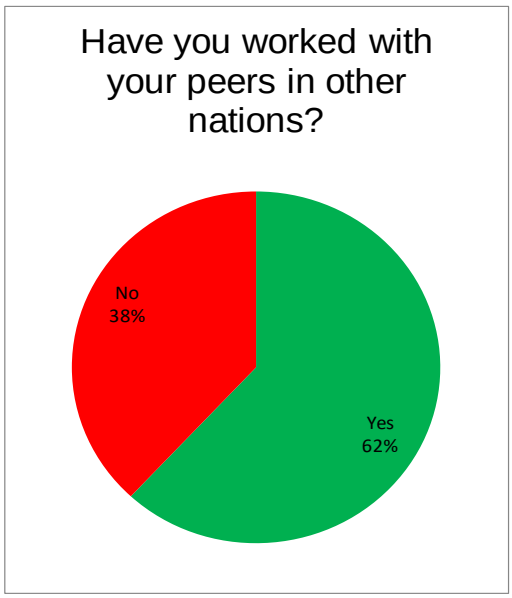

Figure 55. Inquiry about working with peers in other nations.
Data from Question 42. Source: author

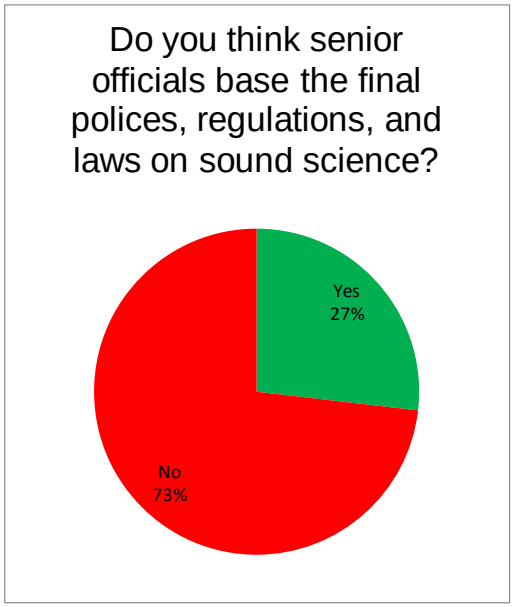

Figure 56. Belief that policy decisions were being made using the best available science.
Data from Question 44. Source: author

Question 43 asked about the role of people that act as senior policy/decision makers and if they considered the effects that their decisions had on the overall effects on international resources. The majority (57%) responded that the impacts of decisions were "somewhat" considered (figure 57).

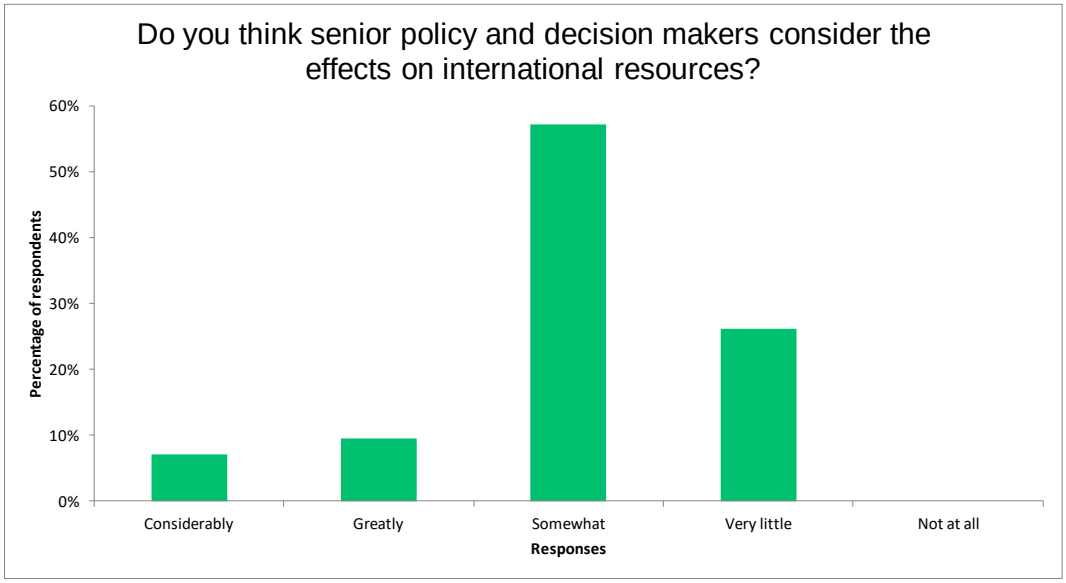

Figure 57. Perception that respondents had of if policy and decision makers took international resources into account when making decisions.
Data from Question 43. Source: author

A smaller portion 9.5% and 7% respectively, thought that impacts were "considerably" or "greatly considered", while 26% felt that "very little" consideration took place. No respondents said that no consideration at all was given. Question 45 sought informant opinions on the importance of biologist recommendations on successful fisheries management programs. More than half (57%) felt that the recommendations of biologists were of "great" or "considerable" importance and nearly a third (30%) felt that it was at least "somewhat" important (figure 58). None felt it was unimportant. Question 46 followed up on the previous inquiry, asking if recommendations should be considered

rather than just asking if they are considered. A clear consensus developed with 95% of responses describing the recommendations of biologists as of "considerable" or "great" importance (figure 59).

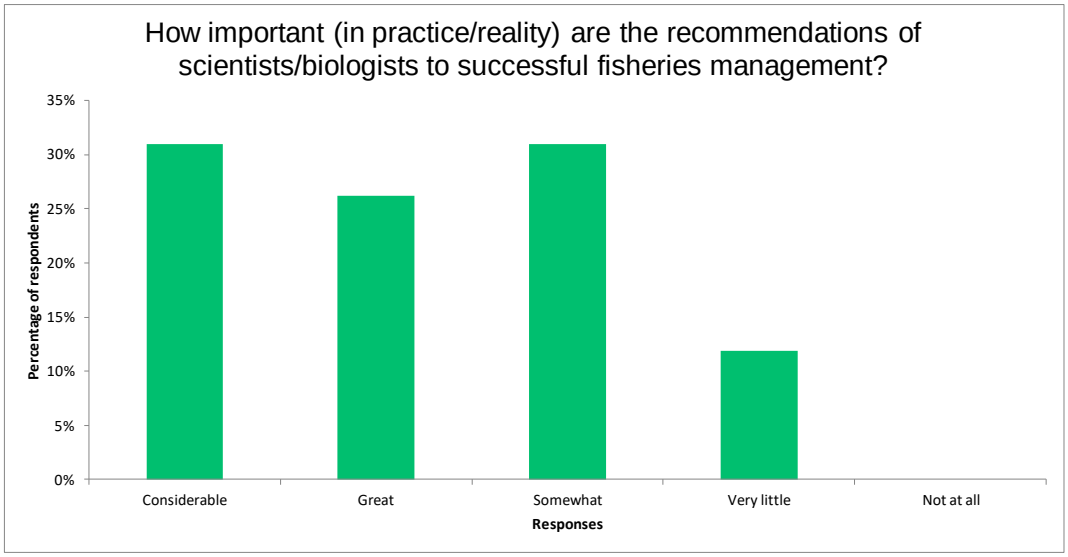

Figure 58. Perceptions of the importance of biologist recommendations for successful fisheries management.
Data from Question 45. Source: author

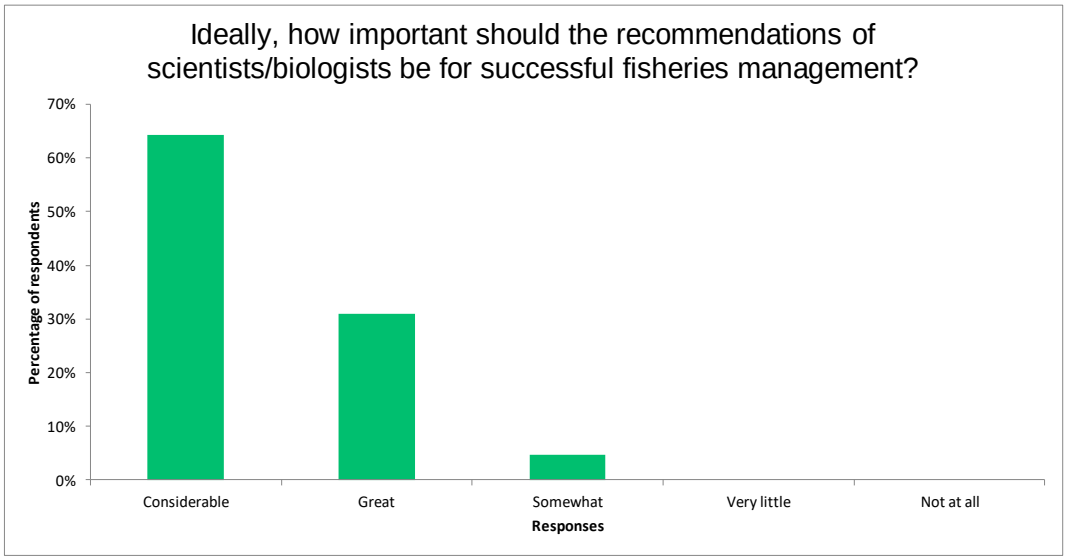

Figure 59. Perceptions of the importance of biologist recommendations should have for successful fisheries management.
Data from Question 46. Source: author

The third category of the survey instrument asked respondents questions (Questions 47-49) referring to issues of the economic importance of fisheries. The first issue addressed was with Question 47, which asked about the level of funding available to fisheries management programs and if that affected their efficacy. Most respondents (74%) felt that the lack of funding had a "severe" effect on the overall outcomes of fisheries management (figure 60). Question 48 asked about the effects of the local economy on the fishermen in the area. More than two-thirds (69%) said that the local economic situation "greatly" or "considerably" effected fishermen and that number rose to 100% when the answer "somewhat" is included (figure 61).

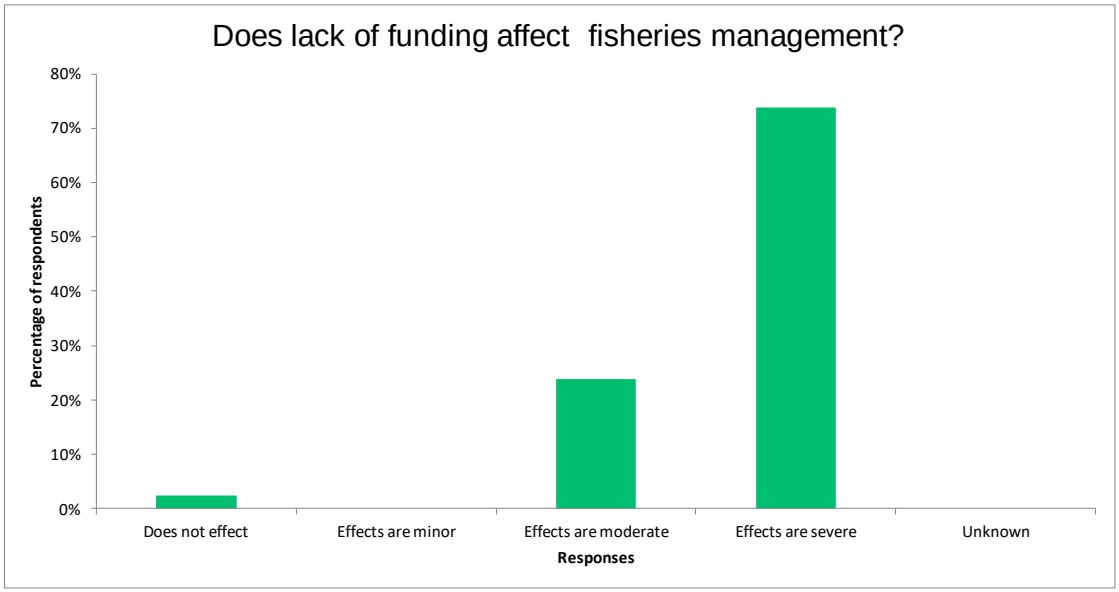

Figure 60. The effects that funding has on the successful administration of a fisheries management program according to survey respondents.
Data from Question 47. Source: author

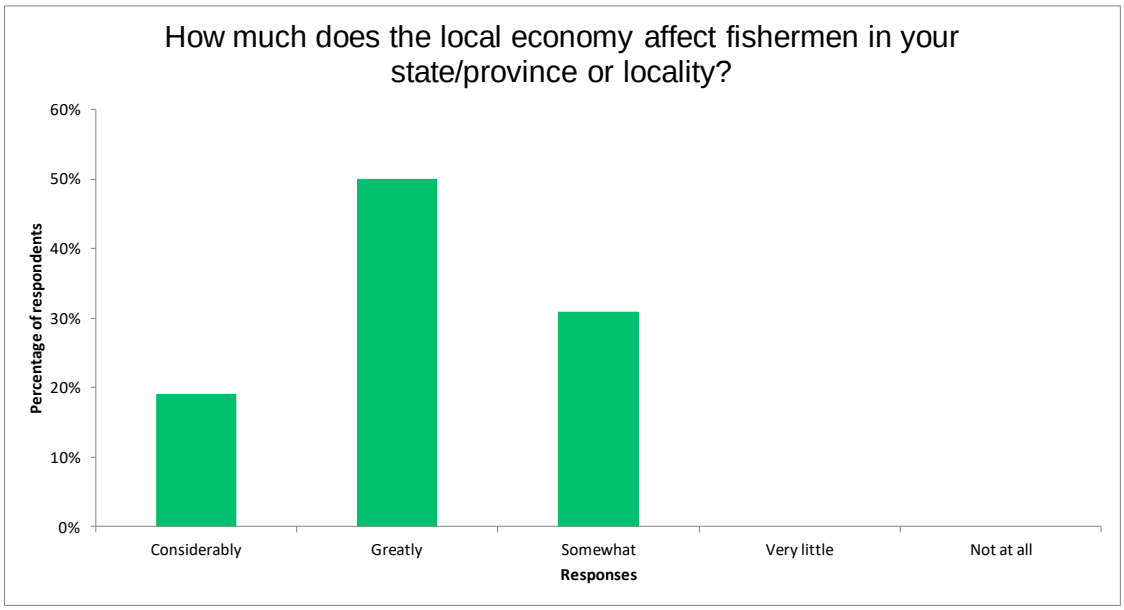

Figure 61. Effects of the local economy on fishermen.
Data from Question 48. Source: author

Question 49 asked about fishing subsidies provided by the government. The responses were evenly split in thirds with equal numbers saying “yes”, “no”, and “unsure” (figure 62).

The final portion of the instrument asked questions pertaining to cultural issues (Questions 50-61). Many of these responses are thus purely opinion-based, even more so than other questions in the instrument. Question 50 asked about the perception of the reason catch limits are set at certain levels, inquiring if the cause was based more on scientific w=evidence or politics. The responses were relatively equally split with 55% responding that politics is the driving factor and 45% answering that science determines the fish catch limits (figure 63).

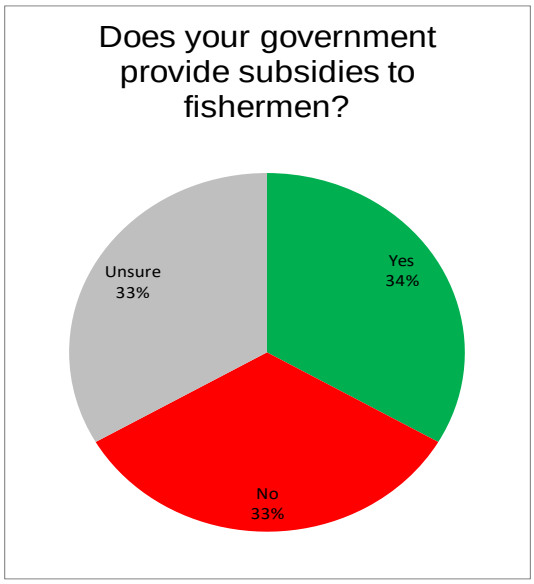

Figure 62. Perspective on the availably of government subsidies to fishermen.
Data from Question 49. Source: author

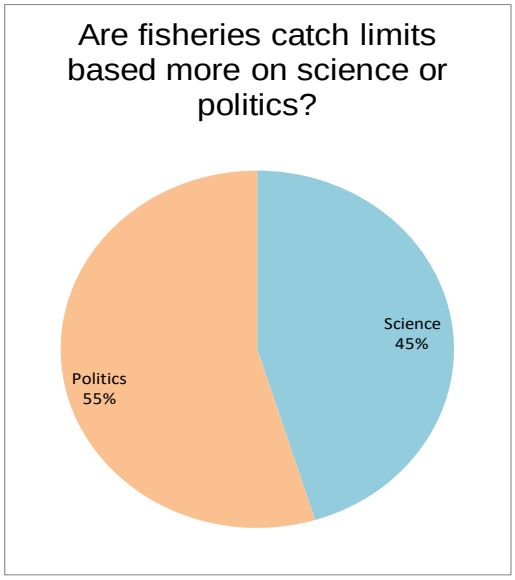

Figure 63. Perception of the relative role of science or politics in setting catch limits on fishing.
Data from Question 50. Source: author

Question 51 asked about the effectiveness of coordination efforts. Respondents had to decide the most effective level of coordination within governance. Regional coordination was seen as the most effective (37%), followed by state/provincial coordination (32%), and then multi-state regional (15%) (figure 64). Questions 52 and 53 asked about the potential to reduce fishing pressures in an effort to improve overall fishery health and available stocks (i.e., the amount of fish). When asked about their own country (Question 52) the respondents were equally split (48% yes, 52% no) on their belief that their nation would voluntarily reduce fishing pressure to improve global stocks (figure 65). When asked about the potential that "other" countries would reduce fishing pressure to reduce pressure on global fish stocks the answer skewed slightly (40% yes, 60% no) (figure 66).

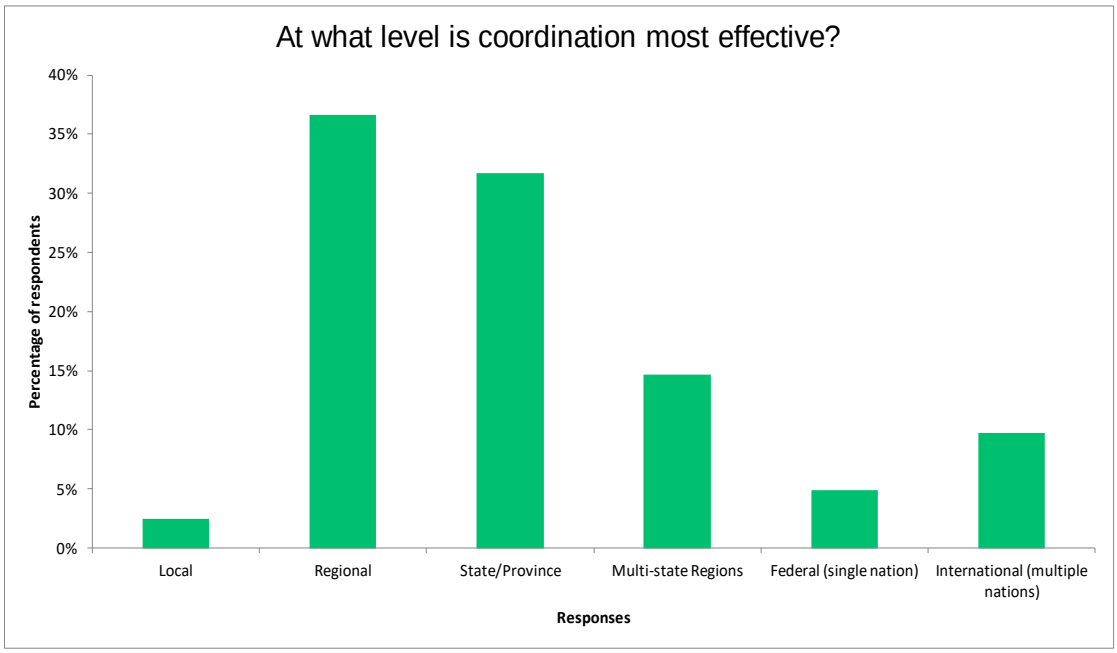

Figure 64. Respondent ranking of the most effective level of coordination for managing fisheries stocks.
Data from Question 51. Source: author

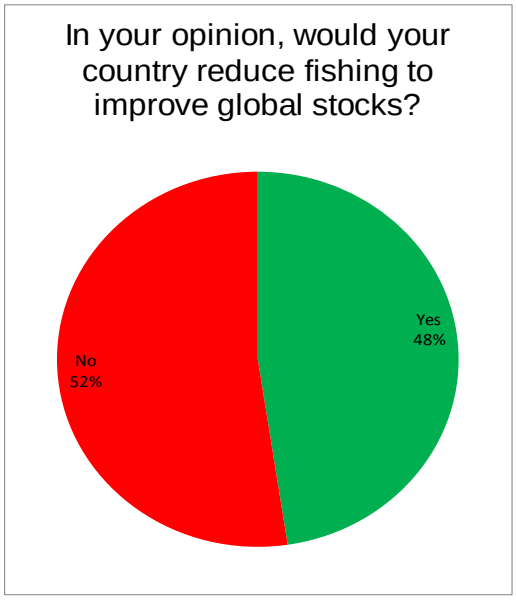

Figure 65. Potential for one's own country to reduce effort to improve fishing globally.
Data from Question 52. Source: author

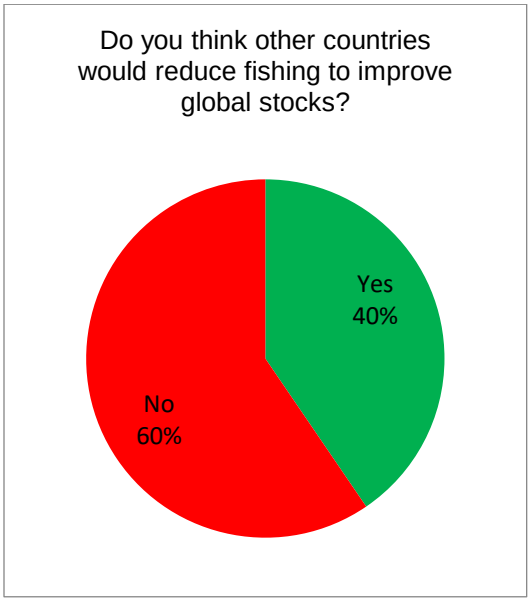

Figure 66. Potential for another country to reduce effort to improve fishing globally.
Data from Question 53. Source: author

Question 54 asked if respondents felt that fishery managers worked cooperatively with one another for the common good (i.e., benefit of all). More than half (59%) agreed that managers are working together towards the common good, though 24% were unsure, and a small portion (17%) felt they were not (figure 67).

