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Socio-Economic Risk Assessment of the Presence of Grass Carp in the Great Lakes Basin

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Executive Summary

"Socio-Economic Risk Assessment of the Presence of Grass Carp in the Great Lakes Basin" provides a detailed socio-economic analysis of the potential economic impact to Canada and the US of the establishment of Grass Carp in the Great Lakes.

The Great Lakes system includes five Great Lakes (Superior, Huron, Michigan, Erie, and Ontario), Lake St. Clair, and the connecting channels, along with many harbors and bays located primarily on the Canada–US border. The lakes are shared between the Canadian province of Ontario (36%) and the US states (64%) of Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, and Wisconsin.

The Great Lakes are the world's largest freshwater system, with 20% of the world's fresh surface water and 95% of North America's fresh surface water. The Great Lakes directly support the lives of approximately 40 million people (roughly 10% of the U.S. population and over 30% of the Canadian population) living in the Canadian provinces and US states that directly border them (OMNR, 2011).

The Great Lakes are an important source of drinking water and support fish, wildlife, plants, thousands of wetlands and a variety of landscapes. They are home to commercial and recreational fisheries, numerous recreational activities, commercial transportation, and provide both tangible and intangible benefits to residents of Canada and the US.

The Great Lakes and their watersheds are facing threats from Grass Carp, an Aquatic Invasive Species (AIS) in North America. The presence of Grass Carp has attracted the attention of the governments of Canada, the US, the province of Ontario, the Great Lakes States, as well as First Nations, the general public, industry associations and non-governmental environmental organizations.

DFO undertook the socio-economic risk assessment study to supplement *Binational Ecological Risk Assessment for Grass Carp in the Great Lakes Basin (DFO (2017))* which was led by the Centre of Expertise for Aquatic Risk Assessment (CEARA), DFO, as part of the Government of the US and Canada's initiatives and recognizing the importance of early intervention to prevent the establishment of invasive species.

The methodology adopted in the study is the Total Economic Valuation technique. Of the major activities presently occurring in and around the Great Lakes Basin, based on the results reported in DFO (2017), Cudmore et al. (2017), and discussions with subject matter experts, the scope of the study included commercial fishing, recreational fishing, recreational boating, recreational hunting, wildlife watching, and the beaches and lakefront use activities for both baseline and risk assessments, as they are perceived to be impacted by Grass Carp. In order to estimate the economic values of identified activities, the study arrived at best estimates of the expenditures made and of the consumer surplus generated by the activities in Canada.

In selecting the scenario for the Risk assessment, in alignment with DFO (2017) and Cudmore et al. (2017), it was assumed that following the arrival of Grass Carp, it would take 10 years for the impact to emerge in areas where the carp were present. Therefore, as the socio-economic study uses 2014 as the base year, it uses an adjusted base of 2024 from which to consider the 10 year and 40 year impacts.

Following DFO (2017), the study assumed that in the absence of additional preventive measures, Grass Carp will arrive, establish populations, survive, and spread throughout the Great Lakes. Since there is no feasible way to separate out the impact of an introduction of Grass Carp into the Great Lakes from other influences in the economy such as urbanization and climate change, the analyses in the study were premised on scenarios both with, and without, the presence of Grass Carp, holding other variables unchanged.

The study used secondary source information, and was benefitted greatly from: (i) community profiles around the Great Lakes, primarily from US Census Bureau, and Statistics Canada; (ii) the bi-national Ecological Risk Assessment (DFO, 2017), including supplementary reports; (iii) a workshop held on February 11-12, 2015, jointly organized by the Great Lakes Fisheries Commission and Policy and Economics, Central and Arctic Region, DFO; and (iv) expert opinion exchanged between a group of subject matter experts involved in the Ecological Risk Assessment and economists involved in analyzing this socio-economic study of the presence of Grass Carp in the Great Lakes Basin.

The study found that the Great Lakes basin provides invaluable services to society through maintaining ecosystem health and biodiversity - some are recognized as direct benefits (e.g. recreational activities) while others are indirect/intrinsic (e.g. climate control, non-use values). The intrinsic values of ecosystem health and biodiversity are hard to define, because they are much more intangible than direct benefits, such as commercial fishing (Krantzberg et al., 2008, 2006). However, the total non-use values might fall in the range of 60% - 80% of the total economic value (Freeman, 1979).

The Great Lakes also provide considerable subsistence, social, cultural, and spiritual benefits to the people residing in the region and to Canada and the US as a whole. The existence of the Great Lakes and diversified activities in and around the Great Lakes have contributed substantially to preserving traditional aboriginal lifestyles in the study region. Socially, the Great Lakes beaches and shorelines provide a “sense of place” and a unique source of community pride and are the key public perception measures of environmental quality. The Great Lakes also provide opportunities for research and educational activities that result in a better understanding of the ecology.

In the absence of additional measures to prevent the presence of Grass Carp from the Great Lakes basin, the study estimated that, starting in 2024, the present value of impact on Great Lakes commercial fishing industry in Canada would be at $244 million and $1,300 million in 10 years and 40 years, respectively. The present value of impact on Great Lakes commercial fishing industry in the US would be at $102 million and $663 million in 10 years and 40 years starting 2024, respectively (see Table 1).

Table 1: Estimated Present Values (USD Mil.) of Affected Activities in the Great Lakes in 10 Years and 40 Years by Country/Activity

Sector Impacted	Canada			The US		
	Baseline (2024)	10 Years (2033)	40 Years (2063)	Baseline (2024)	10 Years (2033)	40 Years (2063)
Commercial Fishing	$230	$244	$1,300	$145	$102	$663
Recreational Fishing	$556	$345	$2,604	$3,000	$2,401	$14,615
Hunting	NA	NA	NA	$31	NA	NA
Recreational Boating	$2,300	NA	NA	$4,900	NA	NA
Beaches/Lakefront Use	$235	NA	NA	$1,100	NA	NA
Wildlife Viewing	NA	NA	NA	$121	NA	NA

Source: Fisheries and Oceans Canada staff calculation, Policy and Economics, Central and Arctic Region.
Note: NA - Not available.

As for recreational fishing, starting in 2024, the present value of impact in Canada would be at $345 million and $2,604 million in 10 years and 40 years, respectively. The present value of impact on Great Lakes recreational fishing industry in the US would be at $2,401 million and $14,615 million in 10 years and 40 years, respectively.[1]

The study also anticipated that the presence of Grass Carp in the Great Lakes would decrease beach/lake front use, wildlife viewing, hunting opportunities and associated economic benefits to some degree, relative to the extent of deterioration of wetlands and bird species habitat and deterioration of water quality and cladophora-related problems caused by the presence of Grass Carp. On the other hand, the presence of Grass Carp may benefit the recreational boating activities in the form of reduced cost for vegetation control effort. However, the impact on such activities could not be quantified as these activities were not directly linked to ecological consequences found in DFO (2017) and Cudmore et al. (2017).

In terms of damage to ecosystem services, the study found that Grass Carp populations have the potential to nearly completely remove aquatic plants, influence other major changes resulting in the loss of ecosystem services such as nutrient cycle control (DFO, 2017) and a non-functioning environment. It is difficult and time consuming to quantify the damage to ecosystem services by the presence of Grass Carp in the entire Great Lakes Basin due to methodological challenges. Despite the difficulty of quantifying, the economic value of damages to wetlands along the Great Lakes may perceive to be substantial.

Over time, the presence of Grass Carp to the Great Lakes basin could change the domination of lake ecosystems from native fish species to Grass Carp, with the potential to damage the public

[1] The estimations of the economic contributions of the Great Lakes discussed in this study should be viewed as conservative estimates. The study attempted to ensure this by adjusting estimation variables where significant variations and uncertainties existed, and by using reasonable proxies based on literature review and experts' judgements.

image of these lakes regionally, nationally and internationally and to also harm the well-being of residents living close to this unique natural resource. The presence of Grass Carp would damage subsistence harvests from the Great Lakes and reduce the social, cultural and spiritual values of the lakes and of lake-related activities. Quantitative assessments of these impacts, however, are not feasible due to a lack of pertinent information.

During the periods considered, there could be factors in the economy at work that might create counteracting forces on the impacts of Grass Carp on communities, businesses, and individuals in the study area. Therefore, the net economic impacts could be counterbalanced at the regional and national levels, while remaining significant for the stakeholders (e.g. communities, harvesters, users), when taking into account the (re)distribution of income and employment as a consequence of change in the scale of activities in and around the Great Lakes basin.

The baseline values and risk reported in the study for Canada and the US should not be directly compared and also with those provided in the extant literature because of methodological differences. Nonetheless, in the absence of more/better data, this study made an effort in identifying the value of certain activities in and around the Great Lakes in Canada and the US and the value of what might potentially be at risk by the presence of Grass Carp.

The study had some limitations due to a lack of information. The most notable obstacles were: (i) lack of Great Lakes' specific information by activity; (ii) forecasted values in 10 and 40 years were based on the values by activity for the most recent year assuming that the values would prevail for the time period covered if everything else remains the same; (iii) lack of a more explicit linkage between the ecological consequences and socio-economic factors; and (iv) lack of adequate information to provide an incremental analysis showing a quantitative estimate or a range of estimates of the socio-economic impact of the presence of Grass Carp.

These limitations were somewhat mitigated through the adoption of assumptions and the application of proxies from the extant literature, with suitable adjustments within the existing time constraints. However, the appropriate remedy would be further research. For example, in order to have a proper assessment of baseline value(s) and impact, a possible next step might be to undertake a comprehensive survey in the study area to obtain values being generated by activity and by lake (including willingness to pay and subsistence harvests). Similarly, for forecasting, estimation methodologies such as General Equilibrium model, which try to identify parameters important to a decision or set of decisions in part to reflect welfare changes from complementarity and substitutability of key goods, may mitigate biases associated with forecasting.

Introduction

With the exception of Lake Michigan, the Great Lakes straddle the Canada-United States (US) border[2] and are the world's largest freshwater system (see Annex 1). At more than 94,000 square miles/244,000 square kilometres of water the Great Lakes are larger than the states of New York, New Jersey, Connecticut, Rhode Island, Massachusetts, Vermont, and New Hampshire combined, and are about 23% the size of the province of Ontario.The Great Lakes basin, including watersheds,[3] covers an area of 766,000 square kilometres (295,700 square miles), an area larger than New Brunswick, Nova Scotia and Prince Edward Island combined. The shoreline of the five Great Lakes and the connecting rivers stretches for 17,549 kilometers (10,900 miles), long enough to reach nearly halfway around the world.[4,5] It is also connected to the Atlantic Ocean by the St. Lawrence Seaway.