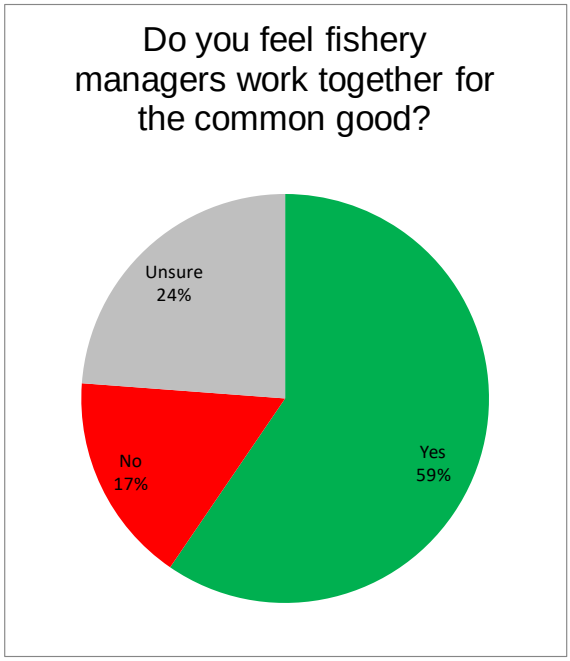

Figure 67. Perception that fishery managers across jurisdictions work cooperatively towards the common good.
Data from Question 54. Source: author

Question 55 asked whether overfishing was a national or international concern. Overwhelmingly most respondents (95%) felt that overfishing is an international concern (figure 68). Questions 56 and 57 asked about fishing quotas in the United States and Canada respectively. Most respondents felt that quotas were very effected by the U.S. government (figure 69) and less so by the Canadian government (figure 70).

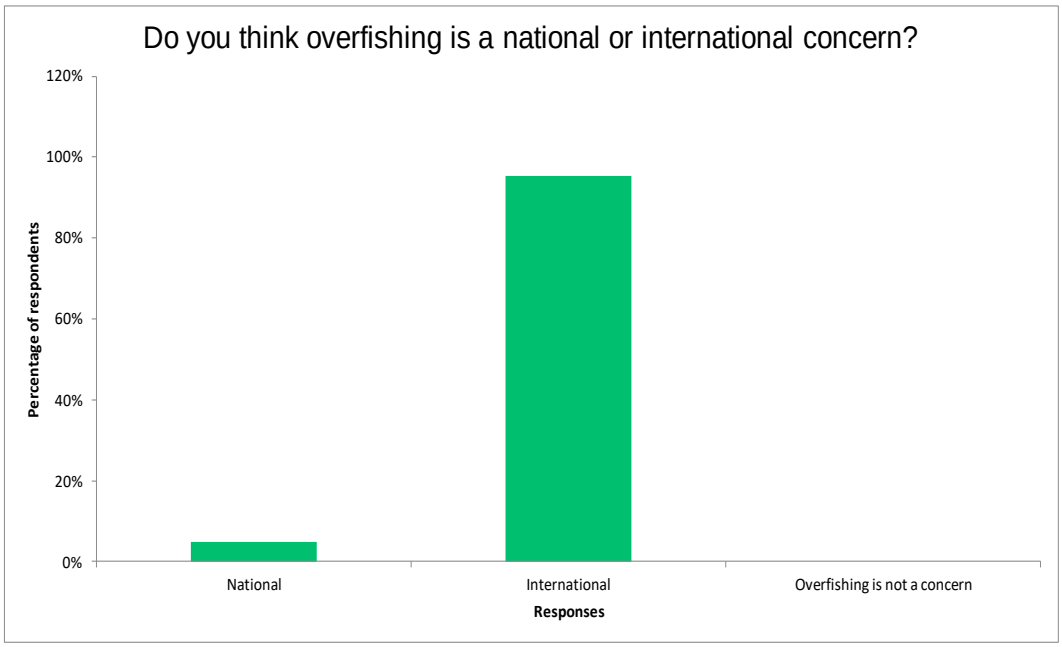

Figure 68. Perception of the level of global overfishing concern.
Data from Question 55. Source: author

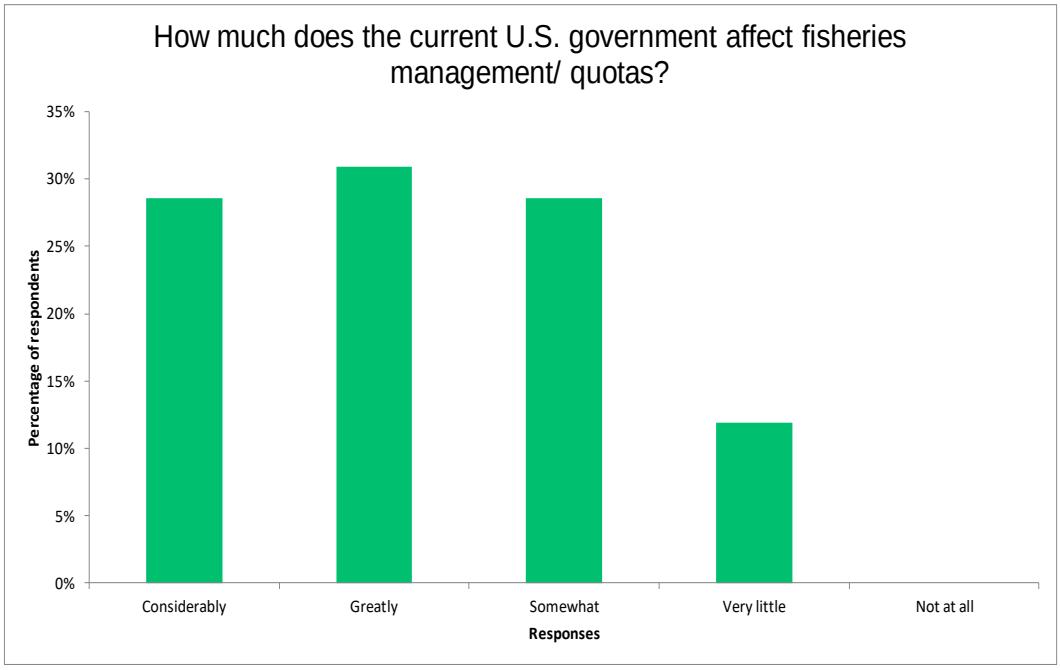

Figure 69. The effects of federal government in the United States on fisheries quotas.
Data from Question 56. Source: author

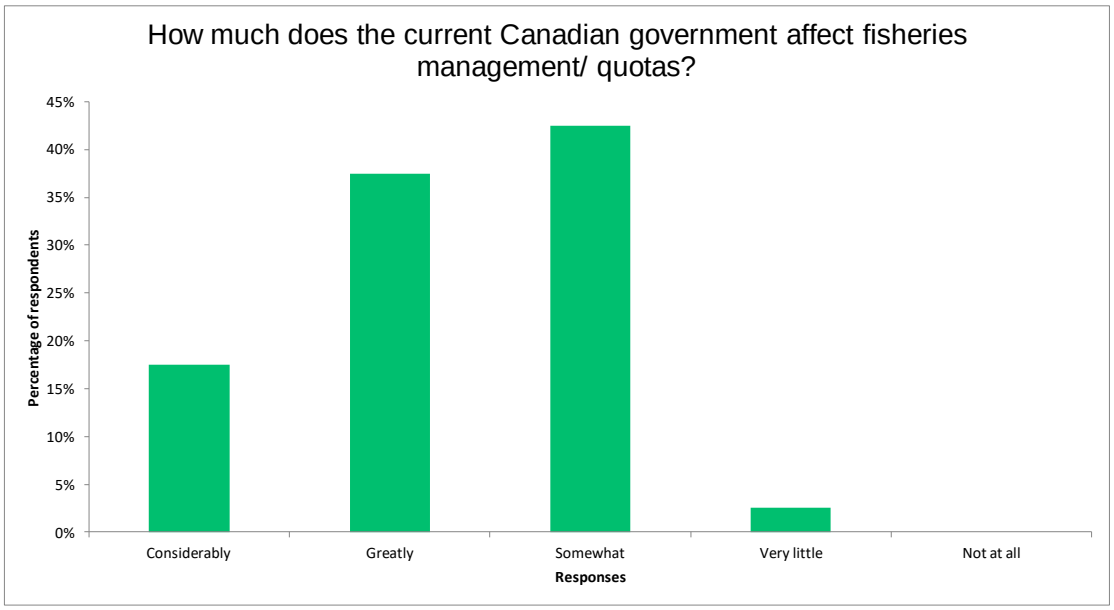

Figure 70. The effects of federal government in Canada on fisheries quotas.
Data from Question 57. Source: author

Question 58 asked if respondents felt that overall fisheries management had improved in the past decade and 71% agreed that it had (figure 71). Question 59 asked if respondents thought that reduction in quotas would result in the increase of illegal fishing/ poaching and 77% thought the amount of illegal fishing would increase (figure 72). Asked if biologists should cooperate in managing fish species that move across boundaries (Question 60), all respondents believed they should (figure 73). Asked (Question 61) if decision makers had a responsibility to ensure that fish are harvested sustainably, all respondents agreed (figure 74). Question 62 had 11 people respond, four of whom expressed interest in being contacted for a potential interview.

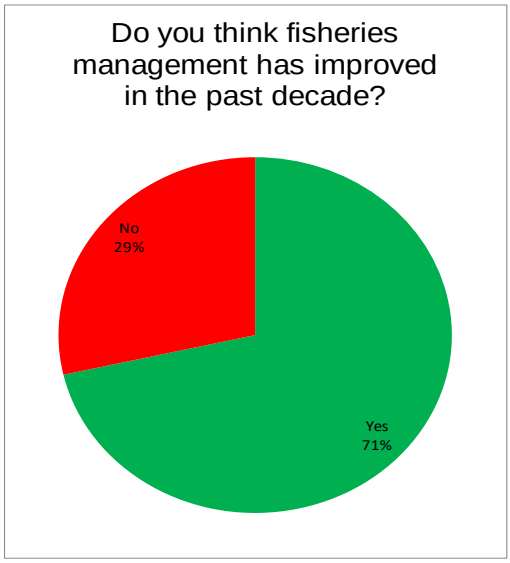

Figure 71. Perception in the improvement of fisheries management.
Data from Question 58. Source: author

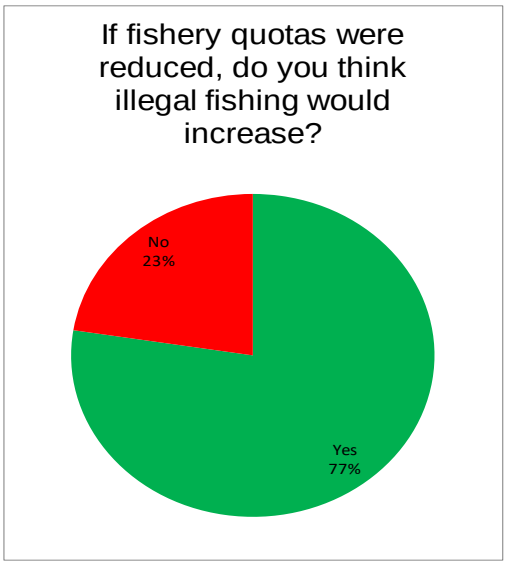

Figure 72. Effects of quota reduction on levels of illegal fishing.
Data from Question 59. Source: author

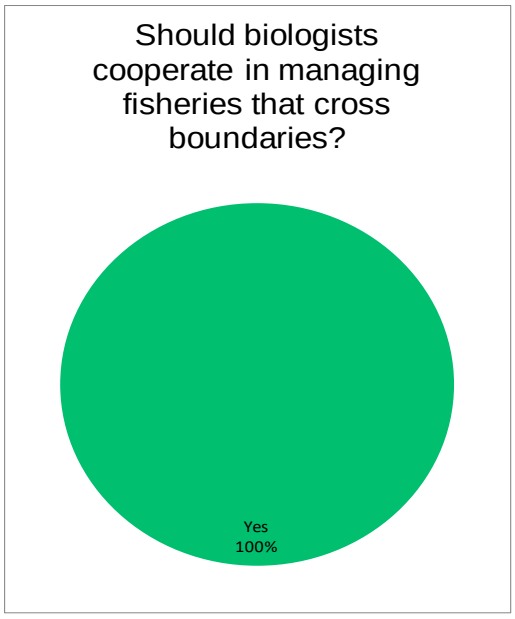

Figure 73. Biologist cooperation across boundaries.
Data from Question 60. Source: author

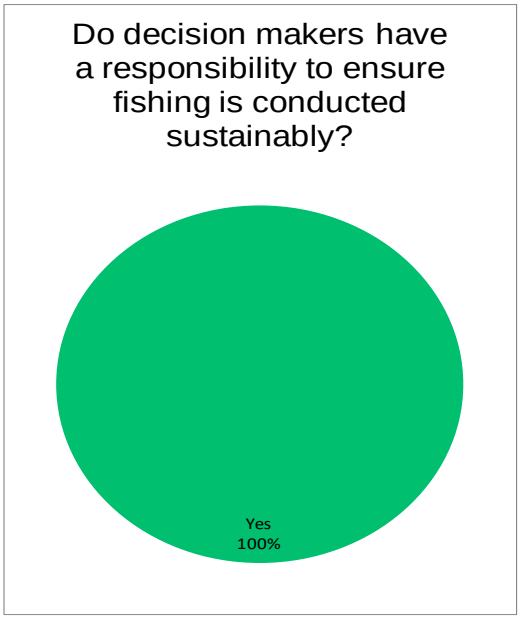

Figure 74. Responsibility of decision makers to fish responsibly.
Data from Question 61. Source: author

Interview Response and Analysis

Using data analysis to organize topics and themes that came up in the various interviews (Oishi 2003), the researcher was able to discern several key findings from each interview. The majority of the interview findings were to be expected based on the questions asked, as well as a general understanding of the fishing industry and the vocational category of the informants. There were, however, several unexpected results including perspectives which had not been previously considered. Most information received was corroborated by two or more informants. There were some findings which were not corroborated or that directly conflicted with the information from another source (i.e., a single conflicting opinion of one informant versus others).

The interviews yielded 20 significant findings. It should be noted that many informants could be characterized within more than one grouping. For example, one informant was concurrently: a government official, a fishery manager, a biologist, and a recreational fisherman. Other common occurrences were overlap in category from a longer vocational period. For example, one informant started as a recreational fisherman, took a job in commercial fishing, then was hired as a fishery biologist, and then worked as a natural resources/fisheries manager. As a result, findings are grouped according to topic, rather than individuals or job category and will be discussed in greater detail in Chapter 5.

Finding 1 relates to the topic of major issues affecting fisheries management across international boundaries. Informants identified invasive species, climate change, the restoration of native species, water diversions, species management, transboundary

coordination efforts, environmental stressors, allocation of resources, lack of data, recruitment, overfishing, and technological advancements as the key issues.

Finding 2 was that artificial selection of hatchery stocks may be having deleterious effects on native populations. From direct genetic effects to differences in behavioral and environmental cues, broodstock fecundity, and the long-term need intervention.

Finding 3 involves life histories. Informants overall felt that the life histories of any given species were important to its management and that if they had a say they would look into it but felt that others that make the regulations rarely did. Species are managed as adults.

Finding 4 concerns maximum sustainable yield (MSY). This fisheries term while understood by informants on a theoretical level did not seem to translate to a practical level. A great deal of confusion and misunderstanding seems to surround sustainable fishing practices and how those are determined and by whom.

Finding 5 concerns the fluctuations and uncertainty of populations historically. Informants were asked about fish population robustness now in comparison to a century prior. As a whole the general view was that it depended on what species was being reviewed. In terms of Atlantic Cod, the clear understanding was that this species is very imperiled from what stocks were 100 years ago. However, determining the stocks viability from 100 years ago was a considered concern. The level of fishing then was heavy, and concerns were raised about a century ago as a realistic baseline. In relation to the Lake Trout, informants felt that the introduction of the invasive Sea Lamprey was such a confounding variable that the question really was, what were the stocks of Lake

Trout prior to the Sea Lamprey? It was surmised by several informants that the populations of Lake Trout prior to Sea Lamprey were already being overfished and that the introduction of the lamprey caused a more concerted conservation effort that likely would not have happened otherwise.

Finding 6 deals with the evolutionary path of a species. In terms of Lake Trout that path is the potential speciation into a group of related Lake Trout subspecies and then eventually the differentiation into full separate species. Informants were split on the issue with some with more current knowledge of genetics being for speciation, and the others against[29]. The issue of artificial selection (Finding 2) also played a large part here. With Atlantic Cod the issue was one of genetic engineering. The long-term fishing effort and fishing regulations both in Canada and the United States based on minimum sizes[30] has artificially removed the largest and most fecund individuals causing selection pressure to become reproductively active at smaller sizes than in the past, effectively causing artificial selection for smaller sized fish.

Finding 7 pertains to stock assessments. Informants acknowledge overall that stock assessments, the ability to quantify the current population values and trends for a species, often lacks validation. Informants related that data transparency, clarification of

[29] This issue also pertains to a long-standing argument amongst zoologists, taxonomists, and biologists in general on the differentiation from one species to another. Splitters tend to see small differences and want to separate organisms into more species (or subspecies). Lumpers tend to overlook 'minor' differences and group like organisms together. For example, Siscowet, a morphotype of Lake Trout have been considered by some authors (splitters) as a subspecies (*Salvelinus namaycush siscowet*), and by other authors (lumpers) as just a variant body type not warranting differentiation to the subspecies level.

[30] Atlantic Cod are primarily caught with nets. These nets are regulated based on mesh size- the size of the openings in the net. Mess sizes allow smaller fish to pass through the net meaning that fish must be of a 'minimum' size to be caught. The smaller the net the smaller sized fish that can be caught. In this method of fishing the largest individuals are removed from the population allowing smaller fish that would otherwise be outcompeted for breeding opportunities to be able to breed and thus by default artificially selecting for smaller fish to become dominant in the population.

methodology, adoption of new technological advances, and independent measures distinct from the models are all ways to improve the understanding of current stocks and trends.

Finding 8 characterized the effects of commercial versus recreational (sport) fisheries. Near consensus was achieved in the opinion that the issue was species dependent. Fish dietary ecologies preclude catch with certain gear types and as such can only be caught by one or the other group[31]. Thereafter, the informants were split as to the effects of which stakeholder group had more impact on fisheries, particularly when discussing the two focal species. Some felt recreational fishermen in aggregate had a greater impact and others believed commercial fishing had the greater impact. The issue of tribal commercial fishing was brought up as a distinction because of the different rules that fishermen had when commercially fishing. Stakeholders in the United States saw tribal commercial fishing (especially in the Great Lakes) as a significant impact. Canadian informants recognized it as an issue but were not as vocal in their assessment of deleterious impacts.

Finding 9 concerns the stocking of non-native fishes. Unsurprisingly, this issue was not considered a concern for those stakeholders working with Atlantic Cod either in Canada or the United States since ocean fisheries are not generally stocked[32]. While the

[31] For example, Lake Whitefish (*Coregonus clupeaformis*), a native Salmonid in the Great Lakes which are related to trout, are primarily planktonivorous- meaning they eat micro invertebrates suspended in the water column. As a result of this ecology, they can only be caught in nets, a gear type common in commercial fisheries and typically disallowed for sport fishermen. Thus, the impact of commercial fishing is severe for Whitefish in comparison to recreational fishing. While Largemouth Bass (*Micropterus salmoides*) live close into shore and are thus more commonly caught with hook-and-line by recreational fishermen.

[32] Recently there have been some efforts in aquaculture to farm-raise fishes in the ocean contained within netted enclosures. This has mostly been applied to Salmon fisheries and has been highly controversial. Efforts have also been undertaken in Scandinavia for farm-raised Cod fisheries, but this has not been tried in North America.

stakeholders working with Lake Trout (in all jurisdictions) unanimously felt that the stocking of non-native species into the Great Lakes was a flawed practice and should be discontinued. However, most acknowledged that the stocking of non-natives will likely continue into the future due to sociopolitical pressures (predominantly from recreational fishermen).

Finding 10 refers to the control of invasive species. Similar to Finding 9, unsurprisingly, for those stakeholders working in the Atlantic this was not considered a key issue but was one of the most important issues with stakeholders working in the Laurentian Great Lakes. While stakeholders working with Cod acknowledged changes in the food web associated with trophic restructuring (by other natives in the absence of Cod), those working with Lake Trout saw the trophic restructuring and cascade failures as a direct result of the influx on invasive (non-native) species[33]. The effects of Sea Lamprey are still obvious to informants. It was identified that continued control of this invasive is required to have a productive Lake Trout fishery-- this was especially true in the lower Great Lakes.

Finding 11 was about reproductive ecology and fecundity (related to life history-finding 3). Stakeholders in the Atlantic were more aware of the issue regarding fecundity than in the Great Lakes (Cod vs. Trout). Atlantic Cod being broadcast spawners that can release millions of eggs was a natural concern for those stakeholders. The Lake trout only releases a few thousand eggs and so the proportionally different fecundity issues were not

[33] A ‘non-native’ species is by definition, any organism brought into a new location. An ‘invasive’ species (can be native- but that is exceptionally rare) is an organism that causes significant ecological harm. Most invasive species are non-native, though not all non-natives are invasive. Over time many non-natives reach equilibrium with the new environment and if they do not cause ‘ecological harm’ are reclassified as ‘naturalized’.

as prevalent with this species. However, the potential for speciation and genetic mixing was of great concern for some informants (see Finding 6).

Finding 12 involves the use and need for law enforcement. Informants from the Great Lakes region found that law enforcement efforts were adequate in scope and size. The majority of informants (both Canadians and Americans) felt enforcement was primarily regulated by a strict adherence to the 'honor system'. Informants felt that fishermen, both commercial and recreational, followed the rules and regulations set before them and were predominantly self-regulating. Occasional 'news events' of an enforcement action was believed to reinforce others to self-regulate to avoid consequences. Informants from the Atlantic (predominantly Americans) saw enforcement as a much larger issue. Many informants felt that 'locals' followed the rules but that poachers from 'outside' were to blame for most of the illegal, unregulated, and unreported fishing (IUU) fishing. Enforcement was seen as necessary to patrol the outer borders of the EEZ rather than internal oversight of local fishermen.

Finding 13 was pertinent to regulation setting and how fisheries resources were protected from overfishing. States and Provinces were seen as the main voice in setting regulations and allocations of harvest (i.e., quotas) and federal governments were seen as having a more advisory role in providing data and recommendations. The vocational category seemed evident in informant answers. State/Provincial informants concentrated on the regulatory aspects and federal informants focused on the oversight/advisory role. Non-governmental informants answered similarly to state/provincial informants. Many American informants seemed ill-informed about the full process of promulgation of rules

and how they may be adopted or altered when needed. American informants also mentioned the sociopolitical aspects of rule setting more frequently.

Finding 14 looks at the potential of overfishing and stock declines. Most informants thought that if data was presented demonstrating that stocks were in decline they would sound 'the alarm' and it would never be ignored. However, informants were unsure if their action would result in concrete actions being taken, especially in a cross-border context. Informants felt that their own nation would be unlikely to take the first step in making changes to regulations in the face of identified concerns unless they first saw steps being taken across the border.

Finding 15 relates to habitat and the efficacy of marine protected areas (MPAs). Atlantic informants readily identified historic habitat loss as a significant concern and saw dim prospects for near-term improvements. Great Lakes informants (predominantly) had the opposite perspective indicating that habitat was relatively unchanged. However, several informants did caveat that with acknowledgement of significant alteration to tributaries and the environmental effects of climate change (warming waters, algal blooms). All informants saw the immense value in MPAs[34], most indicating that their establishment was essential to protect spawning grounds and improve recruitment.

Finding 16 dealt with international cooperation and treaties. Informants were split on their overall knowledge of international treaties and higher-level international regulations. Some were very aware and informed, even able to cite specific treaties and language contained within, however, most were generally aware that there were treaties,

[34] Marine protected areas were often described as 'refugia' or simply as 'protected areas' by Great Lakes informants.

but unable to describe what they were or what affects they directly had on fisheries management. All Great Lakes informants were aware of their cross-border counterparts, and many had worked directly with them at some time in the past. All Great Lakes informants were further informed about various commission and partnerships between the United States and Canada regarding the coordination of efforts on fisheries issues. Atlantic informants were less informed of their Canadian counterparts. At the federal level, there was more awareness than at the state/provincial level.

Finding 17 pertains to the identified factors involved in maintaining stable fisheries. Informants suggested that the following factors are important to the long-term stability in maintaining fisheries resources across international boundaries; invasive species awareness; native species restoration; trust between fishing and management communities, partnerships, enforcement, community buy-in (i.e., fishermen as 'part of the solution'); climate change mitigation; data sharing; political will; and adoption of new technologies.

Finding 18 relates to the availability of funding for fisheries management. Most informants agreed that the current level of funding was generally sufficient. Several informants did caution that by stating that many jurisdictions were overworked, most could probably use more, and many were species dependent. Overall funding was adequate, but on a species basis there was often great disparity between resources. Some suggested certain species were overfunded (major fishery species) and others were severely underfunded (non-game species).

Finding 19 pertains to involvement in fishing activities. Many informants felt that commercial fishing as a livelihood had reduced over time. Many informants however,

had identified that anecdotal evidence seemed to indicate a slight increase in recreational fishing. This was especially noticeable during COVID, and predominantly in the upper Great Lakes.

Finding 20 was designed to capture other concerns that seemed important but did not rise to the level of having been discussed by multiple informants. One such finding was that fish intelligence is rarely considered. The context suggested that fish are seen as commodities rather than wildlife and this allows for the intensive extraction of these resources. Another interesting observation from a few informants was on the lack of knowledge/understanding of 'life underwater'. The context being that we know very little about seasonal migrations, daily movements, territoriality, etc. of fishes and that can affect one's ability to manage resources across borders.

CHAPTER V – ANALYSIS OF THE EVIDENCE

Introduction

This chapter presents the in-depth analysis of the evidence collected through field research and presented in Chapter 4 (Results). Field data collection consisted of on-line self-paced surveys targeted to known user groups with relevant knowledge bases, as well as targeted interviews with users whose knowledge and insights were less likely to be captured through surveys alone, including diplomats and high-level government officials. The objective of this chapter is to pool all the collected data and analyze the significance of the findings. By aggregating the data together, a more robust analysis can be conducted to inform readers of the importance of the collected data and compare and contrast the information found through different collection methods. The collected data is analyzed to test the validity of the three hypotheses specified in Chapter 1. By testing these hypotheses against the collected data, the researcher can evaluate the strength of the evidence and determine how reliably the observed and recorded findings can be used to validate the hypotheses and understand the implications towards answering the stated research question.

This chapter is organized by major themes revealed in the collected data found in Chapter 4. These data were built around a multiple case study design, the aim of which was to compare the information presented between various stakeholders to determine if the themes presented can be used to understand the reasons behind differences in fisheries management outcomes. The triangulation of different datasets amongst various user groups was used to assess the degree of overlap in responses from the multiple

methodologies and sources. It is broken into eight sections: Life history (and speciation); Climate Change; Habitat Management; Overfishing; Economics; Invasive and Non-Native Species Management; Cooperation and Coordination; and Sustainability.

The volume of data with this research is immense. However, there are not enough informants/respondents to use a textual analysis on the basis of a search for keywords. Instead, the 'big picture' and the overall patterns were being sought and were used to look for patterns and trends by identifying shared beliefs that help to explain the witnessed outcomes and identify these issues that are yet to be addressed by existing literature. A thorough thematic analysis provides robust results in the form of categories, themes, and patterns which can be explanatory in understanding the complex interactions that occur in fisheries management with resources that are shared and/or move across national and international boundaries. These themes are then analyzed to determine to what extent they explain the hypotheses.

Life History

All organisms have a beginning, a middle, and an end[35]. Biologists refer to this as their life history. It refers to all the events from beginning to end of an organism's life cycle. It thus encompasses a range of aspects of such events, including feeding, respiration, reproduction, and movements. Since fish live in a medium foreign to humans, their life cycles have only partially and poorly been understood. Fishes that tend

[35] This is not entirely accurate as there are several species which may, in fact, be immortal. Cell biologists have found that certain hydra (*Hydra* spp.) species cells do not undergo apoptosis (i.e., natural programed cell death) and botanists have shown that Quaking Aspens (*Populus tremuloides*) and several other trees can indefinitely clone themselves. Though they are still susceptible to predators, natural disasters, etc. and thus all probably have come, or will come, to an end.

to be of economic importance (i.e., those valued for human use) are generally the most researched and understood. An understanding of the life history of fishes has allowed us to better target and utilize these natural resources. However, incomplete, incorrect, or underuse of this information can, and has, led to the mismanagement of natural resources, including the overuse and potentially the extirpation of some species and as one Canadian embassy official stated, “scientists have found the specifics of their life histories difficult to pin down.”

Fisheries management is a sociopolitical activity based on biological knowledge. According to survey informants ‘life history’ is seen as one of the top three issues in fisheries. A federal government fisher manager stated that, “I think that there’s growing understanding in the importance of considering life history. Most of the fisheries that are exploited are the adults. I can't say policies are made in light of, or in other ways of protecting the younger life stages, but I think there is growing awareness of how the exploitation of adults’ effects future generations like no other time in the past.” Fundamentally, fisheries management is intended to allow the continued use of a natural resource by understanding how much of that resource can be extracted annually and still be able to return and collect similar values in subsequent years. For Atlantic Cod, the key life history information for managers is lifespan, migratory movement, and reproductive ecology (i.e., broadcast spawning and fecundity). The reproductive ecology is especially important to understand because it allows fishery managers to be able to predict the ability of a species to rebound at the population level from fishing pressure. Spawning volumes (eggs dispersed) are especially important in cod, which become increasingly fecund as they age and grow. This means that as fish mature, they release exponentially

more eggs. This is especially important in a broadcast spawning ocean fish for two reasons. The first is 'predator swamping', whereby a population of organisms releases so many gametes at a time that potential predators become satiated and thus most of the gametes are able to survive. The second is the sheer volume of eggs produced. With so many potential predators in the marine environment, very few individuals ever reach adulthood to spawn themselves. Releasing extraordinarily large numbers of eggs ensures that some will survive to maturity and spawn themselves and continue to species. In this system, the more fish there are breeding at one time allows for proportionally more individuals to survive predation and eventually reach reproductive size themselves.

For Lake Trout, the key life history information is lifespan, habitat use and partitioning, speciation, competition, and reproductive ecology. Habitat niche partitioning (use) and speciation are especially important to Lake Trout since they may, in fact, not all be the same, but rather a complex of multiple fishes in the process of differentiation from one another and thus significantly increasing the complexity of resource management. For an organism like Lake Trout, which has low reproductive potential, the removal of individuals from a population can have significant effects on the available gene pool. There are several phenotypes/ morphotypes of Lake Trout that have been shown to be visually, reproductively, and genetically distinct from other populations. One population, Siscowet (*Salvenus namaycush siscowet*) have even been given subspecies status by some authors (Thurston 1962, Goetz et al. 2010, Euclide et al 2022). These differences lead to important differences in habitat use and spawning behaviors and thus may be the

beginning of speciation, which adds considerably to the sustainability calculations of fishing for Lake Trout[36].

The vast majority (>90%) of informants (survey and interview) said life history is an important component of fisheries management. Survey respondents identified it as one of the top three issues in fisheries management and in maintaining a stable fishery. However, a much smaller percentage (~2/3) thought that life history was taken into account when considering updates to regulations and laws and almost one-fifth of informants explicitly stated it was not. With survey respondents this could be due partly to the broad nature of the question. For example, non-game fish are 'managed' locally but rarely considered due to their being a non-target species (i.e., not actively extracted) and therefore unnecessary to craft regulations supporting their sustainable use. When interview informants were asked follow-up questions, this was clearly the interpretation by many, especially fishery managers and biologists. Interview informants clarified that because it is typically adults which are sought (in targeted species), life history is often not considered beyond the simplest metrics (lifespan and adult size). This was similarly the case when asked if all fish were managed the same. Nearly all survey respondents said they were not. Interview respondents clarified that lots of fish are managed differently, and indeed the majority are not managed at all. One fishery manager

[36] Fish which are very similar in appearance have regularly been denoted as separate species such as the recognition of *Naso caesius* from *N. hexacanthus* by subtle "differences in tongue, body and lower lip coloration, shape of the pair of bladelike caudal spines, and presence or absence of a black border on the opercle and preopercle" (Randall and Bell 1992, Dayton et al 1994). Sometimes those distinctions become clearer as more information becomes available, such as a new understanding of genetics as in the case of *Amphiprion pacificus* (Allen et al 2010) or recognizing the differences in breeding behaviors as in *Naso hexacanthus* and *N. caesius* (Dayton et al 1994). Guzman Beautiful Shiner (*Cyprinella formosa*) are of particular note since researchers have discovered that hatchery raised fish will not breed with wild fish due to a difference in fish communication and learned reproductive behaviors (Epifanio and Waples 2016, Holt and Johnston 2014, Abarca et al 1995).

described it as “benign neglect” in relation to the non-targeted fish and that there were lots of different in management approaches for different groups (e.g., non-target species, non-natives, stocked fishes, invasive species). That same informant, among others agreed that where it matters is in fished species, and little effort is made to take into account life histories beyond the most basic metrics.

The other consideration was who was doing the fishing. Commercial fishermen pointed out that they rarely considered size. Since their gear did that work for them, they looked at gross tonnage and quota limits and generally ignored individual fish. In commercial fisheries fish tend to be managed in large scales/volumes and so they are measured by weights and volume not individuals. This was true of Canadian and American fishermen, and especially true in the Great Lakes fisheries whereby-catch is not a concern. Recreational fishermen were bound to standards based on individuals and thus were concerned with the specified allowable sized fish. Most were concerned with two issues of size- one, does it meet minimum size requirement, and two, was it the largest fish they could catch. Cod fishermen were concerned with by-catch on the basis of having to put work into catching a “useless fish” that took time and resources away from more economically important species.

Informants were asked broadly about the inclusion of life history information into the fishing regulations two-thirds of survey respondents felt they were. Again, the issue of the breadth of interpretation of the question confounds the answer. However, it was roughly 50-of interview informants who could ask/were given clarifying information who stated that life histories were rarely considered, were unsure, or ill-informed. One American government decision maker stated, “Of course we use the best available data to

inform decisions. We get all that stuff from the biologists. Really, they tell us what the important issues are, and most of the time it is pretty simple- we all understand how to measure a fish." When informants were asked specifically about how local regulations and rules were created or amended in relation to the information taken from life histories only a third of informants felt that life histories of targeted fish were considered, another third assumed that they were or must be, and the final third felt life histories were ignored.

A significant concern among some stakeholder groups was the issue of artificial selection[37]. The issue presented itself in several ways including fishing pressure, loss of natural genetic diversity, trophy fishing, hatchery selection, and indirect selection through de facto management actions. Many of these considerations are intricately linked to one another. For example, the amount of fishing pressure (especially trophy fishing) directly relates to the loss of genetic diversity. Issues such as trophy fishing (i.e., selectively fishing and removing the largest fish available for sport) are conducted at smaller scales (typically) by recreational fishermen. They can have very serious and negative consequences on fisheries that have low populations (like the Atlantic Cod) by removing the biggest and most fit individuals from the breeding stock. The loss of a large meter long female cod has significantly more impact that the removal of dozens of smaller fish due to the exponential increase in fecundity. Commercial fishermen indirectly cause similar problems by fishing for any fish greater than a certain size. They thus tend to remove a huge proportion of larger individuals allowing smaller individuals the chance to

[37] According to a simple National Geographic definition, "*Artificial selection is the identification by humans of desirable traits in plants and animals, and the steps taken to enhance and perpetuate those traits in future generations*" (NATGEO 2022a).

breed and thus skew the genetic selection for smaller fish and those that reach reproductive maturity faster.

Fish used for stocking come from hatcheries. These can be managed by government, tribal, or commercial enterprises. Regardless of the manager, hatcheries work to maximize the number of fish available to release. Most do some level of genetic testing to try to determine the best individuals to breed, but this is still an artificial process selecting traits that fishery managers deem useful. In addition, those that survive best in captivity are de facto selected as well. A Canadian biologist remarked, "Artificial selection in hatcheries…[The] environment in [a] hatchery is very different than [the] environment in which they are stocked." Those artificial environments rarely make any effort to simulate natural conditions which can lead to difficulty later in the wild (see footnote 2 regarding Cyprinella minnows). An American biologist had this to say, "Most of the hatchery work is designed to jumpstart natural reproduction, if we manage harvest they should return to self-sustaining. This would in theory put hatcheries out of business- which to my knowledge has never happened, hatcheries or casinos, but that is the goal for hatcheries."

Another major confounding issue is the natural process of 'natural selection'[38]. Artificial selection is based on human perceived value to certain traits, while natural selection is done through 'survival of the fittest'[39]. Whereby the best adapted animal to the environment persists to reproductive size to pass on the most adaptive traits to their

[38] According to a simple National Geographic definition, "Natural selection is the process through which species adapt to their environments. It is the engine that drives evolution." (NATGEO 2022b).
[39] 'Survival of the fittest' and 'natural selection' are concepts developed by Charles Darwin and Alfred Wallace in the 19th century on the evolution of species.

offspring for that environment. The process of evolution allows species to maximize their use of available habitat and available resources. If a population of an organism is separated, then over time they start to drift apart from others in the population as slight variations in environment start to select for the best traits. This process, called speciation, can occur if populations are separated spatially/ geographically, temporally (i.e., different time of breeding), or behaviorally.

There is debate within the literature and among practitioners if speciation is occurring in Lake Trout in the Great Lakes. There are at least four[40] different recognized 'types' of Lake Trout; Siscowet, Leans, Lumpers, and Redfins. They are variously described as 'ecotypes', 'morphotypes', and 'phenotypes' depending on the informant/author. One variety, Siscowet were even granted subspecies status for a time within the academic literature. One informant pointed to a previous blog post stating, "Despite some gene flow the phenotypes are genetically distinct, making the siscowet a subspecies of the lake trout" (Carleton 2009). Within the survey respondents 2/3 were unsure if speciation was taking place. This is an especially large level of uncertainty for one of the most recognized fish in the Great Lakes region. Nearly a quarter (22%) felt they were moving in the direction of distinct species and only 13% felt they were not.

The issue was a topic of great discussion among many interview informants. One Canadian informant expressed, "I think there is growing realization that we have a lot more variation in our forms that we ever dreamt, and evidence is coming out in new genetic sequencing and are showing really different pictures of stock structure than what

[40] Some authors recognize as many as 12 different morphotypes of Lake Trout and some have been given official taxonomic status in the academic literature.

we have gotten from past methods or older techniques." This has significant fisheries management repercussions for how Lake Trout are managed. An American informant stated,

> For the most part we manage universally. We are not asking fishermen to identify a lean from a humper or a siscowet. It's a Lake Trout. When looking at daily bag or size limits. They are lumped. As we continue to learn about the different morphotypes or life histories. confirmation of spring spawning Lake Trout around Isle Royale [National Park]- again there is not a... we struggle to delineate those as separate types as fishery managers, until we have a mechanism to do so it limits what we can do beyond a full closure or catch and release kind of thing. for the short term we lump. Maybe someday we will have the ability to run some type of tissue or scan while on the boat either as a manager, or a researcher, or as a fisherman and tell you what we got- "hey this is a redfin and we shouldn't keep it", or this is a common lean and we can, but that is probably a little ways out.

If speciation is occurring, then all current management actions on either side of the border are underrepresenting the current stock assessments of a particular population and could be fishing some to extinction before they are ever discovered. Indeed, according to Goodier (1981) "However, interviews with old-time commercial fishermen suggest that there had existed many discrete or semi-discrete stocks within the lake. Historical documents in the form of government correspondence and reports, explorers' accounts, and Hudson's Bay Fur Co. records yield further evidence." Similar ideas were expressed by both fishermen and fisheries managers on both sides of the border.

Dramatic variation in appearances of Lake Trout have been known for centuries. Historically, before the significant increase in fishing pressure in the late 1940s and 1950s and then the Sea Lamprey induced crash of the fishery, there may have indeed been more varieties (even up to 12 as some authors have suggested), but we fished them all out. With such low populations, organisms then resort to interbreeding as a last-ditch effort[41]. This could certainly have been the case in the 1950s and 1960s and could account for the various genetic discrepancies and uncertainties found in the literature as well as among interview informants. One federal government researcher remarked,

> I think here on the Great Lakes people have lost sight of the fact that they are really quite new. They have only been on the landscape 10,000 years since the last glaciers retreated. I think there are ecomorphotypes that are going through the process of speciation. I think there have been some set-backs, some anthropomorphic stressors that have set back that process some. I think there are some recombining of morphotypes that have resulted from the changes in the ecosystem a loss of diversity. A number of of species in that family that we have lost.