The Great Lakes are the world's largest freshwater system, with 20% of the world's fresh surface water and 95% of North America's fresh surface water. The Great Lakes directly support the lives of approximately 40 million people (roughly 10% of the U.S. population and over 30% of the Canadian population) living in the Canadian provinces and US states that directly border them (OMNR, 2011). Roughly 98% of Ontario's residents (OMNR, 2010) and around 75 First Nation communities (Rashidi, 2014) are presently living along the Great Lakes in Canada.

The Great Lakes are an important source of drinking water and provide habitat for terrestrial and aquatic species, plants and a variety of landscapes. The freshwater resources within the Great Lakes Basin stimulated the early development of the connected states and provinces, with waterfront areas serving as centers of unwavering economic activities. The lakes are the major sources of commercial and recreational fishing as well as host other water-based and beach related recreational activities in and around the Great Lakes Basin. They also provide a navigable seaway to support base industries that depend on marine transport.[6]

The Great Lakes and their watersheds are facing significant threats from the increasing

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[2] The basin includes parts of the province of Ontario and eight states – Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, and Wisconsin.

[3] From west to east, the Great Lakes are Superior (82,100 sq. km), Michigan (57,800 sq. km), Huron (59,600 sq. km), Erie (25,700 sq. km) and Ontario (19,000 sq. km) (Environment Canada [EC], 1990).

[4] https://www.ontarioecoschools.org/wp-content/uploads/2015/11/Great-Lakes-Resource.pdf.

[5] Ontario has over 10,000 km of Great Lakes and St. Lawrence River shoreline. Michigan has 3,288 miles (5,294 km) of coastline along the lakes, giving it more coastline than any other state, except for Alaska. See Live Science (2010, September 16).

[6] Great Lakes Water Quality Board (2016) conducted a survey on a sample of 3,950 residents living in the Great Lakes basin catchment area found that 76% agreed to protect the lakes for the benefit of fish and wildlife and their economic significance in the region and 72% agreed for the lakes importance to human health. About 86% survey participants rated recreational use as a highly important reason to protect the Great Lakes.

number of aquatic invasive species (AIS).[7] All introduced species do not become invasive with negative impact and, the ones that become invasive may widely vary in terms of the severity of impact (Mandrak and Cudmore, 2015). While some AIS play substantial roles in agriculture, aquaculture, commercial and recreational fisheries, there are growing concerns about the risks and detrimental impacts of invasion of increasing number of AIS, varieties as well as the rate of movement (DFO, 2012; Reaser et al., 2007).

The AIS established in the Great Lakes are documented to have led to endangerment and extinction of a wide range of fishes/plants,[8] degradation of ecosystems, and an acceleration of change in ecological cycles[9] which subsequently have hampered human well-being and economic growth (e.g. commercial, recreational activities/opportunities).[10] Besides, vital changes in health, cultural resources and identities, livelihoods due to the introduction of AIS have also been documented for decades (e.g. DFO, 2012; Marbek, 2010a). A recent study conducted by Great Lakes Water Quality Board in 2016 identified Invasive species as the second most significant problem facing the lakes after pollution.

Grass Carp, an AIS from North American perspective, is well-known to be responsible for significant impacts on native species. Grass Carp can disrupt the balance of aquatic life in lakes/rivers, altering nutrient cycles, because of their aggressive eating behaviour, high reproductive rate, and lack of natural North American predators. This allows them to out-compete and crowd out native fish species, including fish that are popular for commercial and/or recreational fishing (EC, 2010, 2004; DFO, 2004; Kelly, Lamberti, and MacIsaac, 2009).

The threat of Grass Carp to the Great Lakes has attracted the attention of Canada, the province of Ontario, national and state governments of the US, First Nations, the general public, industry associations and environmental non-governmental organizations.[11] Stakeholders (e.g. citizens

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[7] AIS is defined as any non-native species whose introduction causes, or is likely to cause, damage to a host ecosystem and existing species. AIS can originate from other continents, neighbouring countries, and other ecosystems within the same country. New non-native species totaling 185 aquatic species and at least 157 terrestrial species were found into the Great Lakes in the past century. Roughly 10% of these species known to be invasive have caused significant environmental, economic and human health damages (EC, 2010).

[8] Bellard, Cassey and Blackburn (2016) found that alien species are the second most common threat associated with species that have gone completely extinct from the five taxa (plants, amphibians, reptiles, birds and mammals) analyzed. State Management Plan (2013) found Invasive species as the second-highest contributing factor to species extinction in aquatic environments worldwide. In the US, AIS was found to be responsible for 49% of imperiled species (e.g. plants, mammals, birds, vertebrates, invertebrates, freshwater mussels) or 53% of fish species (Wilcove, Rothstein, Bubow, Phillips, Losos, 1998).

[9] For a detailed list of changes, see http://nsgl.gso.uri.edu/michu/michui05009.pdf.

[10] The most commonly acknowledged threats in the Great Lakes include the sea lamprey, zebra mussel, quagga mussel, ruffe, alewife, purple loosestrife, round goby and rainbow smelt. For a detailed summary of AIS threatening the Great Lakes, see Felts, Johnson, Lalor, Williams, and Winn-Ritzenberg (2010).

[11] Great Lakes Water Quality Board (WQB) (2016) survey on a sample of 3,950 residents of the Great Lakes region found that 26% of respondents cited to protect the Great Lakes because of its importance as a source of fresh water and 19% valued the Great Lakes in general. A large majority of residents (76%) agreed that the lakes should be protected for the benefit of fish and wildlife as well as their economic significance in the region and 72% agreed to their importance to human health.

in both Canada and the US, industries relying on the Great Lakes fishery, and non-governmental organizations, such as the Ontario Federation of Anglers and Hunters, and EcoJustice Canada,) are looking forward to appropriate measures to prevent the presence of Grass Carp in the Great Lakes.

Aquatic Invasive Species Regulations under the *Fisheries Act* came into force in 2015. Ontario introduced the *Invasive Species Act* in November 2015 that further prohibits the possession, transportation, import or sale of live invasive species, unless authorized by the Minister of Natural Resources and Forestry (MNRF). MNRF conducts inspections of food fish importers and monitors retailers for compliance.

Cross-border efforts were made to establish and renew environmental agreements and local conservation authorities adopted initiatives that focus on learning from and protecting this natural resources. For example, Canada and the US signed the '*Great Lakes Water Quality Agreement*' (GLWQA) in 1972, revised in 1978 and amended in 1987 and 2012, with a commitment to restore and maintain the chemical, physical and biological integrity of the Great Lakes basin ecosystem.[12]

As part of the Government of the US and Canada's initiatives and recognizing the importance of early intervention to prevent the establishment of invasive species, a *Binational Ecological Risk Assessment for Grass Carp in the Great Lakes Basin*, led by the Centre of Expertise for Aquatic Risk Assessment (CEARA), DFO, has been carried out (henceforth referred to as DFO (2017)).[13]

The current socio-economic risk assessment of the presence of Grass Carp in the Great Lakes Basin is intended on supplementing DFO (2017) by providing pertinent socio-economic information to decision-makers in both Canada and the US, help set the priorities and assist in developing options for mitigation measures and/or prevention of Grass Carp in the Great Lakes Basin.

Objectives of the Study

The goal of this study is to provide a detailed socio-economic risk assessment of the presence of Grass Carp in the Great Lakes Basin. The specific objectives of the study are to: (i) provide estimates of the baseline values of affected economic activities in and around the Great Lakes Basin in Canada and the US; and (ii) assessment of the magnitude of the risk of the presence of Grass Carp in the Great Lakes Basin in Canada and the US.

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[12] The partners in delivering the GLWQA are Environment Canada, Department of Foreign Affairs and International Trade, U.S. Environmental Protection Agency; Great Lakes National Program Office, U.S. Department of State, and International Joint Commission.

[13] The study was coordinated by the Great Lakes Fishery Commission and authored by experts from Fisheries and Oceans Canada, the University of Toronto Scarborough, the U.S. Geological Survey and the U.S. Fish and Wildlife Service.

Organization of the Study

The rest of the study is organized as follows: Chapter 1 presents an overview of the Great Lakes; Chapter 2 presents the methodology adopted in the study; Chapter 3 presents the baseline values of affected activities in and around the Great Lakes by sector; Chapter 4 presents the social and cultural values associated with the Great Lakes; Chapter 5 presents the socio-economic impact assessment; and Chapter 6 draws conclusions.

Chapter 1: A Brief Overview of the Study Area

Socio-Demographic Profile[14]

The Great Lakes and connecting channels and rivers are shared between the Canadian province of Ontario, Quebec and the US states of Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, and Wisconsin (henceforth referred to as the Great Lakes states).[15]

The US:

The eight US Great Lakes states have a total land area of 1,073,286 km^2, making up 12% of the land area of the US (see Annex 2A). The average land size of the 8 states is 134,161 km^2, with the largest being Michigan at 206,232 km^2, while Indiana is the smallest at 92,789 km^2.

The Great Lakes states had a combined total population of 85 million, 27% of the total US population in 2015. New York has the largest population with 20 million people. Illinois, Pennsylvania, Ohio, and Michigan each has about 10-13 million people, while Minnesota, Indiana, and Wisconsin are smaller, being in the 5-7 million population range. Population density in the Great Lakes states is 79 people/km^2, much higher than average US population density, excluding Alaska, of 41/km^2. New York has the highest density at 161/km^2 and Minnesota is the most dispersed at 26/km^2.

Within the Great Lakes states, women make up 22% of the farming, fishing, and forestry occupations, much less than their share of the total employed population (48%). While recent data is sparse, a 1998 national survey found that 95% of fishers are men.[16]

Among those 18 or older in the Great Lakes states, 12% do not have a high school degree, lower than the national average of 14%. Those with at least some post-secondary education comprise 58% of the region compared to a national average of 59%.

The average employment rate for the Great Lakes states is 59%, slightly higher than the overall US rate of 58%. Educational services and health care, manufacturing, retail trade, and the professional, scientific, management, and administrative industries made up the majority of employment in the region.

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[14] The socio-demographic profile summarized in this section is primarily based on 2015 American Community Survey, and the US Census for the US and 2011 Community Profiles prepared by Statistics Canada for Canada.
[15] St. Lawrence River, a primary drainage conveyor of the Great Lakes Basin, crosses the Canadian provinces of Quebec and Ontario. It also forms part of the international boundary between Ontario and New York. While not a part of the Great Lakes Basin, Quebec's position along the St. Lawrence Seaway makes it a partner in water resource management with Ontario and the Great Lakes states.
[16] Mean earnings used. The US Census specifically excluded median state earnings of FT/YR workers, although there are separate median earning figures for males and for females.

Only 1% of the population of the GL states is American Indian or Alaskan Native, while 2% of the US as a whole is American Indian or Alaskan Native (see Annex 2C). About 17% of American Indians and Alaskan Natives live in the Great Lakes states. The median age for American Indians in the Great Lakes states ranges from 25 in Minnesota to 33 in Ohio, lower than the national median age of 37. In the region, 20.3% of American Indians over the age of 25 do not have a high school degree, compared to 11% of the general Great Lakes states population and 13% for the American population as a whole. About 23% of American Indians in the Great Lakes states have a post-secondary degree, compare to 40% for the overall population of the Great Lakes states and 38.8% for America as a whole. Median earnings for those over age 16 are also lower, ranging from $20,678 in Minnesota to $26,229 in Illinois for American Indians. In comparison, the median earnings for the general Great Lakes population ranged from $28,188 in Michigan to $34,655 in New York, while median earnings for the US as a whole were $30,926.

There are 88 private establishments in the fishing industry in the Great Lakes states. Most are found in New York and Michigan with 36 and 26 establishments, respectively. Employees in the fishing industry make annual average wages ranging from $14,341 in Pennsylvania to $37,519 in New York, with an average wage of $31,090 for the Great Lakes states. Mean earnings for full-time, year-round workers in the 8 states range from $52,755 in Indiana to $68,860 in New York, with a regional average of $60,861, compared to a US mean of $59,736.

Canada:

In 2016, Ontario had a population of 13 million people, which was 38% of Canada's total population (see Annex 2C). Of Ontarians 15 years of age and older, 16% do not have a diploma or degree, as compared to 17% for Canada as a whole. The percentage of the province's population of 15 years of age and older with at least some post-secondary education is slightly higher as compared to Canada (64% while the national figure was 63%).

The employment rate for Ontario is 94%, as compared to 93% for Canada overall (see Annex 1C). Manufacturing, business services and retail trade sectors employ most of the total experienced labour force age 15 years and over. The median weekly earnings of persons 15 years in Ontario is $962, slightly higher than the national median of $960.

Ontario was home to around 310,000 Aboriginal identity population which was slightly over 2% of the total population in Ontario and 22% of the Aboriginal identity population in Canada in 2011 (see Annex 2D). Of the total 310,000, 209,510 were First Nations, 86,020 were Métis, and 3,360 were Inuit, and the rest reported as other Aboriginal identities (8,050) or more than one Aboriginal identity (2,910). Slightly over 40% of Aboriginal people in Ontario were under the age of 25, compared with 30% of the non-Aboriginal population. In 2011, the employment rates of First Nations people, Métis and Inuit aged 25 to 64 in Ontario who did not have a certificate, diploma or degree were 39%, 47% and 33% respectively.

In 2016, Quebec had a population of 8 million people, which was 23% of Canada's total population (see Annex 2C). Of Quebecers 15 years of age and older, 20% do not have a diploma or degree, as compared to 17% for Canada as a whole. The percentage of the province's population of 15 years of age and older with at least some post-secondary education is slightly higher as compared to Canada (65% while the national figure was 63%).

The employment rate for Quebec is 93%, the same as for Canada overall. Manufacturing, retail trade and the construction sectors employ most of the total experienced labour force age 15 years and over. The median weekly earnings of persons 15 years and over who work full-time in Quebec is $874, lower than the national median of $960.

In Quebec, there was an Aboriginal identity population of about 142,000, which was 2% of the total population in Quebec and 10% of the Aboriginal identity population in Canada in 2011 (see Annex 2D). Of the total, 82,425 were First Nations people, 40,955 were Métis, and 12,570 were Inuit and the rest reported other Aboriginal identities (4,415) or more than one Aboriginal identity (1,550).[17] Four out of ten Aboriginal people in Quebec were under the age of 25, compared with 29% of the non-Aboriginal population. More than half of Inuit (57%) were in this age group, as were 42% of First Nations people and 33% of Métis. In 2011, 53% of Aboriginal people aged 25 to 64 in Quebec had a certificate, diploma or degree from a trade school, college or university (52% of First Nations people, 59% of Métis and 27% of Inuit), as compared to non-Aboriginal counterparts at 66%. In 2011, the employment rates of First Nations people, Métis and Inuit aged 25 to 64 in Quebec who did not have a certificate, diploma or degree were 43%, 44% and 53%, respectively.

A Brief Overview of the Great Lakes Basin[18]

The Great Lakes system includes five Great Lakes (Superior, Huron, Michigan, Erie, and Ontario), Lake St. Clair, and the connecting channels, along with many harbors and bays located primarily on the Canada–US border.

Table 2: Dimensions of the Great Lakes by Lake and Country

Name of the Lake	Area (Sq. Km)[i]			Length of Shoreline (Sq. Km)[ii]		
	The US	Canada	Total	The US	Canada	Total
Superior	53,400 (65%)	28,700 (35%)	82,100	3,721 (48%)	4,027 (52%)	7,748
Huron	23,600 (40%)	36,000 (60%)	59,600	2,428 (28%)	6,282 (72%)	8,710
Michigan	57,800 (100%)	-	57,800	4,319 (100%)	-	4,319
Erie	12,900 (50%)	12,800 (50%)	25,700	1,284 (57%)	952 (43%)	2,236
Ontario	8,960 (47%)	10,000 (53%)	18,960	861 (46%)	1,027 (54%)	1,888
Total	**156,660 (64%)**	**87,500 (36%)**	**244,160**	**12,613 (51%)**	**12,288 (49%)**	**24,900**

Source: (i) Statistics Canada; http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/phys04-eng.htm.;
(ii) U.S. Census Bureau, Statistical Abstract of the United States: 2011
Note: Numbers in the parentheses indicate percent of total area.

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[17] From 2006 to 2011, the First Nations population in Quebec increased by 26%, while the Métis population rose by 47%, and the Inuit population by 15%.

[18] For a detailed discussion on the importance of the Great Lakes to activities, see the respective section in the study.

At 82,100 km^2 (31,699 sm^2), Lake Superior is the largest both in surface area and in water volume (2,903 cubic miles/12,100 cubic km) (see Table 2). It is also the largest lake in Canada and the US. Lake Huron is the second largest Great Lake by surface area (59,600 km^2/23,000 sm^2) and has the longest shoreline and is located in the middle. Lake Michigan (touches Indiana, Illinois, Michigan and Wisconsin) is the third largest one in surface (57,800 km^2/22,300 sm^2) and is located entirely in the US. Lake Erie (touches New York, Pennsylvania, Ohio, Michigan and Ontario), the shallowest of all the Great Lakes, is the fourth largest one in surface area (25,700 km^2/9,910 sm^2). Lake Ontario is the smallest Great Lake in surface area (18,960 km^2/7,340 sm^2), situated below Lake Erie and at the base of Niagara Falls.

Of the total surface area of the Great Lakes, the US accounts for 64% for a total of 156,660 km^2. Of the total, Michigan accounts for 64%, Wisconsin 16%, New York 7%, Ohio 6%, and Minnesota 4%. Illinois, Indiana, and Pennsylvania combined account for 4% of the US portions of the Great Lakes. The Canadian province of Ontario accounts for 36% of the total surface area of the Great Lakes (see Table 2).

In addition to the five Great Lakes, there are a number of rivers and tributaries connecting the Great Lakes. Lake Superior, at the top of the chain, flows into Lake Huron through St. Marys River. Lake Michigan flows out water to Lake Huron through the Straits of Mackinac.[19] From Lake Huron, water flows through the St. Clair River, Lake St. Clair and Detroit River to Lake Erie. Lake Erie flows into Lake Ontario through the Niagara River, including Niagara Falls. The St. Lawrence River lies at the end of the inland waterway, flowing from Lake Ontario into the Gulf of St. Lawrence, which leads into the Atlantic Ocean (Environment Canada and U.S. Army Corps of Engineers, 1993).

The Great Lakes-St. Lawrence Waterway extends 3,700 kilometers (2,300 miles) (Martin Associates, 2011), from the Atlantic Ocean to the head of the Great Lakes making it the largest inland waterway in the world (Canadian Shipowners Association, 2006). It includes 110 system ports located in the eight Great Lakes states and the provinces of Ontario and Quebec (The St. Lawrence Seaway portion extends from Montréal to the middle of Lake Erie). [20]

The Great Lakes hold 20% of the world's fresh surface water and 95% of North America's fresh surface water. They contain 23 quadrillion litres (or (23×10^{15}) litres) of water, of which only 1%

[19] Since Lake Michigan and Lake Huron stand at the same elevation, they are often referred to as one lake hydrologically or Lakes Michigan-Huron (Environment Canada and U.S. Army Corps of Engineers, 1993).

[20] The St. Lawrence Seaway (constructed in the 1950s) allows ships to pass from the Great Lakes into the ocean and considered to be the busiest transportation system in the world. During the Colonial period, the Lake Superior was a major mode of transportation for the fur industry and other trading activities and remains a shipping hub in present days. While the Erie Canal (built in 1825) once offered an inexpensive way to transport cargo, it presently used mostly for recreation.

is renewable (Krantzberg et al., 2006). The Great Lakes contain more than 30,000 islands.[21] Of the thousands of islands scattered throughout the lakes, (many are small and uninhabitable), the largest is Lake Huron's Manitoulin Island with a length of 160 km (100 miles) and an area of 2,766 km^2 (1,068 sm^2) which is also the largest freshwater island in the world.[22]

Of the total size of the Great Lakes basin, the Great Lakes and their connecting channels make up about a third of this area. Forests account for the largest percentage (40%) of total basin area. Agriculture accounts for about a quarter of basin area (The U.S. Army Corps of Engineers, 2008).

The Great Lakes provide drinking water and supports the lives of approximately 40 million people (roughly 10% of the U.S. population and over 30% of the Canadian population) living in the Canadian provinces and US states that directly border them (OMNR, 2011). Roughly 98% of Ontario's residents (OMNR, 2010) around 75 First Nation communities are presently living along the Great Lakes in Canada (Rashidi, 2014).[23] Water withdrawn from the Great Lakes is used in municipalities and supplied to homes, businesses and institutions like schools/hospitals for a diverse range of activities (e.g. drinking, washing, gardening, landscape).