Additionally, the witnessed variation of morphotypes, the plasticity in appearance, could be as a result of this remixing of the genetics amongst populations which had previously been separated. Little has been studied on the ecological differences in morphotypes, but

[41] A classic example of this is Wolf-Coyote hybrids. Grey Wolves normally kill Coyotes on sight and actively persecute them if found near their territories as rival competitors, but during the 1930s and 1940s when populations in the upper Midwest were so low, wolves began to interbreed with coyotes producing hybrids. This fact confounded efforts to analyze Great Lakes wolves for years when genetic techniques for identification were first being developed. Similar taxonomic disagreements about subspecies status for Eastern Wolves is still ongoing.

what has been discovered is differences in appearance, differences in habitat partitioning and water depths, differences in body shape and fat content, differences prey consumption, and behavioral differences in breeding behavior. All precursors to speciation. According to an American fishery manager "one of the reasons we stick so tightly to collecting the scientific data in the same way is it allows us to better understand that. I don't want to undermine the work that population biology folks are doing, that's relevant, but I often wonder if there is not enough deep studies on species. Maybe there is not that much known about a species from an ecosystem perspective."

Climate Change

"I think Climate Change is real and we are seeing the effects on the Lakes and the fish populations right in front of us." This comment from an American biologist would not have been possible a decade ago. American biologists during the George W. Bush Administration were instructed not to discuss 'global warming' and reports were regularly censored and refused publishing clearances. "…political appointees censored climate science reports from government agencies, and mostly got away with it by gagging the scientists. A survey found that nearly half of 1,600 government scientists at seven agencies ranging from NASA to the EPA had been warned against using terms like "global warming" in reports or speeches, throughout Bush's eight-year presidency" (Nuccitelli 2017). This censorship resumed under the Donald J. Trump Administration, though Climate Change had become too large of an issue to be entirely redacted.

During this research, survey respondents ranked Climate Change as the most important issue in fisheries management. Overfishing, habitat loss, life histories, invasive

species were all recognized, but Climate Change was identified by most respondents as the most important issue. It was further demonstrated not only as the major issue affecting management, but one of the most important to the stability of fisheries and their management across international boundaries. Nearly all interview informants spoke at some point about the pervasiveness of Climate Change- its effects, its potential, and its implications. A Canadian federal representative succinctly stated, “Anything we can do to slow Climate Change is going to be important,” while an American fishery manager remarked, “Climate Change is increasing in its effects, and impacts are starting to become more obvious- like algal blooms and higher temps.”

Many would assume that fish are less susceptible to the effects of Climate Change. This is to some degree correct in that water is a natural buffer of extremes, but it is also an environmental driver itself and can act as both a heat source and a heat sink. While the effects on fish are slower to develop, they are often beyond repair once the effects are seen. At Isle Royale National Park, an entire land-locked population of Cisco (*Coregonus artedii*) was extirpated when the entire inland lake it lived in warmed beyond the lethal maximum temperatures for the fish (Brown 2012). Even at the deepest depths of the lake, which likely acted as a refugia for a time, it was too warm.

For Atlantic Cod, Climate Change is an issue. Its impacts are already being seen in the Atlantic with increased temperatures and acidity causing trophic cascades and disruption to food webs, as well as alterations in migrations in order to find appropriate habitat and prey. Certainly, cod and the NW Atlantic will be less impacted by Climate Change in the near-term years than many other locations, but as we have seen, many of the impacts of Climate Change to date have been unforeseen and most are exacerbated by

other mitigating factors. Changes to where cod are found could have profound effects on the stability of existing treaties and agreements between the United States and Canada.

As recently as 1984 the maritime boundaries between the United States and Canada were not settled. The expansion of the exclusive economic zones had redefined where the maritime borders should be and there was overlap in claimed areas. These highly contentious maritime boundary disputes were fundamentally over the cod stocks in the Gulf of Maine and had to be settled by international court arbitration. The Canadian government wrote, “The subject of this dispute is the course of the single maritime boundary dividing the continental shelf and fishing zones of Canada and the United States in the Gulf of Maine area. The dispute centres primarily on the rich fishing grounds and potential hydrocarbon resources of Georges Bank, a large, detached bank seaward of the Gulf of Maine, off the coasts of Nova Scotia and Massachusetts.” (ICJ 1982). The American government suggested that after 200 years of co-management with Canada, “bilateral cooperation in the effective conservation of transboundary fishery resources is not possible or desirable and that “single-State management" is necessarily more efficient than "conservation by agreement” (ICJ 1982). This all centered around a small piece of the ocean. Climate Change could magnify these types of disputes exponentially as habitats and fisheries are affected.

For Lake Trout, Climate Change effects will be more pronounced and observable in the coming years. This is partly because the Great Lakes, while expansive, are a smaller “closed” system and more inland (and thus more susceptible to continental effects). This area is also less predictable. The Great Lakes region is unique in the world. It is one of the only places to have huge inland seas and as such the impacts from the

global Climate Change models are less predicted and predictable. However, some effects are known because we are already observing them. Warming temperatures and less lake ice are proving to be the most severe drivers of change. Warming water temperatures are directly detrimental, but they are also indirectly detrimental as they are the cause of less ice cover in winter. Less ice in winter reflects less sunshine, which in turn means the Great Lakes do not cool as much, setting off a positive feedback loop of warmer and warmer waters. Warming water (along with eutrophication from land sources) creates conditions for algal blooms which can release toxins, and which can cause local reductions in oxygen levels to the point of causing hypoxic conditions and fish die-offs[42]. According to interview informants from Canada and the United States, algal blooms have even started to appear in Lake Superior, the largest and coldest of the Great Lakes. While these blooms have been relatively common in the lower lakes, they were unheard of until recently in Lake Superior.

Lake Trout are a coldwater fish. As the Lakes heat up there will be less and less available habitat (i.e., areas that meet temperature needs) and, more strikingly, may have a direct effect of reproduction and recruitment. An interview informant, when asked how Climate Change will affect Lake Trout responded, “That to me is the million-dollar question. Some of the issues we are seeing with recruitment, mostly prey fish populations are directly tied to changes in climate. General increase in water temperature across all seasons, less severe winters, long strong cold winters are in decline and those strong

[42] Massive die-offs of the non-native Alewife (*Alosa pseudoharengus*) have can be caused by numerous stressors including failure to adjust to temperature extremes and fluctuations in the Great Lakes, low oxygen, lack of food, poor winter conditions, chemical imbalances, and spawning stress (Colby, 1971, Johncox 2022).

winters seem to be important for recruitment. We are almost to the point where we can predict what native fish recruitment will be for a lot of species in the Great Lakes based on the winter severity. So as winters have become less severe as climate has changed [and] we have seen declining recruitment."

Lake Superior is very large and very deep (deepest point is 406m). With an average depth of 152m and a volume of 12,5000km^3 of water, Lake Superior could fill all the other Great Lakes plus three additional Lake Eries (GLC 2022). With this volume, Lake Superior will act as refugia for decades, the other lower Lakes however, will rapidly become uninhabitable as temperatures increase. This is especially important if in fact, speciation is occurring in Lake Trout. There is real potential to loss certain morphotypes in coming years. Cultural and political will to implement Climate Change measures on a national and global scale are needed, but beyond the scope of this study.

Habitat Management

Fisheries management is not possible without proper and available habitat. Habitat management is relatively straight forward on land. Underwater habitat management is more complex. Much of the issue is the lack of direct oversight and measurement. It is the 'out of sight- out of mind' conundrum. Survey respondents ranked habitat loss as the second most important issue in fisheries management as well as the second most important issue in maintaining stable fisheries. Interview respondents also mentioned habitat management, especially the loss of habitat as a major issue for concern.

Informants on the Atlantic coast predominantly described the historic use of trawl nets as a major reason that Atlantic Cod habitat was lost and did not see potential improvements in the next century. A federal fish biologist simply stated that, “Trawl fishing is destructive as well as highly effective.” Informants from the Great Lakes had the essentially the opposite outlook. Most stated that Great Lakes habitats were largely unchanged and relatively pristine such as “for the most part LT habitat has remained pretty much consistent and intact” and “there are no biological deserts in the Great Lakes. No hypoxia areas. Everywhere we can sample for fish we will find fish.” However, several informants did note the significant alteration to riverine habitats feeding into the Lakes, the environmental effects of Climate Change, and the apparent absence of Lake Trout from some areas they would expect to locate them.

For Atlantic Cod much of the historic habitat has been damaged or destroyed by trawling (82% of survey respondents agreed) and this will continue to hamper recruitment to these historic fishing grounds for decades, even with highly migratory species like cod. For Lake Trout, it is not habitat loss, but lack of habitat use that hampers populations. According to an American fish biologist, “nearshore zones- places that used to support fish populations, there were stressors and even though stressors eliminated, it seems like it is really slow to recolonize some of these areas.” One possible explanation is that what appears to be suitable habitat may not be for different morphotypes. One of the factors identified with the apparent speciation of Lake Trout is the niche partitioning of habitats. So, the lack of recruitment to potential habitat may be the result of a not having the correct morphotypes in the area in numbers large enough to migrate to new locations to fill that niche. With low enough fish populations (most survey respondents

described Lake Trout as overfished), they are not forced to migrate to seek distant habitat and thus it remains unused, or as suggested by an interview informant, “Not being reoccupied a function of a lack of recruitment? I think yes. Fish is a creature of habit. Regular migration/movement patterns. They don't deviate much, except when you see really large populations and the habitat maybe being limiting, then fish explore new areas.”

Overfishing

According to Canada and the United States, both the Lake Trout and the Atlantic Cod fisheries are overfished. One would think, that in order to maintain a stable and sustainable fishery, actions would be directly taken to ensure that overfishing is stopped, and stocks restored before continued extraction of resources. Unfortunately, this is not the case and rarely is. One American biologist remarked, “Fishing down the food chain is a really big thing- we are at the point that we are harvesting krill for supplements.”

Part of the problem is the relative impacts of commercial versus recreational fishermen. In discussions with informants, some felt recreational fishermen (in aggregate) had a greater impact on fisheries, and others felt commercial fishing had the greater impact. The issue of tribal commercial fishing was brought up as a distinction because of the different rules that fishermen had when commercially fishing. The results of some survey questions are in question because of this. Based on data from interviews, some survey respondents may have lumped tribal fishing in with commercial fishing. However, since Tribal commercial fishing has separate rules, regulations, and policies as well as lots of cultural and political contexts, Tribal fishing cannot be lumped together with other

commercial industrial fishing. As a whole, survey respondents overwhelmingly felt that commercial fishing has a greater impact. Through the interviews it became apparent that the species being sought has a great influence on the potential fishermen.

Most experts agree(d) that stocks of Lake Trout in the Great Lakes and Atlantic Cod in the northwest Atlantic are overfished. Currently recreational fishermen make a large impact on these populations. Not just in the extraction of fishes, but with the targeted intention of removing the largest fish available. This 'trophy fishing' removes the most valuable fish from the system and negatively affects the ability of the population to recruit and rebound from fishing pressures. Another way in which recreational fishermen are potentially having an impact without realizing it (and commercial fishermen also have this effect) is the survivability of fish following release. Most commercial fisheries document their by-catch (unwanted fish that are thrown back and rarely survive). However recreational fishermen do not document their 'released fish'. Many of these fish do not survive after being released mostly due to swim bladder damage from being hauled to the surface rapidly causing barotrauma injuries catastrophic (Rummer and Bennett 2005, Keniry et al 1996).

Historically, it was commercial fishermen who indiscriminately took too many (large) fish. The advent of new fishing technologies being the main reason that fishermen post World War II became so successful. Commercial fishermen damaged habitat and the food web- further decreasing the ability of cod to reproduce in high enough numbers to replenish what is lost from fishing and other sources of mortality. Recreational fishermen and especially the trophy hunting mentality have made fishermen seek out the largest and most important individuals and this negatively affecting the resources into the future. One

informant noted that, “As those populations have recruitment issues and their numbers decline, we must further regulate harvest. In order to do that we must change expectations from the fishers.”

We must ensure that we are distributing data to the public on the population status of fisheries. As restoration efforts have been underway for several decades, modest increases in stocks have been documented for both trout and cod. However, in the cod fishery, as they have started to return, they have started to have an impact (as they once did) on the ecosystem. This has included the obvious reduction of their prey base. One such reduction has been in shrimp, which had developed in recent years as a substitute resource for fishermen. The public perception has been that there were now some many cod that they are ruining the shrimping industry (Beswick 2017). Yet the reality is that cod are nowhere near their historic levels and in fact have failed to meet their target restoration and recovery goals (NOAA 2022, Bergman 2019).

Interview informants acknowledged overall that stock assessments often lack validation making the data subject to great variation in accuracy and reliability. Data transparency, clarifications in methodologies, adoption of new technologies, and independent measures distinct from the assessment models were all identified as ways to enhance our knowledge surrounding current stocks and their population trends.

> Biological management of fisheries has been built around the concept of 'the unit stock'. At this late stage in development, it is difficult to discern that this apparently commonsense notion may be an instance of misplaced concreteness which places artificial constraints on analyses or on management rules and procedures. In fact. the 'stock' is an abstract term applied to provide a rationale for

> a certain kind of aggregation of catch data. This is not to say that there may or may not be such a thing as a discrete group of fish that may constitute an effective breeding group or stock, but in many cases there is significant uncertainty about the identity of the group from which successive annual catches are made. (ICJ 1982).

This except from a Canadian document 40 years prior highlights the realistic interpretation that fisheries managers as well as federal officials recognized on the movement/migration of "stocks" and the aggregation of catch data as problematic. In referencing the United States official stance on fishery stocks, they go on to note that "The State that has the right to manage the resources of the exclusive economic zone has also the exclusive right to exploit these resources, subject only to limited exceptions. Single-State management, in practical effect, means single-State access to the economic benefit of the resources in question. It is a euphemism for monopoly…" (ICJ 1982).

As recently as 2022 the United States perspective has not altered dramatically, "Cod is an iconic fish of New England and in recent years, Atlantic cod stocks in our region have declined dramatically. NOAA Fisheries is working to rebuild this population." (NOAA 2022). While this is a true statement it clearly ignores the cooperative partnership that the United States has with Canada on these fisheries stocks and reflects the very different perspective the two nations have on the availability of these fish to be extracted. According to the NOAA fisheries 2021 stock assessments of Atlantic Cod both populations (Gulf of Maine and Georges Bank) are overfished and despite having a recovery plan in place for more than a decade, stocks are not expected to reach

their target goals (NOAA 2022). Despite this, “Fishing is still allowed, but at reduced levels.” (NOAA 2022).

The Canadian response has been very different from that of the United States to the cod collapse and recovery. “During the 1990s, most cod stocks collapsed in Atlantic Canada. Today, most of the remaining populations, including northern cod, are deep in the critical zone and are assessed as endangered” (COSEWIC 2020). Cod, which played a critical role in Canada’s economy and culture, just as it has in the United States has assessed the risk to this species as grave. This policy is to restore overfished cod stocks. “Today, the cod population remains too low to support a full-scale fishery. For this reason, the ban is still largely in place.” (HNL 2020).

Survey respondents felt the issue was simple to explain. When asked if catch limits were based on science or politics, more than half of responses claimed politics guides resource extraction more than science. This was seen as true for both Canada and the United States, but the data skewed more towards science taking precedence in Canada.

Fisheries are generally protected from overfishing by regulations. According to survey respondents and interview informants, states and provinces were seen as the main voice in setting regulations and the allocations of harvest (i.e., quotas). The survey respondents and interview informants differed in their view of who should be setting regulations. Survey respondents felt that it should be conducted internationally through joint action between nations, while some interview informants saw the federal governments as having a more advisory role in providing data and recommendations “I think the premise is wrong that on the Great Lakes all the fisheries are managed by the

states and the tribes and the provinces in Canada. The federal role on the Great Lakes is not regulatory in respect to the fisheries. We collect data on status and trends and advise fish managers, we don't offer any regulatory authority- we don't have it. I think the way it is set-up is eloquent.", and others noting that it is federal action that sets laws and maintains treaties. "In the U.S. or anywhere? In the U.S. it is the federal government in close partnership and oversight with the fishery management councils [that set laws]." Another American informant mentioned that "NMFS [National Marine Fisheries Service] writes and promulgates the rules, but indirectly a lot of it comes from the councils. That is unique in the world. There are, are other countries that have similar." While a Canadian informant speculated that "Canada operates in a similar way, tribes have important roles, especially in Canada."

The vocational category of the respondent seemed to be evident in the perceptions and opinions offered. An American biologist for example summed up the process by saying, "The biologists of a region will be looking at possibilities for management changes by looking at data, GLFC meetings, public hearings, websites, meetings with input - sometimes heated depending on who is being impacted by the possible decision, they compile results with recommendation to boards in the states (appointed politicals), look at information and they decide what become regulation so there is political involvement (I think they are governor appointees)." State/Provincial informants concentrated on the regulatory aspects, such as "in Great Lakes it is state regulators, have majority of influence, but with input from other agencies," and federal informants focused on the oversight/advisory role. Non-governmental informants answered similarly to state/provincial informants. Many American informants seemed ill-informed about the

full process of promulgation of rules and how they may be adopted or altered when needed. American informants also mentioned the sociopolitical aspects of rule setting more frequently.

Economics

There was significant disagreement on the impact to economics of fisheries management between survey respondents and interview informants. On the topic of economics in general there was agreement between the two data sources. On the survey one question asked survey respondents to rank issues affecting fisheries management- none identified economics as a top priority, and it tied for 16th out of 18 choices. Another survey question had survey respondents rank 'economics' as 11th (out of 12) in overall importance to maintaining stable fisheries. This agreed with the overall perceptions from interview informants. None of the interview informants identified economics per se as an issue, even when asked specifically about their local area or the impacts on fishermen and livelihoods if certain restrictive actions (e.g., moratoriums on fisheries) were taken. However, survey respondents ranked the 'livelihoods of fishermen' as the 9th (3-way tie) issue in overall importance to fisheries management (out of 18 options provided).

Survey responses demonstrated a difference of opinion with interview informants on how much the local economy affects fishermen. While survey respondents did not rank 'local economic development through fishing' as a priority management issue. Most survey respondents (70%) answered "considerably" or "greatly" when asked about the local economic effects to fishermen. Interviews informants were mixed with some claiming that it was a benefit to the local community by stating, "In my local area it is a

benefit to the economy. It's a cultural thing around here" or "you can go to several grocery stores and restaurants and get local fish for dinner it adds to the economy." Other informants indicated that fishing as an activity had waned suggesting "Yes I do, not as popular as it used to be. Not because of lack of support, I think it's because of video games. And other recreational activities- it's a change in society."

Many interview informants felt that commercial fishing as a livelihood had reduced over time. This was especially evident from informants in the Atlantic region who identified that there were significantly fewer cod fishermen than in the past, and fewer still who based their livelihoods around cod fishing. Informants in the Great Lakes felt there were also fewer commercial fishermen and less recreational fishermen. Many informants however, had identified that anecdotal evidence seemed to indicate a slight increase recently in recreational fishing. This was especially noticeable during COVID, and predominantly in the upper Great Lakes. "My gut feeling is that there was more. It was an activity that people could engage in." and "partly maybe just cultural social change. COVID triggered more effort of people trying to get outside."

The level of funding for fisheries management was another area were there was significant disagreement between the surveys and the interviews. Survey respondents (72%) clearly felt that lack of funding had severe effects on fisheries management. The breadth of the question allows for some interpretation. Potential that respondents felt that 'if' funding is lacking it has severe consequences, or it could be that there 'is' a lack of funding causing severe consequences. Survey respondents may have been referring to other non-game fishes which are chronically underfunded. Most interview informants were very clear that the current level of funding (in their jurisdictions) was 'generally

sufficient'. Claiming that overall funding was adequate, but on a species basis there was often great disparity between resources. Some suggested certain species were overfunded (major fishery species) and others were severely underfunded (non-game species) with statements like, "depends totally on the fisheries. Some fisheries are so underfunded and other have more money than they can spend…some are so over-resourced compared to their socioeconomic benefit" and "Northeast groundfish gets a lot of money compared to its economic benefit" or "you could make an economic argument is it worth spending $20 million to monitor a $27 million fishery- how much is culture worth?" Several informants did further suggest that many jurisdictions were overworked, most could probably use more funds, and many were species dependent. One Canadian federal official commented that a lack of funding "limits their ability to work with the public and alleviate their concerns, they are really taxed to a point where more money would probably benefit them."

Invasive & Non-Native Species Management

Biologists, managers, and decision makers must know what is present in the ecosystem in order to manage it. Native species are divided into two groups; those that are managed[43] (i.e., fisheries species) and those that are not (non-game species). Along with native species, there are often other categories that are may be managed including artificially stocked natives, non-natives and invasive species.

[43] This is a gross oversimplification. In most jurisdictions the non-game species are also managed, but significantly less intensively. They are often passively managed by default through the active management of targeted sport fishes.

Non-native species and invasive species present numerous management challenges. They often compete with, predate, or otherwise impair the life histories of native species. In the early to mid-20th century many areas actively introduced and stocked fish (predominantly non-native species) to enhance recreational opportunities for sport fishermen and to establish lucrative fisheries in the commercial sector. This predominantly occurred in closed systems (rivers, stream, pond, and lakes). It was a regular occurrence in the Great Lakes. Open oceans do not lend themselves to stocking efforts.