The Great Lakes support thousands of wetlands, and a variety of landscapes, plants, fish and wildlife (over 3,500 species of plants and animals inhabit the Great Lakes basin, including over 170 fish species[24]). Lake Superior is home to about eighty (80) species of fish such as lake and brook trout, coho and chinook salmon and yellow perch.[25] During 1974-2011, over 220 bird species were observed at the St. Clair National Wildlife Area of which more than sixty (60) species were recorded breeding in the Area. In addition to birds, about twenty one (21) species of mammals, fifteen (15) reptile and amphibian species, and twenty seven (27) fish species have been reported.[26]

On the Canadian side of the Great lakes, twenty (20) species of fish and eleven (11) species of molluscs are presently protected under the Federal *Species at Risk Act* and/or the Ontario *Endangered Species Act*. In the United States the *Endangered Species Act* listed three (3) species of mollusks as endangered.[27]

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[21] To name a few, in Lake Huron, Georgian Bay includes about 17,500 islands. In Lake Ontario, an archipelago includes nearly 2,000 islands that line the U.S.-Canadian border, and in the St. Lawrence River, an archipelago includes about 1,800 islands.

[22] http://www.greatlakes-seaway.com/en/management/index.html.

[23] The major tribes that have occupied the Great Lakes area include Anishinabe, Chippewa/Ojibwe, Cree, Dakota/Sioux, Huron, Iroquois, Menominee, Mesquakie/Fox, Miami, Missouri, Mohican/Mahican, Oneida, Ottawa, Potawatomi, Suak/Saques/Sac, Winnebag (Great Lakes Information Network, n.d; Hele, 2008).

[24] http://www.glc.org/work/habitat.

[25] For details, see https://www.ec.gc.ca/ap-pa/default.asp?lang=En&n=D29EDF40-1&offset=2&toc=show.

[26] United States Environmental Protection Agency. (2016, December 6). *Great Lakes Facts and Figures*. Retrieved June 1, 2017, from https://www.epa.gov/greatlakes/great-lakes-facts-and-figures.

[27] For details on species and listing status, see http://www.registrelep-sararegistry.gc.ca and http://explorer.natureserve.org/index.htm.

The Great Lakes support a diverse range of economic activities in both Canada and the US (EC, 2010). They provide input for industrial/agricultural production and power generation, support commercial and recreational fisheries, provide recreation, serve as platforms for complex commercial transportation, and provide both tangible and intangible benefits to both Canadian and US residents.

The Lakes provide water for factories and industries, wind power to create electricity, sources of oil and natural gas, and are shipping routes for iron ore, coal, and grain for overseas markets. In industries and agricultural sectors, water is used as input into the production process (e.g. metals, chemicals, paper and allied products), livestock watering and irrigation (e.g. water applied for growing crops and pastures, the maintenance of parks and golf courses). Water is also used for electricity generation (electricity, heating/cooling).

The Great Lakes-St. Lawrence River basin comprises 75% of Canada's manufacturing capacity, 25% of agricultural capacity and 45% of its industrial capacity.[28] Manufacturing industries accounted for 38% of total water intake from the Great Lakes basin and 14.0% from the St. Lawrence River basin (Statistics Canada, 2005). More than 80% of the power generated in Ontario and 95% of Ontario's agricultural lands depend on the Great lakes-St. Lawrence River basin.[29] In terms of contributions of the Great Lakes to US economic activities, they support 7% of American farm production.

The Great Lakes support world-class commercial freshwater fishing in both Canada and the US. They are also popular attractions for recreational activities for residents and non-residents/foreign visitors. Fishing, diving, and boating are a few of the many recreational activities in and around the Great Lakes. The area is home to many park systems, conservation and wilderness areas, and beaches. Highly visited parks occur around all five lakes and in all eight Great Lakes states and the province of Ontario, Canada, including sites that are remote from major population centers. Annual visitation for the 144 state, provincial, and national parks within 5 km of Great Lakes shorelines exceeded 43 million visits each year (Allan et al., 2015).[30] The large number of beaches along the coast of the Great Lakes made it referred to as the "Third Coast" behind the Pacific and Atlantic.[31]

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[28] See https://www.ontario.ca/page/protecting-great-lakes.

[29] https://www.ontarioecoschools.org/wp-content/uploads/2015/11/Great-Lakes-Resource.pdf.

[30] Using contingent valuation technique, Kreutzwiser (1981) estimated the annual net recreational benefits of public marsh at Long Point and Point Pelee on the north shore of Lake Erie to Canadians. The study found that users received a return of 179% for every dollar they spent. These figures do not include winter use of marsh (e.g. skating) and the intrinsic value of wildlife production and protection, biodiversity, nutrient retention or groundwater recharge or discharge. For a detailed discussion of the recreational values of the Great Lakes, see Chapter 4.

[31] To name a few, on the Michigan side of the lake, the most popular "beach" towns include St. Joseph, South Haven, Grand Haven and Holland (Live Science, 2013, May 3).

AIS Threats to the Great Lakes

The Great Lakes basin is facing significant threats from a variety of stressors[32] especially from an increasing number of AIS. The pathways by which AIS entered the Great Lakes varied across time. Some organisms were intentionally translocated for commercial and recreational purposes while other organisms were introduced when goods, equipment, or people relocated.

A literature review conducted for the purpose of this study found that, historically, AIS have been introduced to the Great Lakes through several vectors/sources of transmission and dispersion, including canals and international ship ballast water. Commercial ships traveling only within the Great Lakes system facilitate the inter-lake spread of AIS through ballast water.[33] Other known pathways include the aquaculture industry, aquarium trade, the live-food fish industry,[34] recreational boating, sport fish stocking, bait bucket transfers, canals and waterways, and various horticultural practices.[35]

While many believe that the Great Lakes contain more invasive species than have been discovered, a vast array of literature reported around 185 non-native species harbored in the Great Lakes (Great Lakes Aquatic Nonindigenous Species Information System (GLANSIS); Lodge 2007; Ricciardi 2001). Some estimates suggest that a new invader enters the system every 9-12 months.[36] At least 25 major invasive species of fish have entered the Great Lakes since the 1800s, including Round Goby, Sea Lamprey, Eurasian Ruffe, Alewife, Zebra and Quagga Mussels, Spiny Water Flea, Asian Carp.[37]

Grass Carp, one of the four Asian carp species (bighead, black, grass, and silver carp), are found in the Mississippi watershed, two of which (bighead and silver carp) are known to have established breeding populations in that watershed. There were many pathways in which grass carp moved or were introduced in the US. However, the largest factor was its use as a bio-

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[32] For a detailed discussion on analysis of stressors and ecosystem services in the Great Lakes, see Allan et al. (2013).

[33] According to Bailey, S. A. Deneau, M. G., Jean, J., Wiley, C. J., Leung, B., and MacIsaac, H. J. (2011), during 1959 - 2010, at least 56 AIS were reported in the Great Lakes, with 34 of those attributed to transoceanic shipping such as Zebra and Quagga Mussels, Bloody Red Shrimp. IJC (2011) reported ballast water to be responsible for approximately 55% - 70% of the non-native species established in the Great Lakes since the opening of the St. Lawrence Seaway in 1959. One new species arrives every eight months through ballast water discharged from ocean vessels, and/or hull fouling of ocean vessels (General Accounting Office 2002, Lovell and Stone 2005). Although historically, ballast water was considered to be the largest single source of introduced AIS in Canada, Bailey et al. (2011) found that the Great Lakes ballast water management program (e.g. ballast water exchange and flushing, inspection) provided robust protection against ship-mediated biological invasions.

[34] Over 1500 fish species enter Canada in live trade each year (Mandrak and Cudmore, 2015).

[35] For a detailed discussion, see EC (2010, 2004), DFO (2004), Great Lakes Fisheries Commission [GLFC] (2009), Rixon, Duggan, Bergeron, Ricciardi and Macisaac (2005).

[36] Only a small portion of the invasive species that enter the lakes become established, and only a small portion of those (up to 15%) prove to be invasive and harmful (Gaden, 2008).

[37] Major invasive plant species include common reed, reed canary grass, purple loosestrife, curly pondweed, Eurasian milfoil, frogbit, non-native cattail. See, United States Environmental Protection Agency. (2016, December 6). *Invasive Species*. Retrieved May 30, 2017, from https://www.epa.gov/greatlakes/invasive-species.

control for aquatic macrophytes (an aquatic plant that grows in or near water and is either emergent, submergent, or floating).[38] The grass carp that were stocked escaped through either flooding events or connected waterways, and subsequently colonized larger rivers. During the same time, the Arkansas Game and Fish commission began supplying grass carp to other states that further increased its distribution (Conover et al. 2007).[39] Following this, grass carp was widely marketed for about ten years with little or no restrictions. Other vectors of introduction were illegal stocking of diploid (fertile) grass carp, live sea food trade, illegal shipping of live individual from China, stocking of live carp in local Asian markets, ritualistic/ religious release (Cudmore et al., 2017; Reed, 2011).

Numerous Grass Carp captures have occurred in the Great Lakes Basin since early 1970s. On the US side of the Great Lakes, the first was collected from the Lake Erie basin, Michigan, in the early 1980s and on the Canadian side from Lake Erie, west of Point Pelee, in 1985 (Cudmore et al., 2017; Cudmore and Mandrak, 2004). [40]

In terms of pathways to the specific Great Lakes, the likelihood ranks varied by ploidy and lake. Grass Carp (both triploid and diploid) have arrived to Lake Michigan from outside of the Great Lakes Basin most likely through the Chicago-Area Waterway System (CAWS) due to the proximity of established and invading Grass Carp populations within this connection, including in locations above the electric barrier (Cudmore et al., 2017). In Lake Erie, the most likely pathway was through human-mediated release[41], in Lake Huron through spread from Lake Erie or direct release and in Lake Ontario were likely directly released (DFO, 2017).

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[38] Grass carp first came to the US in 1963 to aquaculture facilities in Auburn, Alabama, and Stuttgart, Arkansas. However, the first stocking of grass carp in a waterbody with access to a stream system occurred in 1971. For a detailed discussion, see Cudmore et al., (2017), Conover et al. (2007).

[39] Although many states banned the importation of grass carp in the late 1970s, grass carp had already invaded the state of Arkansas and many of the surrounding waterways (Conover et al., 2007) and have been recorded from 45 states (USGS, 2016).

[40] Under Asian Carp Program, from over 36 locations in the Canadian waters of the Great Lakes basin, 23 Grass Carp were recorded and analyzed from Lake Erie and Lake Ontario during 2013 -16; nine were fertile and capable of reproducing. All of the fish were born outside the Great Lakes waters and made their way into Canada.

[41] For a detailed discussion on human behaviour involving invasive species, see Drake, Mercader, Dobson, Mandrak (2014).

Chapter 2: Methodology Adopted

This study aims to evaluate the socio-economic risk of the presence of Grass Carp in the Great Lakes Basin in Canada and the US. This was done in two steps: Firstly, baselines values (by sector) or magnitude of economic activities that are predicted to be affected by the presence of Grass Carp have been estimated either quantitatively or qualitatively.; Secondly, the results from DFO (2017) including supplementary reports, and consultations with subject matter experts have been used to provide a quantitative and/or qualitative discussion of the magnitude of values that might be impacted.