Unsurprisingly, this issue was not considered a concern for those stakeholders working with Atlantic Cod either in Canada or the United States, since ocean fisheries are not generally stocked. While most of the stakeholders working with Lake Trout (in all jurisdictions) felt that the continued stocking of non-native species into the Great Lakes was a major concern. The majority of survey respondents (>85%) felt strongly that the continued stocking of non-native species into the Great Lakes should be discontinued, as it is causing 'considerable' negative consequences for native fish and fisheries, and that targeted efforts for greater fishing pressure on those extant populations already established in the Lakes should occur. Additionally, respondents felt that genetically modified fish should not be allowed to enter the Great Lakes and specific regulations should be enacted to prevent their future use.

Lake Trout directly compete with other 'sport' fish that are considered by many to be more desirable. The primary competitors are the stocked salmons (Chinook, Coho,

Pink, and Atlantic) which were intentionally introduced[44] to augment and 'improve' local fisheries. The introduced salmon and the native Trout are apex predators that predominantly feed on the same prey and utilize the same habitat- effectively filling the same ecological niche, and therefore compete with one another for resources. Salmon are very popular game fishes and highly sought thus there is strong political and cultural pressure to continue to stock these non-natives. Most biologists recommend no longer stocking these or other non-native fish but recognize the value of the industry and the reality that it is unlikely to be discontinued in the near-term. Interview informants acknowledged that the stocking of non-natives will likely continue into the future due to sociopolitical pressures (predominantly from recreational fishermen). One interview informant noted, "As a biologist I look it and say I'd rather manage for native species. Salmon in the Great Lakes are incredibly popular and if we said we were going to stop stocking salmon in the Great Lakes we would have a lot of people in an uproar. Ideally, in my perfect fish world we would stop stocking salmon." Many state and provincial agencies get massive amounts of funding for conservation work from anglers who want to catch salmon. Additionally, although stocking efforts have diminished from their height in the 1950s and 1960s, the stocks of many salmon are now relatively established, and many are reproducing and likely self-sustaining.

This indirect threat puts pressure on Lake Trout, and they compete for habitat and prey. Some Lake Trout stocks (morphotypes) may be doing better than others because they are using niche habitats that are not used by the salmon and thus avoid direct

[44] There has been some discussion that Salmon many have also been introduced as a way to manage the invasive Alewife (a marine herring) which had entered the Great Lakes via the man-made Welland Canal.

competition. The most common morphotype of Lake Trout, the Siscowet, is a deep-water fish that uses areas of the Lakes that salmon do not, and thus does not have to directly compete for resources.

Non-natives (stocked or not) are an issue to fishery managers. Invasive species are an overwhelming issue. Non-natives can compete or otherwise indirectly effect native species. Invasive species have catastrophic effects on native species and the entire ecosystem. For those stakeholders working in the Atlantic this was not considered a key issue, but it was one of the most important issues with stakeholders working in the Laurentian Great Lakes.

Due to the nature of ocean currents, habitat requirements, environmental conditions, and other factors, there are fewer invasive marine organisms[45], especially in open ocean and continental shelf ecosystems. This has meant that fortunately Atlantic Cod have not had to contend with the habitat and environmental changes associated with invasive species, yet due to their ecology, the absence of large numbers of cod for many years caused a significant restructuring of the marine food web on the Atlantic continental shelf ecosystems. The trophic cascade changes have altered the predator-prey dynamics and allowed for the replacement of cod as the top predator in the system. anthropogenically driven change to allow one predator (dogfish) to usurp another (cod) similar to the changes seen in the ecosystem following invasive species invasions.

[45] While there are certainly fewer areas in the marine environment that have issues with invasive species, some closed areas, like the Mediterranean Sea have been documented with more than 500 invasives including marine algae which have caused significant harm to the environment (Galil 2007, Chapman et al. 2006).

Invasive species (and their control) are a huge issue for the Great Lakes. Invasives like Quagga and Zebra Mussels (*Dreissena rostriformis bugensis* and *D. polymorpha*) have had dramatic effects on the entire ecosystem causing billions in damages to the fishing industry, changes in lake temperatures and chemistry, and acting as disease vectors (DOS 2009, Lovell et al. 2006). These filter feeders filter water, which seems good. However, their filtration is removing phytoplankton and other suspended particles that would otherwise be eaten by natural prey sources like Fairy Shrimp. Additionally, the clearer water allows light to penetrate further into the water allowing more algal blooms as well as heating the water and changing lake stratigraphy, icing patterns and oxygen turnover, all of which effect negatively the food web for Great Lakes fisheries. According to a Canadian biologist "bigger problem than Climate Change because it predates it. We have seen when invaders have come in and totally flipped the food web on its head. Like Alewife, Sea Lamprey, Bythotrephes, Quagga Mussels and shunting energy into benthos. It's a huge problem, recognizing how disruptive it is to prevent or rather slow the invasion needs to happen."

Informants working with Lake Trout have seen the trophic restructuring and cascade failures as a direct result of the influx of invasive (non-native) species. The effects of Sea Lamprey are still obvious to informants who suggest,

> I have a feeling that if you stopped treating [Sea Lamprey populations] those numbers would skyrocket again, and you would lose a lot of fish. I think they [Lake Trout] would be nearly extirpated again especially in the lower lakes [and] I think that we have, we must continue the lampricide treatments on the Great Lakes. There have been attempts to scale those back over time and to make

> more informed decisions of how we apply the lampricide and we have seen that when we back off that that can cause Sea Lamprey re-expanding. If it were not for lampricide treatments I don't think we would have been able to recover Lake Trout in Lake Superior and if we were to back off from that program we would see a dramatic decline in numbers of top-level fish we have worked so hard to develop in the last 30-40 years.

Sea Lamprey would likely wipe out Lake Trout if constant measures were not taken to chemically constrain their populations. This constant use of lampricides puts toxins into the water and kills native fish, setting up a battle over what animals we value. The cultural value of one species over another. The economic value of one over another. The perceived usefulness of one (native-but not used vs. native and fished for food) over another. Plus, the political pressure to maintain fisheries, jobs, and recreational opportunities. Managers pick one fish over another. Lampricides kill lamprey. Not all lampreys are invasive, or even non-native. There are three native lamprey species in the Great Lakes. Fishery Managers and Biologists from both sides of the border recognize this issue. With arguments and rationalizations such as,

> Sea Lamprey control program focuses on confirmed presence, attempt to avoid areas that don't need to be treated. Nothing to do to protect native lamprey when they are cohabitating. I guess that is an unfortunate circumstance to native lamprey, unless we can get to a point where Sea Lamprey will not decimate the populations [of Lake Trout] we will continue to need to focus on them, put a higher priority on them, on their control than on native populations of lamprey,

[and] we still treat for sea lamprey , and they have to get a pesticide use permit and every time have to defend killing native fish.

Cooperation & Coordination

"Two major themes - one adversarial and the other cooperative in nature - emerge from the long history of the fisheries and boundary relations of the Canadian Maritime Provinces and New England". Despite occasional jurisdictional and boundary problems, Canada and the United States have established a remarkable record of cooperation in fisheries matters. Over the course of many years, the two countries have developed an effective regional practice of joint exploitation and management of shared fishery resources. Indeed, joint arrangements respecting shared resources cover a wider spectrum than fisheries and have been the norm, rather than the exception, for 200 years." (ICJ 1982a, 85)

The above excerpt from the arbitration between the United States and Canada during a dispute over the economically, politically, and culturally important fisheries in the northwest Atlantic illustrates the long-standing cooperation which has occurred for the greater part of two centuries between these two nations. This was the reason that questions of coordination/ cooperation were the most dominant theme (most asked) of the survey comprising at least 20% of the total survey. Yet many of these questions are difficult if not impossible to use, since the question as written was subject to a great deal of potential interpretation. As an example, question 27 asked about if the United States and Canada were working towards common goals in fishery management, whereas question 28 asked if fisheries were managed across state/provincial boundaries at the

local level. The first example is specific to which countries while the second example could be interpreted by respondents as managed within a country's states/provinces rather than the intended meaning of between states and provinces. Further it does not make a distinction of which nations the respondents are being considered.

Broadly speaking, almost half of survey respondents (43%) thought fisheries were managed across international boundaries, coordinated efforts with other states/prov (49%), and thought fishery managers worked together for the common good (59%). Almost two thirds (62%) have worked with peers in other nations and almost three quarters (73%) worked with peers across borders. Regardless of the level or area, survey respondents generally understood the importance of cooperation and coordination and implemented activities with peers across borders. Survey respondents were unsure (33%) if the United States and Canada were working toward common goals in fisheries management though many felt they probably were (45%). This was surprising given the apparent work with peers across borders and the level of cooperation which had been identified as occurring. This could be an issue of uncertainty with the question responses since regional and local (state/provincial) coordination efforts were seen to be the most effective and so the respondents could be unsure of what goals were being discussed and at what level and for what species. Coordination at the federal level was seen as less important by survey respondents and highly variable during interviews, especially in regard to higher level efforts on international issues like treaties and agreements.

Interview informants were split on their overall knowledge of international treaties and regulations. Some were very aware and informed, even able to cite specific treaties and language contained within, however, most were generally aware that there

were treaties, but unable to describe what they were or what affects they directly had on fisheries management. Much of this had to do with the position the informant was in. Those that worked at the federal level tended to be more informed on international issues than those with a more regional or locally focused position. Several federal government officials (both Canadian and American) used the case of the maritime border dispute in the late 1970s following UNCLOS and the adoption of 200 mile (321 km) exclusive economic zones as an example of issues of coordination.

The dispute had started in 1969 when the United States failed to ratify a bilateral agreement known as the 'Agreement on East Coast Fishery Resources'. According to a Canadian official, "The treaty was part of a broad settlement for a permanent agreement on the management and equitable sharing of the Gulf of Maine". The United States failed to ratify the agreement. According to an American official, "It was a vast ocean- main fishing grounds similar in size but no clear sides- all were co-utilized. A clear line in the Gulf of Maine, but stocks significantly moved across the border." Not until 1981 was the maritime boundary in the Gulf of ME decided- and then it was decided in the courts… "Canada and the United States notified to the Court a Special Agreement whereby they referred to a Chamber of the Court the question of the delimitation of the maritime boundary dividing the continental shelf and fisheries zones of the two Parties in the Gulf of Maine area." (ICJ 1982b). Ultimately the court drew a geographically based centerline down the middle of the Gulf. Even during dispute, the Canadian position was that "Cooperation in the conservation and management of fishery resources is the norm for Canada and the United States" (ICJ 1982a). An American fishery manager described the coordination between the United States and the Canada by saying, "Here in the northeast

there is less overlap of border and resources, and more ability to just stay out of each other's way. Stocks are so low that not much fishing has taken place since the crash."

In the Atlantic, the cooperation and coordination between the two nations has been contentious at times, but always cordial. Following the collapse of the Cod industry, both nations agreed to moratoriums on fishing. As time has passed the United States has begun efforts at stock recovery as well as fishing both commercially and recreationally. This is in stark contrast to Canada that still has Atlantic Cod listed as an endangered species[46]. Several informants mentioned this discrepancy in population assessment as a difficulty in co-managing Cod. Regional and local informants were more scattered in their examples of cooperation. Few of the local informants in the Atlantic could point to distinct areas of cooperation beyond general discussions of good will and potential data sharing. Simply put, Cod coordination is confounded by differences in population stability and the migration of stocks making it more difficult to come to consensus on management issues.

Great Lakes informants were aware of their cross-border counterparts, and many had worked directly with them at some time in the past. All Great Lakes informants were further informed about various commissions and partnerships between the United States and Canada regarding the coordination of efforts on fisheries issues. A Canadian biologist described it as, "Many competing parties, multistate and provinces all working directly across the border to some degree." Several American informants described the relationship between Canada and the United States by stating that the "United States

[46] Worthy to note that Atlantic Cod are globally listed as vulnerable (threatened) by the International Union for the Conservation of Nature.

takes the lead in the Great Lakes to some degree by providing data and logistics to Canada." They described that there is a great deal of coordination. "Great Lakes fishery council is very robust and efficient, stock assessments are shared and based on a great deal of data and models."

Some potential explanations for the differences in coordination between the Great Lakes region and the Northeast is the scale, number of parties, and history. Atlantic Cod in the northwest Atlantic Ocean is managed by two provinces (New Brunswick and Nova Scotia) and five states (Maine, Massachusetts, Rhode Island, Connecticut, and New Hampshire). Lake Trout in the Great Lakes are managed by one province (Ontario) and six states (Michigan, Wisconsin, Minnesota, New York, Pennsylvania, and Ohio). Roughly the same number of parties as a whole, but the Lake Trout Management is divided into smaller units (e.g., lakes) and thus there are fewer parties required for consultation and coordination. Better datasets, more certainty on fisheries stocks, and greater data sharing also contributes. Additionally, there is a longer history of cooperative management within the Great Lakes. The United States and Canada have been actively managing and cooperating on Lake Trout in the Great Lakes since the 1950s and the '1954 Convention between Canada and the United States on Great Lakes Fisheries' (ICJ 1982a, UN 1956). Whereas maritime border disputes into the mid-1980s and disagreement on stock assessments and conservation status have hampered Atlantic Cod management.

Sustainability

"There will always be contentious decisions and interest by all parties in getting a bigger piece of the pie." - American diplomat.

Sustainability is an ideal. It is also a mandate, as both the United States and Canada are signatories to UNCLOS. The level of the population at which management tries to maintain sustainability is not always the same value. Wild populations of fish naturally fluctuate from year-to-year. The situation begins with an understanding of what historic populations were and what carrying capacity is. Historic populations refer to a baseline value sometime in the past used to determine if an organism has increased, decreased, or remained stable over a period of time relative to the starting point. Carrying capacity refers to the amount individuals of a given population that can occur within the ecosystem based on current conditions (i.e., prey availability, suitable habitat, and environmental parameters).

When trying to understand what amount can be sustainably fished it is important to recognize the starting value. Pre-colonial times, past century, past decade, or something else can be used, but it is important to recognize that this value may not be what it once was- the baseline may have shifted. Shifting baselines refers to the idea that over time people tend to recognize the amount of a given population is at its maximum or its relative average based on their first exposure to the population.

Historic populations of Atlantic Cod were so great that people fished them off the coast of North America for a millennium without apparent decline in the populations. They were thought to be inexhaustible. Then in the early 1990s the Cod fishery collapsed and there was real concern that the Atlantic Cod may have been fished to extinction. In

the ensuing three decades the population has recovered somewhat, but not nearly to the values prior to the collapse, and nothing compared to the amounts that were caught a century ago. Interview informants[47] were asked how fish population estimates compared to a century ago. As a whole the general view was that it depended on what species was being reviewed. In terms of Atlantic Cod, the clear understanding was that this species is very imperiled from what stocks were 100 years ago. However, numerous informants pointed out that a century is an arbitrary human timeline, and the stocks of Atlantic Cod were almost certainly already heavily impacted from their pre-colonial values as fishing pressure was severe at that time. Informants also pointed out that environmental damages had already started to accumulate, stating "I think you have to go way back, particularly in New England, to find any areas were the bottom and key habitat were not affected by trawling. It's one of those things that is like- what is the actual baseline? At what period in time was there a healthy habitat baseline" and "trawling has just had a very long presence in the region. and if you look where the vessels go they go to the same spots over and over again." A century was not going back far enough to understand a useful baseline of what cod stocks once had been. Knowing what they had been allows one to make targets of what they should be in order to maintain a stable fishery at sustainable levels.

The response to the Atlantic Cod collapse was a moratorium on fishing while biologists tried to assess what had gone wrong and what levels the populations needed to be to return to fishing. The United States has decided on a value for sustainability and a target for recovery. This value approaches the pre-1990 collapse population level. At the

[47] Atlantic coast informants were asked about cod and Great Lakes informants were asked about trout.

current level of fishing, it is affecting the long-term recovery and viability of resources for short-term. Recent assessments from 2020 have identified that the targets have not been met, yet the United States continues to allow fishing of this species. The life history of this fish dictates that only a small amount of fishing pressure is too great to allow the fish to exceed mortality rates and increase in abundance. In Canada, the moratorium remains mostly in effect and the Atlantic Cod is listed as an endangered species. For cod to recover, a baseline population value of significantly before the 1990s must be adopted.

In relation to the Lake Trout, informants felt that the introduction of the invasive Sea Lamprey was such a confounding variable that the question of stocks a century ago was less important to, "what were the stocks of Lake Trout prior to the Sea Lamprey?" A fishery manager surmised that, "All the lakes are lower population wise, hard to really know what they were. We do know in the lower lakes they [Lake Trout] were almost completely extirpated and they have gone through a lot of restoration work over the past 40 years that has been marginally successful." However, it was surmised by several informants that the populations of Lake Trout prior to the Sea Lamprey were already being overfished and that the introduction of the lamprey caused a more concerted conservation effort that likely would not have happened otherwise. Several informants felt that was lost in Lake Trout was not just total abundance, but also a loss of diversity, stating, "What we have lost is some of the diversity, where that be morphological, genetic, that I think was certainly lost through late 40 through the 60s as Sea Lamprey and overfishing occurred" and "Also lost certain behaviors it appears, some of the river run Lake Trout. I don't know how much evidence we have in the US for that, but for sure the Canadian streams did have some Lake Trout strains and probably lost that diversity as

well." Most informants felt that stocks in some lakes (notably L. Superior) had improved to a level that it was probably at carrying capacity (the maximum population the ecosystem can support) and the populations were improving in others. A federal biologist phrased it as "Been major improvements in how we deal with sewage treatment, phosphorus levels. Lake Trout have rebounded to what the new normal is. The population is as healthy as it has been in a long time. Seeing density dependent response (slower growth, slower trajectory of recruitment, leveling off, indicative of carrying capacity. I think it is one of the greatest success stories in the Great Lakes and possibly all freshwater systems."

Beyond the historic population values, we must also review the current values. Sustainability can be achieved at many levels. Populations should be large enough that fishing pressure and natural variability and population fluctuations should not imperil the species. Atlantic Cod are globally listed as a vulnerable (threatened) species. This means that they are in danger of nearing extinction. Canada goes further and lists the stocks in Canadian waters as endangered. The United States, however, does not recognize the opinion of international experts at IUCN and has no legal protections (beyond fishery regulations) for Atlantic Cod. This pertains directly to the politics surrounding fishery regulations and the cultural expectation in the New England to fish for cod.

Most informants thought that if data was presented demonstrating that stocks were in decline they would sound 'the alarm' and it would never be 'ignored'. However, informants were unsure if their action would result in concrete actions being taken, especially in a cross-border context, and depending on who sounded the alarm, stating "Fishermen are going to look at near-term impact, and say it's not as bad as you think",

while “NGOs [will] jump on it and say it’s really bad and we have been telling you.” Informants felt that their own nation would be unlikely to take the first step in making changes to regulations in the face of identified concerns unless they first saw steps being taken across the border. A Canadian fishery manger said, “Take the first step- I’m just not sure… I think we would. Well, I’m not sure we would be the first ones to do it.” Survey respondents had similar views with the responses split nearly 50/50 on if respondents’ own country would stop fishing and split 40/60 (with 40% being agreeing to stop) on if another country would stop fishing. 100% of survey respondents felt that despite this, their decision makers had a responsibility to stop fishing if it was affecting sustainability.

One way to help ensure sustainability is to have some stocks in reserve that are not extracted. In the past few decades this idea has manifested as Marine Protected Areas (MPAs). MPAs not only protect the fishery resources, but they also protect the habitat and allow for significant recovery. Where MPAs have been implemented effectively managers see the areas approach and exceed carrying capacity leading to spillover (excess resources moving outside to MPA to recruit to new areas). Informants phrased it as "Well positioned, well managed, well enforced MPAs have massive benefits. Paper parks not so much. So I think it depends on what sort of MPA you are talking about.” and “There are a lot of opinions on that. If I were to take the US government position it is that we should protect 30% of our waters by 2030 as part of ‘America the beautiful’ and ‘Our Ocean’ conservation pledges. I would argue that if we put 30% into MPAs and they are poorly designed and poorly managed, or in the wrong places they are not going to make a world of difference."

Atlantic informants readily agree that cod is overfished, and the habitat degraded. The idea of MPAs was met with great enthusiasm by most. An American biologist remarked, “Absolutely! We need to have some areas where populations are not under exploitation.” Great Lakes informants felt overfishing was a concern, but habitat was relatively unchanged. Several informants felt that due to the potential that speciation is occurring and given the potential historic extirpation of some varieties the implementation of MPAs was the “Best way we can promote ecotype variation for sure. Maintaining variation in the forms we see by protecting portions of it.” All informants regardless of region or nation saw the immense value in MPAs, most indicating that their establishment was essential to protect spawning grounds and improve recruitment. Survey respondents concurred with three-quarters responding that MPAs have moderate to profound effects on fishery resources.

One of the greatest confounding issues to sustainability is IUU fishing and the requisite need for law enforcement. The extension of exclusive economic zones under UNCLOS was in large part developed as a way of regulating coastal fisheries. Despite this, IUU fishing has continued to be a problem for North America. The area is vast, making enforcement difficult and expensive at best. One potential solution has been the use of the military. Both the Canadian and U.S. Coast Guards regularly undertake fisheries patrols. Interestingly, survey respondents were strongly against this effort.

Interview informants from the Atlantic (predominantly Americans) saw enforcement as a large issue. Many informants felt that ‘locals’ followed the rules, but that poachers from ‘outside’ were to blame for most of the illegal, unregulated, and unreported fishing. Enforcement was seen as necessary to patrol the outer borders of the

EEZ rather than internal oversight of local fishermen. An American federal biologist expressed, “Certainly we need to keep funding and supporting law enforcement because I don’t think we could do it without their role. I guess I think what we have has been working well.”

Informants from the Great Lakes region found that law enforcement efforts were adequate in scope and size. The majority of informants (both Canadians and Americans) felt enforcement was primarily regulated by a strict adherence to the ‘honor system’. Informants felt that fishermen, both commercial and recreational, followed the rules and regulations set before them and were predominantly self-regulating. Occasional ‘news events’ of an enforcement action was believed to reinforce others to self-regulate to avoid consequences. An American federal research biologist remarked, “I would think a lot of the stuff that gets put out is on the honor system and left to the good people to look at the rules and regulations and follow them. Occasionally you hear a story in the news, and I think that really is what keeps most people... from people from not wanting to follow the rules.”

Other difficulties associated with sustainable management are having adequate information from which biologists, managers, and decision makers can make informed decisions. The main data that is used are MSY values and stock assessments, yet these datasets are hard to independently validate and especially hard to understand for non-experts. An American diplomat expressed their perspective on the decisions made from the data they receive, “In some cases they may be pleased with the decisions and sometimes not. It is the nature of our role.” On the other side of the spectrum a fishery biologist remarked that "There is political or social pressures to downplay or not listen to

what science is telling us, biologists need to be more direct or staunch in their knowledge, but there is always uncertainty and maybe that is a part of a biologist understanding of life. We realize there is uncertainty whereas maybe the political social pressures are looking in absolutes. if we don't realize issues around that uncertainty, we need to take a stand and we can get overridden because of uncertainty."

Survey respondents were asked if cod fisheries in the Atlantic and trout fisheries in the Great Lakes were well managed and sustainable. The responses were very clear for cod specifically, with a clear majority stating that they were neither managed effectively or sustainably. The responses were much better for trout management with roughly half of respondents identifying that trout were both managed well and sustainably.

Maximum sustainable yield (MSY) causes a great deal of confusion. This fisheries term, while understood by many interview informants on a theoretical level, did not seem to translate to a practical level. A great deal of confusion and misunderstanding seems to surround sustainable fishing practices and how those are determined and by whom. MSY must start from a baseline assessment of the population and then have realistic values for current stock assessments. Differences in starting baseline, target population levels (future baseline) and the current population values can confound the ability to ensure realistic and sustainable populations. Additionally, with respect to populations that migrate across boundaries, all parties calculating MSY must factor in the values from all stakeholders or risk overinflating the available take.

Interview informants acknowledged overall that stock assessments- the attempt to quantify the current population values and trends for a species, often lacks validation. Informants related that data transparency, clarification of methodology, adoption of new

technological advances, and independent measures distinct from the models are all ways to improve the understanding of current stocks and trends. When asked about the validity of stock assessment values a federal regional biologist responded with laughter, "[laughs] That's a good question… How reliable over time, so how good are the numbers? I'm going to have to pass on that one." Another informant Canadian fishery manager said, "I honestly don't know. I've sat in a few meetings where people give estimates based on their surveys and the data start to contradict each other, how do you what is right and what is not." An American diplomat offered,

> You know my answer has to be they are really well-designed efforts that are designed by experts who have spent years designing these to work perfectly… Maybe rephrasing- where could we make improvements to stock assessments? I think it is transparency in data, it is how it is collected and/or processed so that people understand the strengths and limitations of the datasets and what those stock assessments are based on and also why... a lot of stock assessment scientists only want to use the data if they are perfect because of how much it can affect the confidence, I think there could be better ways to compare how data is collected, analyzed and crosschecked to fill in gaps, so we are not just using the cleanest data but can use more available data. It would allow fishermen who are actually collecting data to go in and use that data with the appropriate caveats and buffering conditions.

Survey respondents and interview informants posited a plethora of factors involved in maintaining stable fisheries. Informants suggested that the following factors are important to the long-term stability in maintaining fisheries resources across international

boundaries; invasive species awareness; native species restoration; preventing overfishing; mitigating Climate Change; habitat protection and restoration; understanding life histories; trust between fishing and management communities; partnerships; community buy-in (i.e., fishermen as 'part of the solution'); climate change mitigation; quality stock assessment data; enforcement of laws, regulations, and treaties; data sharing; political will; and adoption of new technologies. The collaborative emphasis that many of the informants took was surprising in that they discussed gathering inputs from various stakeholders and making informed decisions taken from those consultations. This type of collaboration has been increasing in recent years as federal agencies and many state and provincial agencies require that input be sought from the public. The emphasis on fishermen from diplomats as the eyes and ears of agencies was surprising with informants articulating it as follows:

> Reason is because when fishermen out on the water they are collecting a bunch of info- they know what is going on on the water, but they see it from their own bias and the scientists are looking at it from a different perspective. Managers are making decisions in the middle", "There is really no way to enforce what is going on in the water, so you really need the partnerships with the fishermen who ultimately want a sustainable resource because their long-term viability depends on it and they are often culturally and personally tied", [and] "One of the most important things for sustainability is for fishermen to feel like they are part of the solution.

Fisheries management requires good data. It also depends on an understanding of all potential user groups including commercial, tribal, and recreational. The effects of

commercial versus recreational (sport) fisheries has been a question for many fisheries. Stakeholders often blame one another for decreases in catches both across borders and across user groups. Near consensus with interview informants was achieved in the opinion that the issue was species dependent. Predominantly because of the ecologies and life histories of different species. Some fish, like Atlantic Cod can be caught with a variety of methods and so can be caught by recreational fishermen as well as commercial fishermen. The same is true for Lake Trout. However, this is not the case for all fish because some are only catchable via nets, a gear type generally banned for sport fishing use. The informants were split on which stakeholder group had more impact on the two focal species. Some felt recreational fishermen in aggregate had a greater impact, and others felt commercial fishing had the greater impact. Both user group is correct depending on which species, datasets, and timeframes one is reviewing. For example, historically the commercial fishing of Atlantic Cod had a vastly greater impact than individual sport fishermen, though now the catches of recreational fishermen rivals than of the reduced commercial industry. Recreational fishermen similarly have a greater impact on certain populations of Lake Trout, depending on which Great Lake is being reviewed, sometimes down to the fishery management zone in the lake. A state biologist noted "Wisconsin waters as example- pretty good commercial fishing and they impact more than recreational, but L. Michigan especially in in the southern half, recreational [fishermen] have much more of an impact."

The issue of tribal commercial fishing was brought up as a distinction because of the different rules that fishermen had when commercially fishing. Stakeholders in the United States viewed the effects of tribal commercial fishing (especially in the Great

Lakes) as significant. A state biologist noted "tribal fisheries have agreements through the states so they harvest levels between the states and the tribes, and those can be contentious but in the end they reach a number and stick to it."

The Great Lakes Consent decree affords specific treaty rights of allocation, management, and regulation for fisheries in the Great Lakes, with specific emphasis on Lake Trout and Lake Whitefish. The consent decree was recently revised from the original Treaty of 1836. First in 1985, then in 2000, and then again in 2021 (MUCC 2021). One of the biggest changes was the establishment of an intergovernmental technical committee that ensures the best available science is being used in all management decisions (MDNR 2022). Not everyone agrees that this has been the best approach. One informant, for example, stated, "I don't mean to be snarky about it all, but you know somewhere in the past our forefathers signed tribal agreements and those tribes are really exercising their rights. So, the question is what has more impact recreational or tribal fisheries? I think there is a lot that we don't know how recreational fishermen impact." Canadian informants recognized it as an issue but were not as vocal in their assessment of deleterious effects. This is understandable as Canada had recently revised its federal fishing laws to recognize the place of tribal fisheries and thus the issue was generally settled.

It has been well established that technological innovations were a main driving factor in the collapse of cod. Improvements in gear type (e.g., factory ships, synthetic fiber nets, sonar, 'fish finders') following WWII allowed for significantly greater catches with less effort and in shorter times. Very quickly the fishermen removed significantly more than what was sustainable, and the entire industry collapsed. But some new tools

can be helpful to fisheries management, new technologies to better understand stock sizes, validation methods for stock assessments, ability to learn about life history for greater understanding of a species, and more. A federal fishery manager suggested that "I would say this without making us look too foolish on the research side. I think that there has been over maybe the last 5-10 years development of new tech, ultrasonic tags, acoustic arrays that we can track the fish and sometimes if willing to pay for it in 3 dimensions that is allowing us to learn a lot more about fish movement than we ever had in the past. Before we know where they lived and where they were based on sampling with nets. But now we are able to better track and there is a lot of work left to do."

Several other fishery managers felt that peers in the field were slow to adapt, one noting that "Development of new tools and their testing is so rapid, that my science is changing so rapidly, and I hope for the better, but being able to convey some of these new tools to the managers who may not be involved in the research realm and so getting them to use them and have trust in them is a challenge." Another noted that "new tools for fish managers and have them adopted- it is a real challenge, you'd like to think the new information would be used in regs. There tends to be a hanging on of the old methods and we may have new information about changing how we manage but we are slow to adapt to new information. Fish managers are reticent of new information they really need to be tried and tested. We need a modernization of the field and fish management decision making process based on new data." A federal biologist felt the same was true of fishermen stating that "There has been effort to improve trawl technology to reduce impact over time, but fishermen don't change easily thought there are some really strong innovators. A few key fishermen are trying to understand and

mention that the way they trawl and NOAA trawls for stock assessments are not the same. try to better understand how trawling actually functions in the water column. I know it sounds really bizarre that we are doing this now, and then what impacts it has and how to modify them."

The technology to catch fish has advanced faster than the ability to manage them. This is rapidly changing as fishery managers recognize the need to modernize their methods in order to prevent overharvest and become sustainable. One of the biggest improvements has been in data analysis. Many interview informants explained that there are still a few 'old-timers', and until very recently some provincial and state agencies that had not even gone digital with their data. The ability to collect, analyze, and share data digitally has vastly improved the ability to coordinate efforts and understand what is happening with multiple populations and was expressed by American "I think it has improved quite a bit and I think part of that has to do with technology and our ability to process data. Sharing large quantities of data among agencies has become much easier" and Canadian fishery managers "Everything is electronic now and can be shared has improved pretty substantially."

Another consideration for sustainability in fisheries is the need for a cultural shift in perception about fish. Fish have long been seen as a commodity rather than as a sentient and intelligent animal. As one informant remarked, "difference in perspective in fish management as we have learned more about fish intelligence." There has long been a distinction between 'fish' and wildlife.

This allows for the intensive extraction of these resources. Most fishermen, fishery managers, politicians and the public see fish differently than other animals. We do

not have the same affiliation as we have with warm-blooded mammals. Only recently, scientists have started to understand that fish communication with one another. They make sounds, they use extra sensory systems to perceive and interact with each other and the environment. Fish can learn and have excellent memories. The old belief that Goldfish are quite content in a 1-gallon fishbowl is not correct. An American biologist summed up the situation, "No changes in how fish viewed in my career. Interested, [Fisheries Managers are] driven by not having public outrage." There is no need to change the status quo in fisheries. Without public perception of the sentience of fish, there will be no public outcry. Without a public outcry there will be no political will to makes changes in how we manage this group of organisms. Whales were hunted to near extinction for food and resources until public outcries in the 1960s turned the tide. A similar shift in the cultural understanding and value in fish needs to occur for fisheries to become truly sustainable.

Another interesting observation from a few informants was on the lack of knowledge/understanding of 'life underwater'. The context being that very little is known about seasonal migrations, daily movements, territoriality of fishes that can affect states' ability to manage resources across borders. Without the best available information on the life histories of fish, we will continue to manage these resources similarly. This works if the ecologies of the fish are similar, but utterly breaks down when the fish have different lives. As an American biologist pointed out, "The second we mange on a species by species instead on on an ecosystem basis, there was a big push 10 years ago. There are groups that do ecosystems fisheries analysis, but it is not changing the way we manage. It's more like ecosystem analysis than ecosystem management. So, we continue to

manage species in isolation without taking into account their actions with each other and the environment."

Conclusions

The 62 answers to the survey questions and the 20 findings from the interviews reported in Chapter 4 were consolidated and grouped into eight major themes. These themes were each discussed in turn to explain the current situation in fisheries management issues between the United States and Canada. These data point to certain factors being associated with successes and failures between these two nations and when comparing the outcomes of two distinct fish species which move across the U.S.-Canadian border and that have long been and are still actively sought in commercial, recreational, and tribal fisheries. The conclusions drawn from these data are presented in Chapter 6 (Conclusions) in relation to the three suggested hypotheses that may explain the answer to the research question.

CHAPTER VI – CONCLUSIONS

Introduction

This chapter is the culmination of information gathered and discussed from all previous chapters in the dissertation, incorporating the analysis of outcomes from the data collection and analysis and synthesizes that into answers to the utility of validity of the three hypotheses that were used to address the research question. On the basis of an assessment of the extent of the validity of the hypotheses, the researcher articulates 15 recommendations for action to improve the co-management of fisheries that move across international boundaries. The chapter begins by reviewing and assessing each of the three hypotheses. It then discusses the shortcomings which have been identified through the data collection and analysis. Next, it discusses opportunities for future research. Last, it closes with a series of recommendations based on the data collected from the interviews and surveys on how to make improvements to co-managed fisheries.

Assessment of Extent of Validity of Hypotheses

This dissertation research began with three hypotheses that were posited to help explain the answer to the research question - Why do nation states not have uniform outcomes in fisheries management? In response to this research question, the following three hypotheses were presented and assessed. First, the failure of policymakers and practitioners to take into account the biology (the natural ecology and life histories) of species and treat all fish as the same, results in mismanagement of fishery stocks. Second, these same officials do not take stock of their actions (and those of their constituents)

relative to those of their international neighbors—falling into a classic tragedy of the commons, where all parties seek to maximize their own catches despite dwindling resources. Policymakers' emphasis on their own fishing interests relative to those of competing states results in the diminution of global fishery stocks. Third, the four Cs (Concern—Is there a problem?; Cooperation-Should/Do we work together?; Coordination—Do we work toward common goals?; and Commitment—Is there will to make sacrifices to the greater good?) are addressed at various, and often low, levels within the governmental hierarchy, with biologists and local managers using some or all of them, while senior officials and those at higher levels fail to do so.

The first hypothesis (lack of inclusion of life history information) was supported by the data. The second hypothesis (cross-border information not taken into consideration) was not supported, and the third hypothesis (the four Cs) was partially supported. Each hypothesis and the stated acceptance or rejection will be treated in turn in the remainder of this chapter.

1) Failure of policymakers and practitioners to take into account the biology (the natural ecology and life histories) of species and treat all fish as the same, results in mismanagement of fishery stocks.

This hypothesis was supported by the data. A majority of informants (more than half) from interviews as well as respondents to the surveys (>50%) on questions pertaining to sustainability, life histories, and major issues in fishery management felt that fishery management decisions were not being guided by detailed knowledge of life histories.

Nations party to UNCLOS, which include the United States and Canada, are expected to manage their fisheries stocks sustainably. Sustainable fisheries management requires that biologists and fisheries managers are able to develop accurate counts of current and projections of future population status in order to make realistic stock assessments, and thereby provide realistic values for quotas or other resource extraction targets. In order for these values to be useful, they must be accurate, and they must be consistent.

Accuracy centers on being able to understand at any given time how many fish are in the sea. For a resource that is out of sight, this is an extraordinarily difficult challenge. Not only is the resource hidden from view, but it is also masked by the presence of countless other resources in the area, which are mobile, move daily and seasonally, and are affected by external forces beyond the control of the fishery manager (wild population- birth death, weather, prey availability, disease, climate change, and other anthropogenic factors like IUU fishing).

The way to solve this conundrum was developed decades ago with stock assessments and catch data. Stock assessments are expensive, time-consuming, and fraught with potential variable that can cause errors. Fishing vessels go out and sample fishery stocks and through heavy use of statistical models predict the total number (of fish) available based on the effort and time it took to collect the sample. In addition, they need to account for the type of gear used and the number of fishermen. In order to do so, they conduct test sampling with similar gear and methods as the rest of the fishing fleet and then incorporate the actual catch data from fishermen to try to better understand how the extraction of resources has affected the overall population.

Fish have long been managed as an inexhaustible resource. The stock assessments are based on models that usually do not include most aspects of life history. The management process has been for adults, not recruitment. More pointedly, present assessments are based on the current trends in the adult populations, with little regard to other life stages or the ability to recruit to the population. If there are fewer adults, then there are fewer offspring, and fewer offspring means that proportionally fewer will ever grow to reach adulthood (i.e., lack of recruitment). By managing only for adults, governmental and non-governmental institutions associated with the fishing industry overestimate future stock potential and slowly diminish the stocks' ability to replenish itself. This has been especially true with cod, which rely on vast egg production efforts in order to swamp predators and ensure enough offspring survive. In essence, most fishery management efforts historically assumed nearly unlimited resources and thus focused on MSY (maximum take) and not stock recovery. The very fact that Atlantic Cod are listed as globally threatened but still fished by the United States belies this fact. These fish can't recover that is partially why they are still not 'recovered', and the targets have not been met and also further evidence that stock assessments may not reflect reality. The issue is less of a concern in the Lake Trout fishery since there are considerably fewer potential predators for this species- reflected in the relative paucity of their spawning efforts (i.e., a few thousand versus a few million).

The databases built on these assessments expand over time. Fishery managers in some jurisdictions have recognized the need to incorporate additional life history data into the modeling for population status. However, data must first be available in order to be incorporated and secondly this only increases the costs. For these reasons, stock

assessments are conducted infrequently and only on the most valuable species. There are no stock assessments being conducted on non-game fishes (typically the prey bases for the targeted fisheries). And the stock assessment models historically (and currently) do not account for many of the life history of the target fish, much less the life history of the non-game prey species. By managing fisheries for a (single) target species rather than an ecosystem approach we are intentionally ignoring crucial data to inform decision making to improve sustainability for the future.

Biologists know fish need different management, many current regulations reflect this (e.g., difference in catch size and daily bag limits), but little emphasis is placed on life history differences in the modeling (sustainability) efforts. The migration of cod from one location to another is a significant driver of this species effective management, especially across management (or international) boundaries. The potential of adaptive radiation[48] occurring in trout is the greatest concern for effective long-term management. Lake Trout morphotypes need to be managed separately from one another until such time as academic consensus can be reached as to their taxonomic status. Without such action, one risks potentially fishing subspecies to extinction (if it has not already occurred).

In addition to the life histories, fishery managers need to also consider a broader spectrum of abiotic factors in developing new stock assessments. Societal, environmental, and technological changes must be considered. Ignoring technological change has been identified as the primary cause of the cod fishery collapse. With habitat change and Climate Change, one must also consider where and when to undertake stock

[48] Adaptive radiation is an ecology/evolutionary biology term that explains the process where an ancestral species diversifies into a plethora of new forms particularly in the face of a changing environments, resource availability, or habitat niches. African cichlids in the rift lakes are a classic example.

assessments. Scientists are loath to discard long-term data collection sites. However, with fishing effort, gear change, habitat change, and alterations to the environment from Climate Change and invasive species it may no longer be relevant to continue to assume historically used stock assessment locations are representative today.

A great deal of emphasis is placed on tonnage of fish caught (catch data) from year to year, assuming that those values remain relatively stable. When life histories are not fully considered, this can lead to consistency issues. Consistent fishery data is reproducible and transferrable from year to year. It provides the reason fish managers are reticent to do assessments in new places or use new technology, because then the values are not equal and year to year assessments cannot be made. This exposes a fundamental flaw in the stock modeling process. It bears repeating that interview informants were very clear on this point stating that, "We have not adapted our management processes or our science. Surveys still take place in the same places over and over" and "It is a real challenge; you'd like to think the new information would be used in regs [regulations]. There tends to be a hanging on of the old methods and we may have new information about changing how we manage, but we are slow to adapt to new information. Fish managers are reticent of new information they really need to be tried and tested. We need a modernization of the field and fish management decision making process based on new data."

Continuing to measure fisheries extractions by gross tonnage allows the correlation to older catch data. This allows for a comparison of historical and current catches. This methodology is inconsistent with sustainable fishery management because

it consistently only accounts for a single age class, adults[49]. Because the stock assessments are based on commercial fishery techniques and data, they use a specific gear type, nets, to account for the fish taken. Nets are regulated and calibrated for fishing based on mesh size. The smaller the mesh size, the smaller the fish which can be captured. Mesh sizes catch a certain minimum size fish and theoretically allow smaller fish to escape. Managing for mesh size removes the largest and most fecund adults further affecting population recovery and encouraging smaller fish in future generations by artificially being selected for reproductive readiness at an earlier age and thus smaller size.

The failure to incorporate all aspects of ecology (especially life histories) has led to discrepancies in how fisheries are managed. For some species (cod), this has been catastrophic and while for others (trout) it has had much less significant effects. Just as important has been the failure to ensure a full understanding of the stocks and the life histories of non-game fish, leading to mismanagement of fishery resources, decreases in native fishes at the expense of targeted fisheries, dramatic alterations of the food web, and potentially the extirpation of some fish.