The analytical principles set down in Treasury Board of Canada Secretariat (2007) guided the analysis. They are: (i) all feasible options, including the status quo, are considered; (ii) impacts that cannot be expressed in quantitative values are discussed qualitatively; and (iii) non-market values are considered (and can be gauged based on existing or similar data gleaned from the literature).

The methodology adopted for the analysis is the Total Economic Valuation (TEV) technique, which relates all benefits to human welfare measures. The economic valuation method was chosen because (i) it is defined as the sum of benefits involved and can be used to assess economic benefits quantitatively or qualitatively; (ii) it allows for a robust measurement and comparison of values and presents these values in terms that people are familiar with; and (iii) it is both logical and comprehensive due to its foundations in microeconomic theory, emphasis on marginal values, and inclusion of all aspects of the associated values. Moreover, since the TEV approach is followed by economists in valuing environmental goods and services, the relevant literature could be consistently analyzed using this framework.

In the study, the TEV framework considers that the benefits provided by the Great Lakes are linked to both use and non-use values:

TEV = Use Value + Non-use Value

The use values are subdivided into current and future use values. Current use values are sub-categorized as direct and indirect use values. Finally, direct use values are sub-categorized as extractive and non-extractive use values. Based on the TEV framework developed by EnviroEconomics (2011), a revised chart showing the total economic values, along with definitions for all categories and sub-categories of values, is provided in Matrix 1.

Under the category of use values, extractive use values include activities such as commercial and recreational fishing, and non-extractive use values include activities such as wildlife watching and beach use. Indirect use values generally include ecosystem services and biodiversity. The future use values include option value to use the resource in future for commercial and/or recreational activities, as well as possible sources of research value. Finally, non-use values include bequest value (also known as legacy value) and existence value.[42]

Of the major activities presently occurring in and around the Great Lakes Basin, based on the results reported in DFO (2017), Cudmore et al. (2017), and discussions with subject matter experts, the study recognized that the presence of Grass Carp may impact commercial fishing, recreational fishing, recreational boating, hunting, and the beaches and lakefront use activities. Hence, the scope of the study encompassed these activities for both baseline and risk assessments. Other activities (water use, aquaculture, oil and gas, commercial navigation) were predicted to have either negligible or no impact by the presence of Grass Carp and, thereby, excluded from discussions.

In order to estimate the economic value of the Great Lakes Basin and the impact should Grass Carp establish in those lakes, the study includes estimates of: (a) the expenditures at market values, and (b) the consumer surplus, based on information obtained from extant literature.[43] The values presented in the study are in US dollar (USD), unless otherwise specified.

AIS can lead to significant ecosystem alterations, including general reductions in biodiversity (DFO, 2012, 2017) and accelerated extinction rates of native species. While it is difficult to precisely determine the impacts of AIS with a high degree of certainty (Jude et al., 2004), there are some critical factors that help inform the magnitude of AIS threats such as the species' reproduction rate, the species' ability to compete with other species, and the quantities of biomass the species consumes. Moreover, the full effects and consequences of AIS sometimes take decades to emerge (DFO, 2017, Cudmore et al., 2017; Simberloff, 2011).[44]

Assuming that only the current management measures are in place and all other things remain unchanged, DFO (2017) evaluated the likelihood of arrival, survival, establishment, and spread of *Grass Carp (*both triploid (sterile) and diploid (fertile)) in the Great Lakes basin, and the magnitude of the ecological consequences, based on a qualitative scale and corresponding ranking of certainty, for 5, 10, 20, and 50 years from 2014 to the connected Great Lakes Basin.[45]

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[42] See Matrix 1 for details.

[43] In this study, the consumer surplus estimates are assumed to be constant across all levels and for perceived changes for an individual. While this assumption may be plausible for small changes in recreational activities but it may be unrealistic for large changes, this assumption is necessary for the practical application of consumer surplus values. Provided that the consumer surplus estimates may vary by a variety of factors such as differences in recreation site, user population characteristics, methodological differences (Rosenberger & Loomis, 2000), the values are adjusted based on expert judgment.

[44] A suitable example is the sea lamprey, an AIS that has severely impacted the Great Lakes region since its population exploded in the upper Great Lakes in 1940's and 50's (though arrived in 1830's) which subsequently resulted in the signing of the 1954 *Convention on Great Lakes Fisheries* between the governments of Canada and the US. For details, see http://www.dfo-mpo.gc.ca/regions/central/pub/bayfield/06-eng.htm. Another example is Asian Carp. The partial impact being felt in the Mississippi River basin is the result of an invasion that started decades ago, and the consequences have yet to be fully realized.

[45] The Great Lakes Basin was defined as the Great Lakes and its tributaries up to the first impassable barrier. Lake St. Clair was considered to be part of the Lake Erie basin.

While there may be effects of triploid Grass Carp within localized wetlands if Grass Carp populations aggregate in these areas, DFO (2017) ranked the ecological consequences for all lakes negligible with moderate certainty at the lake-scale for all time periods because of their inability to establish. Lakes Michigan, Huron, Erie, and Ontario are most likely to experience increasing ecological consequences within 20–50 years. Lake Superior remained negligible over time given the low probability of introduction. The study further concluded that, under current conditions, there is an expected time lag associated with the full ecological consequences of an established population of Grass Carp in the Great Lakes basin.

In alignment with the conclusions drawn in the DFO (2017)[46] pertaining to ecological consequences, and in compliance to the instructions provided in DFO (2015) the study excludes triploid Grass Carp from detailed socio-economic risk assessment and assumes that following the arrival of diploid Grass Carp, it would take ten (10) years for the impact to be felt in the area where they are present. Therefore, the time periods considered for risk assessments begin in 2024, and are for intervals of 10 years and 40 years as the study uses 2014 as the base year.

The study also adopted an average value of impact where a range of values is provided in DFO (2017) and Cudmore et al. (2017). Cudmore et al. (2017) defined: (i) negligible impact as undetectable changes in the structure or function of the ecosystem (no detectable change in composition of submerged aquatic vegetation); (ii) low impact as minimally detectable changes in the structure of the ecosystem (detectable change in composition of submerged aquatic vegetation (SAV) through to a <10 % decrease in vegetation); (iii) medium impact as detectable changes in the structure or function of the ecosystem (10–24% decrease in SAV at 5 Grass Carp/hectare); and (iv) extreme impact as restructuring of the ecosystem leading to severe changes in abundance of ecologically important species and significant modification of the ecosystem (>50% decrease in SAV at 15 Grass Carp/ha). Accordingly, the current study used 10% decrease as low impact, 17% (an average of 10% and 24%) as medium impact and at least 50% as extreme impact. Moreover, the study assumed symmetric impact of the presence of Grass Carp on all species which is linear over time.

Except for commercial fishing, the study extrapolated baseline values to the base year of 2014 using the inflation rate, given that the data pertained to different years. As information is available for commercial fishing on an annual basis for both Canada and the US, the study will take the average of recent five years data to reduce biasness in estimation.

For the socio-economic risk assessment, adjustments are necessary because future losses are worth less than current losses. Money today, even in an inflation-free economy, is always worth more than money obtained in the future, because of its earning potential as well as the psychic gratification of having money now rather than tomorrow. Therefore, the discounting of future impact was performed according to the Treasury Board of Canada's recommendation of

[46] Sources are discussed in detail later in this chapter under "data sources".

3%. This rate represents the social opportunity cost.[47] The discount formula used for present value is:

$$PV = FV_t / (1+i)^t$$

PV is the present/current value, FV_t the future value in year t, and *i* is the discount rate.

Data Sources

The data used to develop the community profiles around the Great Lakes primarily came from United States Census Bureau and Statistics Canada.[48] While the extant literature provides very limited data on AIS, where appropriate, the study used information available at relevant websites and in the literature as secondary sources of information. Moreover, where information on a particular risk was unavailable, the study used proxies based on rational judgment from the findings of relevant studies in comparable situations with appropriate adjustment(s) as necessary, or made a qualitative assessment of risk. The scenario followed for the study and the assumptions made were based on information derived from DFO (2017) which incorporated existing, ongoing, and new research results to inform the potential for Grass Carp arrival, survival, establishment, spread and impact in the Great Lakes Basin.

Establishing a linkage between ecological risk assessment and human risk has historically been challenging due to uncertainties in terms of the direction and the rate of change in environmental and human behavior. Therefore, in addition to results extracted from DFO (2017), the study greatly benefitted from expert opinion exchanged between a group of subject matter experts involved in the ecological risk assessment and economists involved in the socio-economic study through personal communications. The report was also benefitted from a workshop held on February 11-12, 2015, jointly organized by the GLFC and DFO, with a view to arriving at a shared perspective on the economic value of the Great Lakes from which a number of economic risks and impacts might be explored.[49] This discourse helped to provide a defensible foundation for the socio-economic risk assessment.

It is also important to recognize that projections of the extent and degree of risk caused by AIS

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[47] A discount rate of 7% is usually recommended by TBS. However, TBS also recommended a social discount rate of around 3% in certain circumstances, for example, where consumer consumption is involved. The rationale for using the social discount rate is that a lower rate to assess the impacts reflects the behaviour of individuals and also corresponds to the ethical principle that current generations must always consider the well-being of future generations by complying with a sustainability constraint (Organization for Economic Co-Operation and Development, 2006).

[48] American community profile data was originated from the 2015 American Community Survey, the 2015 Population Estimates, and the US Census (https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml). Canadian community profile data came from a variety of tables provided by Statistics Canada (http://www.statcan.gc.ca/eng/start and CANSIM http://www5.statcan.gc.ca/cansim/a01?lang=eng).

[49] The workshop was attended by representatives from the Great Lakes Fishery Commission, University of Notre Dame, The Nature Conservancy, University of Wyoming, and National Oceanic and Atmospheric Association, Cornell University, Pennsylvania State University, Ontario Ministry of Natural Resources, and Department of Fisheries and Oceans.

are problematic because scientists rarely find opportunities to predict risk in relatively undisturbed environments. Since there is no feasible way to separate out the risk being predicted from the presence of Grass Carp into the Great Lakes from other influences in the economy (e.g. climate change, urbanization), the analyses in the study were premised on scenarios both with, and without, the presence of Grass Carp, holding other variables unchanged. For instance, the study projected that the reductions in native fish populations would be solely caused by Grass Carp. Other changes and/or developments in the economy that might alter the native fish biomass in the Great Lakes were assumed to be absent during the period of analysis.[50] Another implicit assumption for the analysis is that the state and structure of the economic sectors will remain the same as where it is now.