2) Second, these same officials do not take stock of their actions (and those of their constituents) relative to those of their international neighbors—falling into a classic tragedy of the commons, where all parties seek to maximize their own catches despite dwindling resources. Policymakers' emphasis on their own fishing interests relative to those of competing states results in the diminution of global fishery stocks.

[49] Depending on the mesh size and minimum size requirements, fisheries may take other age classes including sub-adults and juveniles. Typically, fish mature as they grow in size and fisheries typically set mesh size to catch a minimum size, which is usually a known adult size.

This hypothesis was not supported by the data. It was assumed that differences in fishery management outcomes for the target species were predominantly caused by a lack of awareness or concern by decision makers and leadership about how fisheries were managed on either side of the international border. This was shown to not be the case according to the data taken from the majority (>50%) of informant interviews and the majority (>50%) of survey question responses regarding cooperation, stakeholder engagement, and decision making. According to the data, stakeholders involved in the co-management of species that move across the international border are well informed and aware of what actions are occurring across the border. The various regional fishery councils, commissions, working groups, and others coordinate and reflect on their actions at the local (state/provincial) and regional level.

At the federal level, informants were divided in their perceptions of how well their respective governments incorporated both the information from their own experts and those of experts from other areas. Some felt that the role of the federal government was to provide information to local stakeholders, while other felt it was the responsibility of the federal government to provide direction and leadership in crafting policy and regulation at the national level. There can also be a lack of political will to create public anger due to changes in fisheries management and so the status quo (historical ways of doing things) prevails.

There were differences in how the Canadian government and the United States government responded to data on the cod and trout fisheries. The Canadian government was relatively stable in its approach to both species, taking into account the best available scientists from Canada, the United States, and internationally. This is reflected in the

differences in protected status of Atlantic Cod. In Canada, the view of the federal government is that Cod stocks are too low to fish, and they are afforded federal protected species status. This is not the case with the U.S. government. If the United States placed cod on the list of federally protected species, it would cause the cessation of fishing for this iconic species that Washington still currently allows. This would cause political tensions and outcry from the local fishermen. It would also make the recovery plans more effective and help to not only meet recovery targets but potentially move towards increasing the baselines. United States officials have decided that they do not want to entirely stop since they still can fish. With the Lake Trout the Canadian and United States U.S. find more overlap in their management. This has more to with personal relationships and regional centers in Great Lakes and their long history of cooperation in a relatively small area. Everyone seen as playing for the same team. Data are freely shared, and all levels of stakeholder find consensus in management actions. They are all working toward achieving shared common goals and thus it is easier to get collective action.

Neither fishery falls into a ‘tragedy of the commons’ issue per se, since not all parties seek to maximize their own catches despite dwindling resources. In the Atlantic Cod fishery, there are differences in effort in the extraction of these shared resources with significantly more pressure applied by the United States. However, there is also disagreement over how much the resources are shared setting up an argument that they are not a common resource. It has been the position of the United States (though not all biologists and fishery managers) that the fishes that are extracted in their EEZ do not migrate into Canadian waters. This is likely truer today than in centuries past, as the

stocks are considerably smaller and the habitat lost in places, but unlikely true based on recent surveys and studies. However, it is the position of the Canadian government that these stocks do in fact migrate. In the Great Lakes Lake trout fishery, the fishes are co-managed in an almost idealized scenario. Data are shared, quotas co-developed, and efforts made to keep resource use to sustainable levels. Though biologists on both sides of the border agree that these stocks are overfished (i.e., dwindling resources), each country is seeking to fish to their maximum extent, and many of the fish move freely across the border, there is so much cooperation between the two nations that they are not competing for these shared resources, but rather equitably distribute them among all parties.

3) The Four Cs of sustainable fisheries management are incorporated.

Concern—Is there a problem?

Cooperation -- Should/Do we work together?

Coordination—Do we work toward common goals?

Commitment—Is there will to make sacrifices to the greater good?

This hypothesis was partially substantiated. The conception of the four Cs is a framework for fishery management that was developed by the researcher to understand how the outcomes from one species or country might prove to be different than others. Using the majority (>50%) of informant comments and survey question responses (>50%) on issues pertaining to the 4 Cs, it was determined that commitment was lacking, and thus the hypothesis could only be partially accepted. Specifically, informants and survey respondents articulated (>50% agreement) that their respective governments

would be unwilling to take first steps towards reductions in fishing pressure and thus demonstrated a lack of willingness to make sacrifices.

As hypothesized, the four Cs (concern, cooperation, coordination, and commitment) are partially implemented within the context of fisheries management between the United States and Canada. They are addressed at various levels within the governmental hierarchy (and across stakeholder groups), with biologists and local managers using some or all of them, while senior officials and those at higher levels failing to implement the final factor, commitment. Concern is present to varying degrees, cooperation, and coordination are evident, but it is commitment that tends to be the limiting factor. The major issues identified in the literature, surveys, and interviews included invasive species, climate change, the restoration of native species, water diversions, species management, transboundary coordination efforts, environmental stressors, allocation of resources, lack of data, recruitment, overfishing, and technological advancements rely to a greater or lesser degree on one or more of the four Cs.

The first C, concern, asks if stakeholders recognize there is a problem which needs to be addressed. Both the United States and Canada recognize to varying degrees that there is need for concern in the fisheries surrounding Lake Trout and Atlantic Cod. Evidence of these concerns can be found in legal protections for species, moratoriums on fishing (for various times and extents), management actions for invasive species, and amendments to fishing regulations and laws.

Concern for Atlantic Cod was abrupt and severe. The total collapse of the fishery in the 1990s caused a temporary stoppage in industrial commercial fishing efforts in both Canada and the United States. However, the United States does not recognize the same

level of impairment (i.e., concern) as Canada or the international community. Overfishing is recognized, but efforts at extraction continue. Concern is thus present historically and currently, but the levels of concern are not equal. Concern nevertheless exists between both countries and measures are taken by both nations to protect fishery resources.

Concern for Lake Trout has waned recently as previous management actions undertaken cooperatively between the United States and Canada have been mostly successful. Trout were likely overfished historically (1940s and 1950s), though it was the accidental introduction of Sea Lamprey that likely kickstarted conservation measures that otherwise would not have been implemented until decades later. The near total collapse of the Great Lakes trout fishery forced the United States and Canada to work to find a solution to the Sea Lamprey invasion, and in doing so reorganized how the commercial fishing industry extracted Lake Trout. Trout reproduce slowly (only a few thousand eggs) and so the removal of adults in a short time period has a magnified effect as new recruits are slow to replace. Recently, biologists have begun to raise concern that Lake Trout are overfished and recognize that without constant Sea Lamprey control measures the Lake Trout population would again collapse. Concern is shared by both nations for the continued management of this species.

The second C, cooperation, asks if stakeholders work together. There is a great deal of cooperation in fisheries management between the two nations. Even during international court disputes (following the expansion of the EEZs) both recognized their centuries history of working together. At the local and regional levels fishermen, biologists, and fishery managers regularly work together to set management goals. This is especially evident in the Great Lakes through participation in public meetings, the Great

Lakes fishery commission, binational forums, and interagency working groups. Most informants were at least aware of their counterparts, even if they had no direct involvement, they were aware of others that did as well as programs and efforts. In the Atlantic, there was less obvious cooperation, primarily due to differences in national status of cod, but efforts were undertaken between both countries to remain committed to recovery efforts, and information and data was freely shared (though the results and the interpretation of those results were not always agreed upon). In the Great Lakes region there is a great deal of cooperation between Canada and the United States. In many areas the U.S. federal government takes the lead on data collection and freely shares these data. As a result, Trout are managed very cooperatively, and cod are managed semi-cooperatively.

The third C, coordination, asks if stakeholders work toward common goals. Through actions taken in binational forums, working groups, state/provincial coordination, regional fisheries councils, and implementation of treaties, the governments of the United States and Canada can be understood to be working toward common goals and coordinated actions. A key area for coordination is in maintaining regulations and requirements of the commercial fishing industries that are similar, if not identical, to one another. This is done very assuredly within the trout fishing industry, while the cod fishermen have different requirements based on different population status assessments and perceived risks to the species. While the fishermen do not cross the border, the fish do, and this can lead to management problems and perceptual concerns across the border. Coordination at the local or regional level seems to be the as most effective and that

follows with the impression from informants that federal oversight and administration is less useful and harder to organize because of the many layers of politics involved.

Coordination in the Atlantic region occurs more at the federal level to agree upon broad issues involving fishing quotas and opportunities. Stakeholder tensions (from certain user groups) on either side of the border can be high and stakeholder (fishermen) engagement occurs to varying degrees on fear for loss of resources, economic concerns, and sustainability. Canadian fishermen feel that overfishing persists in the American industry, and American fishermen think the level of concern for population status is too conservative. The different opinions on population status presents friction points due to a desire by all parties to improve the fishing opportunities, but not on how that is being done. There is a common goal, but not much collaboration to jointly arrive at those goals.

Coordination in the Great Lakes region happens at all levels of stakeholder engagement. Data on population status are cooperatively analyzed and the outcomes and results agreed upon. Further evidence of the robustness of these coordinated efforts is the additional inclusion of Tribal nations. This could be an area of tension and be a significant challenge, but it is seen as an opportunity to work together toward common goals. With everyone working together on the same data there are no surprises, and all voices of stakeholders are incorporated into the decision-making process. Frequent public engagement meetings allow for all voices to be heard from the fishermen through the fishery managers to tribal leaders and diplomats.

Coordinated efforts between the governments of the United States and Canada happen very frequently and effectively in the Great Lakes and the Lake Trout fishing industry. The efforts at Atlantic Cod management in the Atlantic region are less

coordinated. Similarities in management methodologies, regulations, laws, and cultural expectations of fishermen all contribute to coordination and the attainment of common goals.

The last C, commitment, asks if stakeholders make, or are willing to make, sacrifices for the greater good. More pointedly, would a nation limit its fishing industry extractions in an effort to improve the overall conditions and populations of the targeted fish. Willingness to make sacrifices is lacking in both nations. It is especially true in the United States according to surveys, interviews, history, and endangered species act listings. However, in the Great Lakes region parties were forced to make sacrifices in fisheries extractions with the Sea Lamprey introduction and thus compelled to work together for decades. The simpler life history of Lake Trout and a firm commitment to restore the fishery came from local and regional support on both sides of the border.

Nowhere is it more apparent that the United States commitment is restricted than in the northwest Atlantic, where it has reopened the fishery for cod, despite being well below the historic baseline and the fish being considered globally threatened with extinction by international conservation agencies. American biologists have developed a plan to open the fishery while simultaneously recovering the stocks. Fishing was opened (to a much lesser degree) and recovery plans were developed. This was a very different action than the commitment shown by the Canadians, who still have the fishery essentially closed. The cod industry on both sides of the border never worked well together; rather, they were quite adversarial (recall the expansion of the EEZs). The cod fishery worked and was ‘co-managed’ by passive default. The fishery remained intact not because of sound policy and oversight; it remained intact due to the overwhelming

productivity of this coastal fishery. Until, after centuries of harvest (and decades of overharvest), the fishery was fished to collapse. Moratoriums were initiated, and after decades the stocks started to recover (slightly). To this day, the United States does not fully recognize the problem (or consider it a priority) at the political/national level. At the local and regional level, the problem is understood, and fishery managers and fishermen work with what they have, to protect what is left. Recovery plans are in place, but it takes more than a plan to recover stocks. It takes political will to be unpopular and say no fishing for years, sometimes decades. When the fishery is available to reopen, then fishing pressure will never be able to be what it was. Fishermen will have to take a sustainable amount, or you fish yourselves back into the same predicament.

Commitment in the Great Lakes trout industry was forced upon both parties. The threat was external. It was the accidental introduction of an invasive species. It was a threat perceived as caused by neither party[50], and so all the four Cs were easy to implement. Both nations rallied around a common enemy and were willing to make sacrifices and to work together for decades.

Part of the differences between the differences in the two fisheries today is the amount of time spent on the problem. Cod have been fished heavily (at times to the maximum extent available) for centuries, and so it is a relatively new idea that they need to be sustainably managed. After centuries of limitless extraction, it has only been 25-30 years since attempts were made to bring sustainability to cod fisheries. Add to this that they started with a damaged and degraded habitat

[50] The introduction of the Sea Lamprey was, in fact, entirely the fault of the United States. The creation of the Welland Canal which bypassed Niagara Falls allowed the introduction.

and with a commercially extinct population stock. Trout have been less intensively fished (compared to cod) historically, and the problems came at a time before the people collapsed the fishery (though they likely would have). The accidental introduction of Sea Lamprey likely kickstarted conservation measures that otherwise would not have been implemented until decades later. Now, 75 years after the Sea Lamprey induced collapse trout are the picture of effective management between two nations.

Several successful treaties, including incorporation of Tribal fisheries and law changes to accommodate tribal fishermen's treaty rights and still the fish are managed well. Each nation gets its set allocation of the resource total. They use the same numbers (for the stock assessments) and have the same listing and understanding of the resource trends. While the fishery is divided into management zones, all parties view the fish as one connected population. Data is collected and analyzed, and biologists and fishery managers feel that the best available science is being used to develop quotas for each management zone. Most still feel that trout are overfished, and thus there may be a time in the future where hard decisions will need to be made. However, according to the surveys and interviews most respondents felt their nation would only reduce total fishing pressure if the other nation did first. There was a sense that neither nation would be willing to make the first moves to walk away. This is likely to become a large issue as more data comes in from molecular studies on the

variation of trout. If these are formally taxonomically defined, that will cause a significant shift in the fishery resources, abundance, and spatial distribution. That could reflect a situation like the 1980s with the cod stocks and nations changing tactics and opinions despite centuries of co-management if resources are found to be scarce.

Another area which will take commitment from both parties if fisheries management is to be sustainable is the implementation of Climate Change mitigations. As we have seen with the trout industry, having a long history of working cooperatively towards common goals creates a positive feedback loop whereby future coordination is easier. In the face of climate change, we need to start this process now. So that as the impacts are felt in future decades a framework is already long established on how to respond to stressors.

Climate Change has been identified as one of the top drivers along with habitat loss and invasive species. These top three issues are all interconnected. By working on one we invariably also make advances in another. Spatial distribution of the Cod populations are shifting as habitat is altered as a result of the effects of Climate Change (Engelhard et al 2013; Rogers et al 2019). The movements of these resources across borders are likely to have pronounced effects on the access to this resource and potentially be the source of conflict impacting food security, culture, and livelihoods of coastal communities (Koehn et al 2022). This is true not just for cod, Brander (2007) pointed out more than a

decade ago that Climate Change is going to affect the distribution and production of fisheries available for humans to exploit. With increasing human populations, the increased need for fisheries also expands. Due to the numerous effects of Climate Change, those resources may not be available, either due to direct decreases in populations or through migrations due to habitat loss or necessary environmental conditions.

The United States and Canada have not had uniform outcomes in fisheries management despite a long history of co-management of fishery resources. There is concern for maintaining these resources and cooperating and collaborating to ensure success. Unfortunately, a lack of commitment has led to known overfishing problems and partially explains why individuals and the states and institutions they lead continue to have the inability or lack the political will to alter their behaviors. Furthermore, the continued use of outdated methodologies and techniques limits the usefulness of stock assessments, which notably lack sufficient information on the life histories of target and non-target species to be able to maintain fisheries at sustainable levels. Fortunately, jurisdictions have started to take considerable note of management actions unlike any time in the past. With an understanding of life histories, coordination of data collection and analysis, and a commitment of political will to place fishery recover ahead of short-term gains the stocks of both Lake Trout and Atlantic Cod in the United States and Canada can be made sustainable.

Shortcomings and Opportunities for Future Research

Several areas in the research have been identified as having potentially caused confusion (to respondents) or shortcomings in the research. These potential shortcomings were identified in both the on-line survey instrument and in the interviews. One such concern was the overall low response rate for the surveys. The response rate was low for the survey, both in terms of absolute numbers of survey takers relative to the potential pool of respondents, and in terms of the number of respondents who choose to take the survey but failed to answer all the questions.

The totality of the respondent pool is unknown and there is an unknown number of people who engage in actions related to the topic. Many who were sent the survey may not have had any knowledge of the topic but clicked through out of curiosity. For example, members of the Canadian Fishery society may have no knowledge of the focal species and thus opted to not take the survey. Others may have had some expose (e.g., were fisheries managers) but then discovered the topic was more nuanced and specific than they felt knowledgeable to answer.

Despite having been reviewed by multiple people beyond the researcher, and having been beta tested, numerous problems were identified in the on-line survey instrument when data had been collected and analysis had begun. The most significant problem was that nowhere in the survey did the instrument ask respondents to identify their nationality. Surveys were intentionally sent targeting user groups in both the United States and in Canada. However, the completed surveys could not be segregated by nationality, severely limiting the comparative capacity of certain questions. An example can be found with Question 44, which asked, “Do you think senior officials base the final

polices, regulations, and laws on sound science?" Were respondents reflecting on all senior officials from any country? Senior officials from one country or another? Was the respondent Canadian and offering an opinion of American senior officials, or Canadian and answering in regard to Canadian senior officials?

Several questions were found to be poorly worded. It was concluded in the data analysis that some questions could have been interpreted in multiple ways by respondents, and thus the responses recorded in the data could also potentially be interpreted in multiple ways beyond the intent of the question. For example, Question 9 asked, "As a whole, do you think United States/Canadian fisheries are overfished?" This yes or no question could be answered based on the idea that it is asking about both Canadian and American fisheries, or one or the other. They could be answering based on their own country- but what country is that? They could be answering meaning one country or the other. The answers are ambiguous because there is no way to understand the way that they interpreted the question and thus the meaning in their response. Another example, Question 29 asked, "Are fisheries managed across international boundaries?" The question for respondents is what fisheries are being asked about? All fisheries, targeted fisheries? Or across what boundaries? American versus Canadian fisheries, British versus Spanish fisheries, or any of a multitude of other potential interpretations could be used to develop an answer with no way of knowing how it was interpreted.

Several questions overlapped to such an extent as to be redundant. This was evidenced by the point that several respondents pointed this fact out in the final open-ended question asking for 'other comments'. An example of this can be seen in similarity of Question 34, which asked, "Do you work with peers across state/province or national

borders?" versus Question 42, which also asked, "Have you worked with your peers in other nations?"

There was not enough distinction made between recreational versus commercial fishing implications on certain questions. This resulted in several responses in which it was unclear which stakeholder group was the intended user group or which fish stock they were envisioning the response being attributed towards in the respondent's selection of answer. Additionally, there was no way of determining if the respondents were answering relative to commercial fisheries or tribal fisheries[51]. An example is Question 20 which asked, "Which mode of fishing has a greater impact on fish stocks, commercial or recreational?"

In connection with the interviews there was not an opportunity to seek out numerous representatives of all stakeholder groups. Issues with scheduling and available time limited the options of how many of each group was represented in the data. Obviously, an individual does not necessarily reflect the overall opinion of an entire user group. Caution is needed in extrapolating the response of individuals as representative of their nation or their stakeholder group. In addition, many interview informants self-identified as belonging to multiple stakeholder categories blurring the distinction between stakeholder groups.

There are two disparate suggestions for future research potentially addressing this topic. The first is logistically based and the second theoretical. Logistically there are ways similar research could be improved. Based on issues identified above and the results

[51] Tribal fisheries can to some degree be lumped in with all other commercial fishing. However, it is better to think of them as a subset of commercial fisheries because in most jurisdictions they operate with their own set of rules, regulations and policies that differ from other commercial fishermen.

found in chapter 4, adding more demographic questions to discern differences in respondents and informants would be helpful. Adding questions pertaining to the now identified themes, as well as the respondents' opinions of potential causative factors could be added in future research. Targeting a broader spectrum of respondents with both surveys and interviews to include stakeholder groups that were underrepresented in the data such as diplomats and fishermen.

Theoretically, there are other connected areas of research that may yield additional explanatory power to this research question as well as lead to interesting answers to other identified questions discovered through this research. One of the major areas where future research would be helpful in extending this same project to the west coast of North America, in an effort to validate the conclusions regarding how the United States and Canada interact on co-management of natural resources. Focusing on the disparate effects of the Canadian moratorium extensions on Atlantic cod populations versus the renewed fishing efforts of Americans may demonstrate greater explanations of why the Atlantic Cod populations have continued to fail to reach target recovery goals. That could help to broaden the applicability of the findings. The potential for speciation in Lake Trout is a pressing and time-sensitive areas of future inquiry. It is plausible, and indeed likely, that the continued management of Lake Trout as a single monophyletic taxon is diminishing the viability of the disparate morphotypes and potentially driving new species towards extinction. Further it could explain the continued absence of Lake Trout from microhabitats that previously were productive fishing grounds. The effects of non-game management on the overall management of target species and the impacts of the available prey base and available habitat impacts would also be of interest. Finally,

greater scrutiny of recreational fishery impacts including seeking data on creel surveys and reviewing data on the effects of catch-and-release recreational fisheries survival rates and how that compares to the effects of bycatch on commercial fisheries.