The socio-economic risk reported in the study is mostly speculative providing the best estimates from available research. Furthermore, since DFO (2017) delivered the foundation for the socio-economic assessment, the uncertainties associated with the socio-economic assessment must be greater than, or equal to, that of DFO (2017).

Scope of the Study

The scope of this socio-economic study aligns with the scenario provided by the DFO (2017), particularly in terms of socio-economic risk of the presence of Grass Carp, and includes:

a. a discussion of the methodology used in the study;

b. an overview of the Great Lakes Basin;

c. a description of the baseline scenario by activities predicted to be impacted, based on the available quantitative and qualitative information, and an attempt to reduce and/or eliminate any gaps. The baseline scenario included the current direct human use of the study area, non-market value (e.g. ecosystem value), and a profile of local demographics. The baseline scenario provided a comprehensive socio-economic and ecosystem value of the study area;

d. a description and quantification of the particular risk/impact that are expected to be felt. Qualitative descriptions of risk were provided if they were not quantifiable and/or if no feasible proxies were available; and

e. identification of the uncertainties and shortcomings of the analysis.

[50] Developing ecological and socio-economic risk assessments is an iterative process, which involves researchers identifying and filling data gaps in order to develop an assessment of the risk. This, in turn, influences the need for refining the scope of the risk assessment, further triggering the need for more data and/or new assumptions.

Chapter 3 - Baseline Values of Impacted Activities around the Great Lakes Basin

This chapter provides the situational overview, estimating the economic values generated by the activities occurring in and around the Great Lakes Basin that are perceived to be impacted by the presence of Grass Carp. The values provide baseline values of the activities from which the socio-economic risk of Grass Carp in the Great Lakes Basin is estimated.

As discussed in Chapter 3, the activities included for the development of the baseline are commercial fishing, recreational fishing, recreational boating, hunting, and beach and lakefront use. In order to estimate the economic values of these activities, the study tried to arrive at the best estimates of the expenditures made, as well as the consumer surplus generated by the identified activities, as information from extant literature permitted (see Matrix 2).

The remaining portion of the chapter provides a detailed discussion of the methods applied and then estimates the economic values of the above-mentioned activities occurring in and around the Great Lakes Basin.

Commercial Fishing

Commercial fishing and associated industries are significant employers, particularly, in many smaller Great Lakes communities, and are an important economic development initiative for many Aboriginal communities in the Great Lakes region.

The Ontario Ministry of Natural Resources and Forestry (OMNRF) is responsible for regulating Ontario's commercial fishery. According to OMNRF (2015) there are nearly 650 active commercial fishing licences in Ontario, of which 160 are held by First Nations communities and First Nations and Métis individuals.

According to data supplied by OMNRF, during 2010-14, on average 12,575t of fish were commercially caught annually from the Great Lakes, generating an estimated average landed value of $33.0 million. OMNRF (2015) estimated that, in 2011, commercial licence holders caught nearly 12,000t of fish for which the dockside/wholesale[51] value was CAD33.6 million. Once the fish had been processed and sent to food stores and restaurants in Ontario, the US and around the world, the industry's total contribution to the economy was CAD234 million to Ontario's economy. This implies that the value added to the landings by the processors resulted in a value more than seven times higher than the dockside value.

For the US side of the Great Lakes, according to the US Bureau of Labor Statistics, there were 93 fishing industry establishments operating in the Great Lakes states in 2014. According to the National Oceanic and Atmospheric Administration National Marine Fisheries Service (NOAA

[51] "Dockside value" refers to the price paid for the fish as it comes off the boat and before it is processed.

NMFS), during 2010-14, on average annually 7,792t of fish were landed, generating an estimated average landed value of $20.7 million (see Table 3). [52]

Table 3: Average Landings, Landed Values ($000) and Market Values ($000) of Commercial Fishing in the Great Lakes during 2010-14

Variables	Canada**			The US			Total Great Lakes		
	Landings (kg)	Landed Value (USD)	Market Value (USD)	Landings (kg)	Landed Value (USD)	Market Value (USD)	Landings (kg)	Landed Value (USD)	Market Value (USD)
Erie*	10,374	$26,956	$188,693	2,543	$5,394	$37,759	12,917	$32,350	$226,452
Huron	1,680	$4,971	$34,795	1,319	$3,790	$26,533	2,999	$8,761	$61,328
Michigan	NA	NA	NA	2,439	$8,047	$56,331	2,439	$8,047	$56,331
Superior	341	$515	$3,606	1,468	$3,398	$23,783	1,809	$3,913	$27,389
Ontario	180	$471	$3,299	23	$87	$607	203	$558	$3,906
Grand Total	**12,575**	**$32,913**	**$230,393**	**7,792**	**$20,716**	**$145,013**	**20,367**	**$53,629**	**$375,406**

Sources: (i) Ontario Ministry of Natural Resources; (ii) National Oceanic and Atmospheric Administration, Office of Science and Technology, Fisheries Statistics Division.
*Note: NA – Not Applicable; * Lake Erie landings included landings occurred in Lake St. Clair; ** The numbers have been converted to USD by applying exchange rate between CAD and USD for the respective year.*

However, neither the existing data nor the literature provides the total economic value (e.g. WTP) of commercial fishing generated for the Canadian economy. With respect to the contributions of the Great Lakes commercial fishery, it should be noted that since the fishing industry is fairly competitive because of the availability of close substitute goods (e.g. fish from other parts of Canada or meat), the associated consumer surplus could be safely assumed to be insignificant.

Therefore, to calculate the total economic contributions of commercial fishing in the Great Lakes, the present study tallies only the market values of the landings, calculated by applying the ratio of market value to dockside value (as mentioned above) to the average landed value during 2010-14 for both Canada and the US.[53] Following this approach, the economic contributions of commercial fishing in the Great Lakes for Canada and the US are estimated to be approximately $230 million and $145 million per year, respectively (see Table 3). However, it should be noted that the economic contributions of commercial fishing may have differed from actual contributions to some extent because market price proxies were used to fill in the gap in market value/price data.

[52] For details on landings and landed values of commercial fishing in the Great Lakes for both Canada and the US by Lake during 2010-14, see Annex 3B.
[53] In the absence of the value added information for the US side of the Great Lakes, the study applies the ratio of market value to dockside value calculated for the Canadian side of the Great Lakes. Another feasible approach is to multiply the landings by an estimated market price for the year 2008. The limitation of this approach is that it fails to capture the changes in price over time. For example, landed price increased from $0.88/lb in 2008 to $1.27/lb in 2011. The approach adopted in the study allows inclusion of this price dynamism in the estimation.

Recreational Fishing

The anglers in the Great Lakes are made up of residents of Great Lakes States/Provinces, and non-residents and foreign anglers visiting Canada and the US.

There are a number of sources (e.g. U.S. Fish and Wildlife Service, 2014; Austin et al., 2007; DFO, 2008; EC, 2000) that estimated the value of recreational fishing in the Great Lakes, employing different methodologies (e.g. survey question sequencing, Nested Logit models).

For Canada, the most relevant and recent information on expenditures incurred for recreational fishing in the Great Lakes was estimated in DFO (2008). Moreover, the consumer surplus value associated with recreational fishing that is not captured by expenditures is reported in a couple of studies (e.g. EC, 2000; Rosenberger, 2016).

DFO (2008) estimated a total of 441,263 anglers spent 4.8 million angling days in the Great Lakes including connecting rivers in 2005 (see Table 4). Of the total 4.8 million days fished, resident anglers accounted for about 4.2 million days, while non-resident Canadian anglers accounted for 23,412 days fished in the Great Lakes basin. Foreign anglers accounted for the remaining 11.5% of days (554,000).[54]

Table 4: Great Lakes Anglers and Days of Fishing in Canada by Lake in 2005

Great Lake	Anglers Number		Fishing Days	
	Resident	Non-resident and Foreign	Resident	Non-resident and Foreign
Lake Ontario	85,699	10,849	971,610	57,046
Lake Erie	62,684	10,477	725,362	64,308
Lake St. Clair	21,519	21,150	261,014	120,039
Lake Huron	135,389	26,732	1,756,366	226,282
Lake Superior	25,010	11,657	183,695	56,368
St. Lawrence River	20,175	9,922	324,595	53,401

Source: DFO (2008).

In terms of expenditures, DFO (2008) estimated that anglers spent a total of CAD214.6 million (equivalent to USD177 million) in Canada in direct expenditures and invested CAD228.3 million (equivalent to USD189 million) in major purchases and investments that could be wholly attributable to recreational fishing in the Great Lakes in 2005.[55] The total direct expenditures

[54] Resident anglers fished an average of 14 days, non-resident Canadians averaged 5 days and foreign anglers averaged 7 days. All anglers caught 23.6 million fish of all species on the Great Lakes in 2005. Resident anglers caught over 19.5 million of the total harvest. Foreign anglers caught 4.1 million and only 86,000 fish were caught by Canadian non-residents (DFO, 2008).

[55] The amount remained relatively stable over the past 10 years in terms of current dollars.

and major purchases/investment in recreational fishing in the Great Lakes for Canada was estimated at CAD443.0 million (equivalent to USD366 million) (see Table 5, Annex 4A and 4B).

Table 5: Major Purchases/Investments and Direct Expenditures ($000)* by Type of Anglers and Lake, 2005

Variables	Lake Ontario	Lake Erie	Lake St. Clair	Lake Huron	Lake Superior	St. Lawrence River	Total
Major Investments	**$39,621**	**$41,929**	**$11,704**	**$57,148**	**$8,502**	**$29,740**	**$188,644**
Resident Angler	$39,175	$37,932	$11,667	$51,287	$6,212	$29,530	$175,802
Non-Resident Angler	$102	-	$17	$2	-	$2	$121
Foreign Angler	$344	$3,998	$21	$5,860	$2,290	$208	$12,721
Direct Expenditures	**$37,108**	**$27,563**	**$11,488**	**$76,095**	**$14,093**	**$10,909**	**$177,257**
Resident Angler	$32,399	$24,257	$6,737	$57,557	$7,523	$6,366	$134,839
Non-Resident Angler	$1,153	$2	$1	$295	$35	$228	$1,713
Foreign Angler	$3,556	$3,305	$4,750	$18,243	$6,535	$4,316	$40,704
Grand Total	**$76,730**	**$69,492**	**$23,192**	**$133,244**	**$22,594**	**$40,649**	**$365,901**

Source: DFO (2008).
*Note: * The numbers have been converted to USD by applying exchange rate between CAD and USD for 2005.*

Ready et al. (2012) estimated that 6.6 million anglers lived and fished in the 12-state study area in 2011. The Great Lakes fishing accounted for 32.8 million days (GL Warm, GL Cold and Anadromous). The study also found that, of the overall average of 28.0 days of fishing on day trips annually, Great Lakes fishing (coldwater, warmwater, and anadromous runs) accounted for 3.8 days of fishing. About half of Great Lakes fishing day trips (1.9 days) were for warmwater species. Moreover, of the overall average of 3.3 days of fishing on overnight trips annually, Great Lakes fishing accounted for 0.6 days of fishing. About half were for warmwater species and half were for trout and salmon.

Table 6: Great Lakes Anglers and Days of Fishing in the US by Lake in 2011

Great Lake*	Anglers$^{\alpha}$ (in 000)	Angling Days (in 000)	Trip and Equipment Expenditures ($000) *Direct Expenditures*	*Investments*	*Total*
Lake Ontario$^{\beta}$	143	2,214	$93,100	$66,236	$159,335
Lake Erie$^{\Omega}$	639	8,451	$416,019	$295,977	$711,995
Lake Huron$^{¥}$	262	4,410	$170,574	$121,355	$291,929
Lake Michigan	413	2,585	$268,882	$191,297	$460,179
Lake Superior	147	1,527	$95,704	$68,089	$163,793
Tributaries	159	1,254	$103,517	$73,647	$177,164
Grand Total	**1,665**	**19,661**	**$1,147,795**	**$816,600**	**$1,964,395**

Source: U.S. Fish and Wildlife Service (2014)
*Note: * Numbers for Lake St. Clair, including the St. Clair River, and St Lawrence River were found negligible; α Detail for participants does not add to total because of multiple responses; β includes Niagara River; Ω includes Detroit River; ¥ includes St. Mary's River.*

U.S. Fish and Wildlife Service (2014) estimated a total of 1.7 million recreational anglers (resident – 1.5 million; non-resident/foreign – 224K) spent 19.7 million days on 15.2 million trips on the US side of the Great Lakes in 2011 (see Table 6).[56] Of the total 19.7 million days fished, resident anglers accounted for about 18.2 million days, while non-resident/Foreign anglers accounted for 1.5 million days fished in the Great Lakes basin.

In terms of expenditures, anglers spent $1 billion in direct expenditures in 2011 (see Table 6, Annex 4C and 4D). Moreover, the total direct expenditures and major purchases were $2 billion and accounted for 15% of the total expenditures made in the 8 Great Lakes states ($12.1 billion). Since expenditures and investment is not available by Lake, the study extrapolated the numbers by lake by using the proportion of anglers by lake (expenditure - $689; purchases – $491 (inflation adjusted for 2014)) reported in U.S. Fish and Wildlife Service (2014).

Another aspect of recreational fishing is bait fishing, a substance used to attract and catch fish. Bait harvesting (often harvested from mixed stocks in the wild) occurs throughout North America (Drake and Mandrak, 2014), with the bulk of the baitfish coming from southern Ontario, particularly from Lakes Simcoe and Erie. Approximately 60% of anglers in Ontario use live baitfish. Approximately 1,200 commercial bait licences are issued every year, representing an industry worth over CAD20 million annually. The bait industry harvested approximately 144 million fish in 2010. Of these, 60% or approximately 86 million were mixed bait species. Among the remaining 40%, Emerald Shiner made up the majority, with over 58 million harvested and Cisco with over 90,000 harvested. Leeches are also an important bait species, with over 26 million harvested commercially in 2010 (OMNRF, 2015).

According to the USDA (2014), there were 66 baitfish farms in the Great Lakes states in 2012 with USD6 million in sales. These accounted for 40% of baitfish farms in the US and over 20% of total sales. Around 94% of Great Lakes baitfish sales come from Minnesota, Ohio, and Wisconsin, while fathead minnows and suckers make up the large majority of baitfish sold. It is, however, unclear how much, if any, of this baitfish production is produced or dependent on the Great Lakes.

Pertaining to the estimation of consumer surplus, although the range of values provided by the literature is broad, there are some convergences across studies.

From the Canadian context, based on the results of a survey conducted in 1996, EC (2000) estimated the daily consumer surplus associated with recreational fishing in Canada to be CAD11 in 1996 dollars. Dupont (2003) presented WTP values for three user categories (active user, potentially active user and passive user) with respect to three recreational activities (swimming, boating and fishing) using data for Hamilton Harbour, Ontario. The fishing estimates ranged from CAD11 - CAD39 for unspecified improvements to recreational fishing. DSS (2008) calculated trip value (the aggregate consumer surplus for a given angling product

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[56] The discrepancy from the number reported in Ready et al. (2012) is likely due to the generally fewer days fished on average reported by National Survey respondents and the generally wide confidence intervals associated with National Survey data at the state and regional levels.

was divided by the forecasted total number of trips from all origins) ranging from CAD9 to CAD148 for the Credit River Watershed, which drains into Lake Ontario between Toronto and Hamilton. Using a similar methodology followed by DSS (2008), Marbek (2010) calculated an average trip value of CAD41 for the same watershed.

The most recent estimate was provided by Recreation Use Values Database for North America (henceforth referred to as Rosenberger (2016)) that contains contained 421 documents of economic valuation of recreation activities in the US and Canada from 1958 to 2015, totaling 3,192 estimates in per person per activity day units, adjusted to 2016 USD. Rosenberger (2016) compiled 957 estimates and reported a mean use value of freshwater fishing in Canada at $18 per angler-day in 2016, which is similar to the value reported by EC (2000) after inflationary adjustments.

As for the US, previous fisheries research conducted in the Great Lakes suggests a range of $20-$75 as the likely net value per fishing day in the Great Lakes. Following the contingent valuation methodology, based on 39 studies and 122 estimates for the US, Rosenberger & Loomis (2000) presented a range of estimates for consumer surplus of fishing (cold water, warm water, and salt water) to be $2 - $211. Apogee (1990) used a value of $70/angler day in consumer surplus for recreational fishing on the Great Lakes. Using literature review, Kaval (2007) created a database that reported consumer surplus for fishing in US parks in the amount of $53/person per day. Loomis (2005) compiled five literature reviews on recreational use values and found a mean value of $47/day for fishing. Ready et al. (2012) estimated that average net value at $20/angler day which was strictly applicable only for changes that result in small changes in fishing behavior. The study also noted that the value was at the lower end of the predicted range of $20-$75 probably because it was based on not only Great Lakes fishing but also fishing in inland waters which was less highly valued.

Rosenberger (2016) compiled 957 estimates and reported that the mean use value of freshwater fishing in Midwestern US was $48/angler day in 2016, a value consistent to the value reported by Loomis (2005).

Therefore, to calculate the total economic contributions of recreational fishing in the Great Lakes for Canada and the US, the present study added inflation adjusted expenditures on recreational fishing in the Great Lakes (estimated by DFO (2008) for Canada and U.S. Fish and Wildlife Service (2014) for the US) and the estimated economic values using information provided by Rosenberger (2016) for both Canada and the US. In the absence of lake specific information for the US, the study extrapolated the consumer surplus for the US by lake using the proportion of angling days by lake reported in U.S. Fish and Wildlife Service (2014).

Following this approach, the economic contributions of the recreational fishing in the Great Lakes was estimated to be $556 million/year (expenditures – $471 million; consumer surplus – $84 million) for Canada and $3 billion/year (expenditures – $2 billion; consumer surplus – $1 billion) for the US side of the Great Lakes.

It should be noted that no single study reviewed in this sub-section covered the entire study area. Therefore, the numbers used as well as adjustments were based on best available information. However, given that both spending propensities and consumer surplus values vary across states/provinces, recreational sites, targeted fish species and fishing type, the proxies applied to estimate the economic values of recreation fishing in the Great Lakes may have caused biases to some extent. Finally, the numbers presented for Canada and the US should not be directly compared and also with those provided in the extant literature, because of the differences in methodology followed by different studies/surveys that includes but not limited to differences in scope, estimation procedures, time periods considered, and industries covered.

Recreational Hunting

Many bird species migrate through and use the Great Lakes. Wetlands, including coastal marshes and freshwater estuaries, of the Great Lakes provide important and productive nursery areas for many bird species, which rely on these habitats for protective structure, hunting grounds, migration stops, and raising offspring. The most common breeding waterfowl in the Great Lakes region include mallards, blue-winged teal, wood ducks, ring-necked ducks, and Canada geese. Inland and coastal marshes are vital to ensure food and cover for staging waterfowl, especially during the spring (Yerkes (undefined)).

A few studies (e.g. OMTCS TRU, 2017; Rosenberger, 2016; US FWS 2014; EC, 2000) provided estimates of the number of hunters and the economic values of hunting activities at provincial/state level in Canada and the US.

From the Canadian context, EC (2000) found that residents of Ontario spent $201 million on hunting wildlife. The average hunter spent $CAD639 during the year, or CAD37/day of participation. The Federal, Provincial, and Territorial Governments of Canada (2014) found that Ontarians spent CAD68 million in 2012 on Waterfowl hunting and that the average Canadian waterfowl hunter spent CAD83/day or CAD609/year in 2012.

Using data from Statistics Canada's Travel Survey on hunting visitors in Ontario, OMTCS TRU (2017) estimated that there were 442,000 visits spending a total of CAD138 million (average CAD311/hunter per trip). Raftovich et al (2012) reported that there were 56,305 migratory bird permits issued in Ontario in 2011.

From the US context, US FWS (2014) estimated 5 million hunters who participated in hunting activities in the Great Lakes states spent 93 million hunting days (both resident and non-resident) and expended $10.3 billion in the Great Lakes states in 2011. The average hunter spent $2,085 that year.

Literature pertaining to the economic benefits of hunting activities (e.g. waterfowl) occurring in and around the Great Lakes is sparse. Austin et al. (2007) estimated that approximately 20,000 hunters and 200,000 hunting trips depend on Great Lakes ecosystems each year in the US.

These estimates are based on 5% of the estimated 400,000 waterfowl hunters and up to 4 million days of waterfowl hunting per year in the Great Lakes states in 2004 and 2005.

Pertaining to the estimation of consumer surplus, EC (2000) estimated that the consumer surplus associated with hunting (included only waterfowl) in Ontario was CAD220/yearly or CAD18/daily, in 1996 dollars. Rosenberger (2016) estimated a mean value of $18/day per person consumer surplus for waterfowl hunting in Canada.