There were several surprising issues identified by respondents, informants, and discovered through data analysis. The first was that fisheries managers felt that economics was of only minor concern to the management of fisheries, despite the huge body of relevant literature making the opposite argument. They understood that economics certainly affects fisheries, but that at the local and regional levels, economics was a factor for some fishermen, but not to the overall management of the resources. Another interesting finding was that the majority of data suggests that fish are still viewed by many as more of a commodity than a sentient animal. Public opinion surrounding commercial fisheries and their effects on dolphin[52] (*Tursiops* spp., *Stenella* spp., etc.) populations caused a public outcry and resulted in fishing practices to "save the dolphins", dolphins being considered by most as a highly intelligent and sentient creature. Yet most fish are poorly understood by the public and are lumped together as a common resource. It is only recently that biologists are asserting that many fish communicate (much like dolphins and whales), have emotions, excellent memories, and other "higher" level intelligence. These surprising issues illustrate that there are many more research opportunities for future work in this field.

[52] Concern was over dolphins (the marine mammals- not the fish of the same name) being caught in commercial tuna fishing nets.

Policy Recommendations

There are a number of potential actions Canada, and the United States can take to improve the outcomes for species management in fisheries that are co-managed or otherwise cross borders. The following are recommendations for 15 actions that can be taken to improve transboundary fishery management.

First, one of the simplest such actions to adopt is the use of best practices across all regions and jurisdictions. Many informants identified a need to introduce better and updated science into fisheries management. Ensuring that Canada and the United States are using best practices and adopt policies, regulations, procedures, and methodologies as needed will require the adoption of the best available science.

Second, and directly related, is investment in new technologies. Many jurisdictions are still using antiquated techniques, and several have only recently begun digitizing their data. Investing in tests of new methodologies will be especially helpful in improved data collection and methods to validate stock assessments.

Third, improve data collection methodologies and using the best available science is much more valuable if decision makers are sure to heed the advice and warnings of biologists and fishery managers at the state/provincial level. These professionals are the subject matter experts, and their opinions can be used to curtail the next potential fishery collapse. Such experts not only collect and understand the implications of those date, they also actively cooperate and collaborate with their peers and colleagues. The inferences that these experts can thus make from the raw and analyzed data should be given significant weight and often become the basis for the majority of decisions.

Fourth, additional to these recommendations is the adoption of policies that remove political interference from biological advice. The most forward way to ensure this is through passage of specific laws and the installation of scientific integrity policies. Agencies in both the United States and Canada that have adopted scientific integrity policies are less likely to have issues with political interference, as there are clear rules and procedures which must be followed, including the use of best practices and the best available science.

Fifth, all collected data should be shared across all jurisdictions and, sixth, be made available to the public. Raw data that is made available can be utilized by many more researchers, allowing for significantly more data analysis and hypothesis testing than agencies or individuals could do alone. These additional collaborators could potentially save money and resources as well as providing additional insights and perspectives on the status of natural resources including causes and implications.

Seventh, stakeholders should be engaged at all levels. Raw data is not useable data for all stakeholders. Eighth, in addition to the raw data, analyzed data and finished products should be made available to all stakeholders as well as having a summarized version of the data analysis/finished products available in plain language. By making data, analysis, and products available to all stakeholders (at all levels) more support, understanding, and engagement can be expected. An informed public can be a supportive public, but also help to maintain accountability and sustainability.

Ninth, coordination of fisheries management should begin at the national level by using local and regional knowledge and expertise. At the federal level, there is an opportunity to collate data from across regions and allows for a look at the ‘big picture’.

Trends can be seen that may otherwise be undetectable. Analysis of data from all jurisdictions can be used to determine areas of success and failure. This is, of course, predicated on the previously recommended sharing of data from local and regional jurisdictions and utilizing local expertise to understand the implications of the data at finer scales.

Tenth, formalized thresholds should be set for required actions. When/if data analysis shows that there are declines in fisheries stocks for unknown (or known) reasons, there should be plans and procedures in place for reductions in fishing quotas and pressure. These criteria should span across jurisdictions for legal protections, mandated targets, and closures. This recommendation also requires that data has been shared across jurisdictions, there is a federal review at a large scale to understand trends, and the advice of biologists is heard.

Eleventh, fishery stocks have fluctuated dramatically in the past several centuries from both natural and anthropogenic causes. An effort should be made to establish a target baseline for fishery stocks that is required. It is unlikely that stock baselines will ever return to those from centuries past. However, baselines must still be established and maintained over time based on the expected/desired extraction needs as well as ecological functioning of the ecosystem. Governments must ensure that commercial, recreational, and tribal fisheries are all included in the determination of baseline needs so that stocks can be sustainably managed. The recommendation that threshold actions be set would be required.

Twelfth, investments should be made into research. Lack of information on life histories, Climate Change effects and mitigations, species diel patterns, migratory

behavior, and habitat use have led to ill-conceived and poorly executed active management actions. These should be priorities. Specific attention should also be paid to non-game prey species and non-adult life stages. Additionally, research efforts should focus on molecular genetics of Lake Trout morphotypes to determine taxonomic status and trends before potentially irreversible loses occur.

Thirteenth, significant efforts should be implemented to prevent invasive species. It is much more effective and economical to prevent the introduction of a species, rather than respond to established populations of invasives. Invasive species cause significant negative consequences on native species and can undermine previously taken and future actions to restore native species and habitats. Removal is costly, and often impossible once a species becomes self-sustaining. Early detection and prevention have repeatedly been demonstrated to be considerably more effective (and less expensive) than post introduction response.

Fourteenth, habitat restoration should be made a priority. Without quality habitat any other management actions are destined to be ineffective at best and more likely wholly unsuccessful. Landscape level ecosystem management allows for the systems to be largely self-managing (i.e., passive management). When natural processes are available for species, management is both more effective and less costly. This is predicated on having large intact (and functioning) ecosystems. Habitat restoration (active management) is costly initially, but cheaper in the long-term if conditions can be improved to the point where management can become passive as the ecosystem begins to function. As ecosystem functionality returns, resources can be diverted to be used in other places.

Fifteenth, global Climate Change will continue to have widespread and deleterious effects. Exhaustive efforts should be made to implement actions to limit Climate Change. Slowing the rate of change is the first step towards the continuation of our use of this planet. It is well documented that weather conditions are becoming more severe. We must take action to slow the rate of climate change by implementing mitigation strategies and focusing on the use of green energies and reduce the influx of greenhouse gas emissions. Only then can we start to make attempts to undo some of the anthropogenic effects. Habitat restoration efforts and landscape level management of ecosystems are ways in which fisheries management can help to alleviate stressors on our planet.

APPENDIX A – On-line Survey Instrument

SURVEY INSTRUMENT QUESTIONS

Fisheries Management requires thoughtful consideration of resources that tend to be out of sight, widely distributed, highly variable both spatially and temporally, and present dramatic variation in life history and ecology. Through this research, I hope to discover ways in which fisheries management could be improved across transnational boundaries. This anonymous survey is expected to take approximately 15 minutes to complete. There are no direct benefits or risks to participants, however, the research findings will be applicable and useful in general to the field of study. This survey collects demographic information (which can be skipped, if desired) and is otherwise completely anonymous. This survey is being undertaken in order to gather research data towards the completion of a PhD at the University of Southern Mississippi (USM). Participation in this study is completely voluntary, and participants may withdraw from this study at any time without penalty, prejudice, or loss of benefits. For additional information please contact the Institutional Review Board (IRB Protocol Number 22-749) at USM at 601-266-5997, or the Investigator, Paul Brown at 906-275-8415 or w923176@usm.edu

Do you wish to continue?
- Yes
- No

What is your level/role?
- Biological technician
- Biologist/Scientist/Academic
- Local manager/Supervisory biologist
- Program Manager/ Regional biologist
- Policy maker
- Elected official
- Senior policy maker
- Other

How long have you worked in fisheries (in any capacity)?
- 0-1 years
- 1-5 years
- 5-10 years
- 11-15 years
- 16-20 years
- Over 20 years

Select the top three issues in overall importance to fisheries management.
- Climate change
- Overfishing
- Illegal/Unregulated fishing
- Habitat loss
- Life history
- Ocean acidification
- Migration/ seasonal movements
- Artificial stocking
- Invasive species
- Recreational fishing
- Commercial fishing
- Law enforcement
- Changes in food web/loss of species diversity
- Employment and local economic development through fishing

History and practice
Political support for the fishing industry
Economics
Livelihoods of fishermen

Are the life histories of species a factor in fisheries management?
Yes
No
Unsure

Do the maximum sustainable yield (MSY) calculations include the fishing effort from other nations?
Yes they do
No, but they should
No
Unsure

Do life history differences factor into regulations?
Yes
No
Unsure

How much do stock assessments affect policy/regulatory decisions?
No effect
Effects are minor
Effects are moderate
Effects are severe
Unknown

As a whole, do you think United States/Canadian fisheries are overfished?
Yes
No

As a whole, do you think United States/ Canadian fisheries are well managed?
Yes, both Canadian and American managed well
Yes, Canadian managed well
Yes, American managed well
No, neither is managed well

Are cod fisheries in the Atlantic well managed?
Yes, both Canadian and American managed well
Yes, Canadian managed well
Yes, American managed well
No, neither is managed well

Are cod fisheries in the Atlantic sustainable?
Yes
No

Are trout fisheries in the Great Lakes well managed?
Yes, both Canadian and American managed well
Yes, Canadian managed well
Yes, American managed well
No, neither is managed well

Are trout fisheries in the Great Lakes sustainable?

- Yes
- No

Has the historic use of trawl fishing damaged the habitat of Atlantic cod?

- Yes
- No
- Unsure

Should greater fishing effort be targeted for non-native species?

- Yes
- No

Should the stocking of non-native fish be allowed to continue?

- Yes
- No

Does the stocking of non-native fish negatively affect native fish?

- Yes
- No

How important are Marine Protected Areas (MPAs) to fisheries management?

- No effect
- Effects are minor
- Effects are moderate
- Effects are profound
- Unknown

Which mode of fishing has a greater impact on fish stocks, commercial or recreational?

- Commercial
- Recreational

Do you think Atlantic cod are overfished?

- Yes
- No

Do you think lake trout are overfished?

- Yes
- No

How much of a concern is artificial stocking of non-native species to the recovery of native stocks?

- Considerable
- Great
- Somewhat
- Very little
- Not at all

Select the top three issues in overall importance to maintaining stable fisheries.

- Changes in CPUE (catch per unit effort) (i.e., fishing effort)
- MSY calculations (maximum sustainable yield) (i.e., population statistics)
- Law enforcement
- Economics
- Life history/ecology
- Habitat
- Pollution

Stock assessments (estimation of the number of fish)
Overfishing
Illegal, Unreported, and Unregulated (IUU) fishing
Other
Unsure

Are the many phenotypes of lake trout a precursor to speciation?
Yes
No
Unsure

Are North American fisheries laws and regulations more restrictive than those in other countries?
Yes
No
Unsure

Are the United States and Canada working toward common goals for fishery management?
Yes
No
Probably
Unsure

Do you think fisheries are managed across boundaries at the state/provincial level?
Yes
No
Probably
Unsure

Are fisheries managed across international boundaries?
Yes
No
Probably
Unsure

Do local fishing laws account for differences in life history?
Yes
No
Probably
Unsure

How important are regulations regarding genetically modified fish?
Very important
Somewhat important
Little importance
Not at all

Who has the most influence in creating fisheries regulations?
Local community
Fishermen
State/Provincial government
Biologists/Academics
Federal agencies
Congress
Diplomats/ national representatives
National leaders

At what level of government should fisheries be regulated?

- Local
- Regional
- State/Province
- Multi-state/provincial Regions
- Federal/National (single nation)
- International (multiple nations)

Do you work with peers across state/province or national borders?

- Yes, I work with other states/provinces
- Yes, I work with other nations, states/provinces
- No, I do not work with other states/provinces
- No, I do not work with other nations, states/provinces

Do catch limits consider all fishers? (i.e., do catch limits in the United States include Canadian effort and vice versa)?

- Yes
- No
- Probably
- No idea

Do you coordinate efforts with other states/provinces?

- Yes
- No

Are all fish managed the same?

- Yes
- No

How much emphasis should governments place on poaching?

- Maximum consideration
- Some consideration
- Very little consideration
- None

Should the military be used in peacetime to monitor for poaching/illegal fishing activities?

- Yes
- No

How well enforced are fishing regulations in your state/province or locality?

- Considerably
- Greatly
- Somewhat
- Very little
- Not at all

Do you know any of your peers working in fisheries management across the border in the United States/Canada?

- Yes
- No

Have you worked with your peers in other nations?

- Yes
- No

Do you think senior policy and decision makers consider the effects on international resources?

- Considerably
- Greatly
- Somewhat
- Very little
- Not at all

Do you think senior officials base the final polices, regulations, and laws on sound science?

- Yes
- No

How important (in practice/reality) are the recommendations of scientists/biologists to successful fisheries management?

- Considerable
- Great
- Somewhat
- Very little
- Not at all

Ideally, how important should the recommendations of scientists/biologists be for successful fisheries management?

- Considerable
- Great
- Somewhat
- Very little
- Not at all

Does lack of funding affect fisheries management?

- Does not effect
- Effects are minor
- Effects are moderate
- Effects are severe
- Unknown

How much does the local economy affect fishermen in your state/province or locality?

- Considerably
- Greatly
- Somewhat
- Very little
- Not at all

Does your government provide subsidies to fishermen?

- Yes
- No
- Unsure

Are fisheries catch limits based more on science or politics?

- Science
- Politics

At what level is coordination most effective?

- Local
- Regional
- State/Province
- Multi-state Regions

Federal (single nation)
International (multiple nations)

In your opinion, would your country reduce fishing to improve global stocks?
Yes
No

Do you think other countries would reduce fishing to improve global stocks?
Yes
No

Do you feel fishery managers work together for the common good?
Yes
No
Unsure

Do you think overfishing is a national or international concern?
National
International
Overfishing is not a concern

How much does the current U.S. government affect fisheries management/ quotas?
Considerably
Greatly
Somewhat
Very little
Not at all

How much does the current Canadian government affect fisheries management/ quotas?
Considerably
Greatly
Somewhat
Very little
Not at all

Do you think fisheries management has improved in the past decade?
Yes
No

If fishery quotas were reduced, do you think illegal fishing would increase?
Yes
No

Should biologists cooperate in managing fisheries that cross boundaries?
Yes
No

Do decision makers have a responsibility to ensure fishing is conducted sustainably?
Yes
No

Would you be willing to talk more (virtually) with the researcher?
*Remember that **this survey is anonymous**. If you are willing to speak more about this research topic please fill in your email address below. This question will automatically be separated from the survey to ensure that the survey will remain anonymous.*

APPENDIX B – Semi-structured Interview Survey Instrument

SURVEY INSTRUMENT QUESTIONS

Potential pool of questions for semi-structured interviews

General

Do you work for a government agency? If yes, which one?

What is your level/role?

How long have you worked in fisheries (in any capacity)?

What are the three most important issues in fisheries management?

Potential answers/prompts as needed

Climate change, Overfishing, Illegal/Unregulated fishing, Habitat loss, Life history, Ocean acidification, Migration/ seasonal movements, Artificial stocking, Invasive species, Recreational fishing, Commercial fishing, Law enforcement, Changes in food web/loss of species diversity, Employment and local economic development through fishing, History and practice, Political support for the fishing industry, Economics, Livelihoods of fishermen

Scientific/technical

Does artificial selection in hatchery stock negatively affect wild fish?

Are the life histories of species a factor in fisheries management?

Do the maximum sustainable yield (MSY) calculations include the fishing effort from other nations?

Do differences in life history effect fishing pressure?

Do life history differences factor into regulations?

Does cod migration factor into its management?

How much do stock assessments affect policy/regulatory decisions?

As a whole, do you think United States/Canadian fisheries are overfished? are they well managed?

Specifically, are cod fisheries in the Atlantic well managed? Are they sustainable?

What about trout fisheries in the Great Lakes? Are they sustainable?

How healthy are cod stocks compared to a century ago?

Has the historic use of trawl fishing damaged the habitat of Atlantic cod?

How many phenotypes are there of lake trout?

Should greater fishing effort be targeted for non-native species?

Should the stocking of non-native fish be allowed to continue?

Does the stocking of non-native fish negatively affect native fish?

When should fisheries be closed to fishing?

How important are Marine Protected Areas (MPAs) to fisheries management?

Which mode of fishing has a greater impact on fish stocks, commercial or recreational?

How much of a concern is artificial stocking of non-native species to the recovery of native stocks?

Where do you get data on the current status of fisheries stocks?

How reliable do you think these data are?

What issues are important to maintaining stable fisheries?

Potential answers/prompts as needed

Changes in CPUE, (i.e., fishing effort), MSY calculations (i.e., population statistics), Law enforcement, Economics, Life history/ecology, Habitat, Pollution, Stock assessments (estimation of the number of fish), Overfishing, Illegal, Unreported, and Unregulated (IUU) fishing, Other

Are the many phenotypes of lake trout a precursor to speciation?

Political

Are North American fisheries laws and regulations more restrictive than those in other countries?

Are the United States and Canada working toward common goals for fishery management?

Do you think fisheries are managed across boundaries at the state/provincial level?

Are fisheries managed across international boundaries?

Do local fishing laws account for differences in life history?

How important are regulations regarding genetically modified fish?

Who has the most influence in creating fisheries regulations?

How much influence do international treaties have on fisheries management in the United States and Canada?

At what level of government should fisheries be regulated?

Are you familiar with the laws and regulations regarding fishing in the United States/Canada?

Is the history of exploitation a consideration in policy updates or changes to regulations and laws?

Do you work with peers across state/province or national borders?

Do you know who sets fishing policy for your nation?

Do catch limits consider all fishers? (i.e., do catch limits in the United States include Canadian effort and vice versa)?

Do you coordinate efforts with other states/provinces?

Are all fish managed the same?

How much emphasis should governments place on poaching?

Should the military be used in peacetime to monitor for poaching/illegal fishing activities?

To what extent does illegal fishing produce negative effects locally in your area?

How well enforced are fishing regulations in your state/province?

Do you know any of your peers working in fisheries management across the border in the United States/Canada?

Have you worked with your peers in other nations? How many times and in what contexts?

How often have you worked to coordinate your efforts with your international counterpart?

Do you think senior policy and decision makers consider the effects on international resources?

Do you think senior officials base the final polices, regulations, and laws on sound science?

How important (in practice/reality) are the recommendations of scientists/biologists to successful fisheries management?

Ideally, how important should the recommendations of scientists/biologists be for successful fisheries management?

Economic

Does lack of funding affect fisheries management? How much?

How much does the local economy affect fishermen in your state/province?

How much money is brought into the national economy through fishing each year?

How many jobs are supported nationwide by the fishing industry?

How much of the GDP for the United States comes from fishing?

How much of the GDP for Canada comes from fishing?

Does your government provide subsidies to fishermen?

Cultural

What is the most important step in the near-term to improve fisheries management/ sustainability?

What is the most important long-term step(s) to take to make fisheries more sustainable?
Are fisheries catch limits based more on science or politics?

At what level is coordination most effective?

In your opinion, would your country reduce fishing to improve global stocks?

Do you think other countries would reduce fishing to improve global stocks?

Do you feel fishery managers work together for the common good?

Do you think overfishing is a concern? Nationally or internationally?

How much does the current U.S. government affect fisheries management/ quotas?

How much does the current Canadian government affect fisheries management/ quotas?

Do you think fisheries management has improved in the past decade?

If fishery quotas were reduced, do you think illegal fishing would increase?

Should biologists cooperate in managing fisheries that cross boundaries?

Do American and Canadian biologists cooperate in managing fisheries that cross boundaries?

Do decision makers have a responsibility to ensure fishing is conducted sustainable?

APPENDIX C –IRB Approval Letter

Office *of*
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NOTICE OF INSTITUTIONAL REVIEW BOARD ACTION

The project below has been reviewed by The University of Southern Mississippi Institutional Review Board in accordance with Federal Drug Administration regulations (21 CFR 26, 111), Department of Health and Human Services regulations (45 CFR Part 46), and University Policy to ensure:

- The risks to subjects are minimized and reasonable in relation to the anticipated benefits.
- The selection of subjects is equitable.
- Informed consent is adequate and appropriately documented.
- Where appropriate, the research plan makes adequate provisions for monitoring the data collected to ensure the safety of the subjects.
- Where appropriate, there are adequate provisions to protect the privacy of subjects and to maintain the confidentiality of all data.
- Appropriate additional safeguards have been included to protect vulnerable subjects.
- Any unanticipated, serious, or continuing problems encountered involving risks to subjects must be reported immediately. Problems should be reported to ORI via the Incident submission on InfoEd IRB.
- The period of approval is twelve months. An application for renewal must be submitted for projects exceeding twelve months.

PROTOCOL NUMBER:	22-749
PROJECT TITLE:	Policy Implications of Managing Biodiversity and Natural Resources Across International Boundaries
SCHOOL/PROGRAM	Political Science &Legal Studies
RESEARCHERS:	PI: Dillon Brown Investigators: Brown, Dillon~Pauly, Robert~
IRB COMMITTEE ACTION:	Approved
CATEGORY:	Expedited Category
PERIOD OF APPROVAL:	09-May-2022 to 08-May-2023

Donald Sacco Jr.

Donald Sacco, Ph.D.
Institutional Review Board Chairperson

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