For the US, Austin et al. (2007) applied $32 per trip to 200,000 Great Lakes waterfowl hunting days and estimated a surplus value of hunting in the amount of USD6.4 million around the Great Lakes in the US. Gan and Luzar (1993) estimated a WTP in the amount of $396 to increase the daily duck bag limit from three ducks per day, with lower and upper limit estimates of $327 and $491, respectively. Using meta-assessments of the literature based on 13 recreation demand studies carried out during 1967-1998, Rosenberger et al. (2001) presented a range of $4 - $250 consumer surplus per waterfowl hunting day. Applying conjoint valuation approach analysis on waterfowl hunters in Louisiana,[57] Kaval (2007) found that consumer surplus for hunting in US parks was $48 per day. Loomis (2005) found a mean surplus of $47 per day for hunting in the US. Rosenberger (2016) estimated a mean value of $35/day per person consumer surplus for waterfowl hunting in the Mid-Western part of the US.

In summary, the recreational hunting related expenditures provided in the extant literature for Canada is not Great Lakes specific and provides insufficient information on consumer surplus to enable the present study to use reliable proxies to estimate economic values of recreational hunting on the Canadian side of the Great Lakes. Hence, the present study refrains from estimating economic values of recreational hunting around the Great Lakes in Canada.

On the other hand, while not Great Lakes specific, the literature contained adequate information that may be used as proxies to estimate economic values of recreational hunting on the US side of the Great Lakes. Therefore, in the absence of hunting related expenditures in and around the US side of the Great lakes, following Austin et al. (2007), the present study applied 5% to US FWS (2015) reported numbers. Moreover, the consumer surplus generated by these activities was estimated by multiplying number of waterfowl hunting days and consumer surplus per day estimated by Rosenberger (2016) for the Mid-Western US.

Following this approach, the present study estimated that economic contributions of recreational hunting activities around the Great Lakes in the US at $30 million/year (expenditure - $$21.6 million; consumer surplus - $8.8 million (inflation adjusted for 2014)).[58]

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[57] Conjoint valuation approach analysis, widely used in marketing research, offers an alternative resource suited to outdoor recreational activities characterized as multi-attribute.

[58] Please note that the number only includes waterfowl hunting by US residents and excludes all other hunting and foreign hunters. Hence, the number estimated here should be considered as a very conservative estimate of hunting activities in the Great Lakes. US FWS (2015) estimated that waterfowl hunters constituted 11% of all hunters, 6% of all hunting trip-related expenditures, and 7% of all hunting equipment expenditures in the US.

Recreational Boating

Despite a relatively short boating season compared to the rest of Canada and the US, boating in the Great Lakes provides a great deal of activity and enjoyment and supports a number of industries in the Great Lakes region, generating income and jobs especially in coastal communities. The Great Lakes Commission (Undefined) reported that there were about 4.3 million recreational boats (a third of all US recreational vessels) in the eight Great Lakes states and that nearly one-quarter of all recreational boats in the Great Lakes states belonged to residents of Great Lakes shoreline counties.[59] The U.S. Army Corps of Engineers (2008) estimated that 17 million boating days occurred on the Great Lakes and connecting waters in 2003, representing 18% of all boating in Great Lakes states. More than half of all boats kept at marinas in Great Lakes states are stored at marinas providing access to the Great Lakes and connecting waters.

From the Canadian context, More than 910,000 boats are used primarily on Great Lakes waters. There were 1.8 million recreational boats in Ontario (NMMA Canada, 2012), of which approximately 780,000 (65%) were used in the Great Lakes.[60] Every year, more than 1.5 million recreational boaters travel the waters of the Great Lakes (OMNR, 2012). The Québec Marine Trade Association estimates that of Québec's estimated 879,000 recreational boats, 93% (813,075) are used on the St. Lawrence River.[61]

Several studies (e.g. Dutta, 1984; Hushak, 1999, Dupont, 2003; The U.S. Army Corps of Engineers, 2008; Ready et al., 2012) have assessed the economic values associated with recreational boating in the Great Lakes from the Canadian and/or the US context.

From the US side, using travel-cost method, Dutta (1984) found that the economic value of recreational boating and fishing activities in the Central Basin of the Ohio portion of Lake Erie was USD48.44 million in 1982. Hushak (1999) estimated that the total boating expenditures of Ohio's boat-owning households was $2.6 billion during October, 1997 - September, 1998. Recreational Marine Research Center at Michigan State University estimated that an average boat owner using the Great Lakes spends about $3,600 per year on vessel ownership, including $1,400 on craft-related expenses (e.g., equipment, repairs, insurance, slip fees) and $2,200 on boating trips (e.g., gas, oil, food, lodging) involving an average of 23 boating days (cited in The U.S. Army Corps of Engineers, 2008).

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[59] Michigan, with its considerable Great Lakes coastline, recorded nearly one million recreational boats, followed by Indiana with 216,145 and Pennsylvania with 3% recreational boats that belong to people residing in Erie County (The U.S. Army Corps of Engineers, 2008; (Great Lakes Commission Feature Report, Undefined)).

[60] Drake, Bailey and Mandrak (2017) conducted a survey on 767 active recreational boaters in Ontario and found that nearly 40% of respondents used their boat in the Great Lakes Basin and in inland waters in 2009.

[61] See http://www.miseagrant.umich.edu/discovernemi/images/PDF/GLC-rec-boating-final.pdf. Recreational boating was estimated to be the highest in the lower lakes and urban areas (e.g. Toronto, Chicago). However, marinas were also abundant in some less populated areas, such as Georgian Bay (Allan et al., 2015).

The U.S. Army Corps of Engineers (2008) estimated that registered boaters using the Great Lakes and connecting waters spent 17 million boating days and expended $3.8 billion in 2003 ($2.4 billion in trip-related expenses and $1.4 billion in craft-related expenses).[62]

NMMA Canada (2012) estimated that the total direct and indirect and induced expenditures from recreational boating in Ontario was in the amount of CAD3.5 billion in annually, but provided no specific estimate for the Great Lakes. Only Krantzberg et al. (2006) provided the value of recreational boating in Canadian Great Lakes which was interpolated from US values using proportional population estimates. The study estimated the economic value of boating in Canadian Great Lakes at CAD2.2 billion annually.

With respect to consumer surplus, using travel-cost method, Dutta (1984) found that the economic value of recreational boating and fishing activities in the Central Basin of the Ohio portion of Lake Erie was $48.44 million in 1982. Rosenberger and Loomis (2001) estimated net value per motorized boating trip at $34 and for float boating at $62 per person. Connelly, Brown, and Brown (2007) estimated mean net economic value (above current expenditures) per day per boat at $69 for boating on Lake Ontario and on the St. Lawrence River. Rosenberger (2016) reported mean use value of nonmotorized boating at $20/person per day and motorized Boating at $34/person per day for the Midwestern part of the US in 2016.

Dupont (2003) estimated that the median WTP for improvements to Hamilton Harbour, Ontario, Canada, to support recreational boating was in the CAD8 to CAD43 range for passive and active boating users, respectively. In a contingent valuation study of recreational boating on Lake Ontario and the St. Lawrence River in 2002, Connelly et al. (2005, 2007) reported that average net value per recreational boating day to be almost $87 ($2012) or $29 of net value per person per day assuming equal distribution of net value among people on the boat. Though no specific value was provided for boating, EC (2000) estimated that the consumer surplus associated with outdoor activities in natural areas[63] for Ontario residents was CAD147/person annually, or CAD10/person per day, in 1996 dollars. Rosenberger (2016) reported that the mean use value of nonmotorized boating was $80/person per day for Canada in 2016 (no motorized boating estimate was provided).

Therefore, the present study only considers inflation adjusted recreational boating expenses estimated by the U.S. Army Corps of Engineers (2008) for the US and inflation adjusted recreational boating expenses estimated by Krantzberg et al. (2006) for Canada. Since the extant literature suggests substantial variations in the estimations of net values or consumer surpluses across different types of boating activities and locations, the present study refrains from estimating consumer surplus associated to recreational boating in the entire study area.

[62] An estimated 107,000 boats were kept at Great Lakes marinas and the boat owners spent $665 million on trip-related expenses and $529 million on craft-related items during boating season in 2003.
[63] "Outdoor activities in natural areas" included sightseeing, photographing, gathering nuts, berries and firewood, picnicking, camping, swimming/beach activity, canoeing/kayaking/sailing, power boating, hiking/backpacking, climbing, horseback riding, cycling, downhill skiing, snowmobiling and relaxing in an outdoor setting.

Following this approach, the economic contributions of recreational boating around the Great Lakes are estimated to be $2.3 billion and $4.9 billion per year in Canada and the US, respectively.

Beaches and Lakefront Use

Beaches support a diversity of wildlife habitats, numerous rare species, and globally significant features such as barrier beach-dune ecosystems. Public-access beaches are widely distributed among the Great Lakes, except for Lake Superior and northern Lake Huron where beaches are markedly fewer. Beach use is estimated to be highest near cities but substantial lengths of shoreline of all of the Great Lakes, with the exception of Lake Superior, have moderate to high estimated number of beach use (Allan et al., 2015).

Ontario has nearly 300 public beaches along Great Lakes coast (Ontario's Great Lakes Strategy, 2016). In the US, Michigan, for example, is surrounded by four Great Lakes (Superior, Michigan, Huron, and Erie (including Lake St. Clair)) and has 594 identified public beaches providing enormous recreational opportunities (Song, Lupi & Kaplowitz, 2010). Austin et al. (2007) estimated that the annual number of swimmers and swimming days at Great Lakes beaches were 8 million and 80 million, respectively. The benefits of beach and lakefront use along the Great Lakes reported in extant literature vary across estimation technique, scope of work and water bodies.

From Canadian context, using survey data and the travel-cost method, Sohngen et al. (1999) estimated that the recreational value of a day trip to Lake Erie beaches was in the range of CAD26 - CAD44. Using data from a 1995 contingent valuation study of recreational improvements for Hamilton Harbour, Hamilton, Ontario, Dupont (2001) estimated individual, sex-specific WTP for swimming, boating, and fishing in the Harbour, and found that the mean WTP for swimming for men and women were CAD30.55 and CAD27.69, respectively. Those values were much lower than a recent study that investigated the WTP for improvements to Hamilton Harbour, which determined the range to be CAD16.06 - CAD75.18 for swimming activities (Marbek, 2010b). Krantzberg et al. (2006) estimated the WTP value for Canadian Great Lakes beach goers to be in the range of $197 - $247 million (CAD200 - CAD250 million), which was derived by proportionally scaling the value derived by Shaikh (2004) for the US.

From the US perspective, Chen (2013) estimated 20.9 million day trips taken by Michigan adults to public Great Lakes beaches in the summer of 2011. The value of access to a public beach for a day trip was estimated to be $32-$39/person per trip and over $400 million per season to all Lake Michigan public beaches for day trips for adults living in Lower Peninsula of Michigan. The resulting values were about $53/person per beach day for access to a site for a trip of four nights or longer. Using results from a survey of 1500 Chicago beach-goers, Shaikh (2006) estimated that the average day at the beach was worth approximately $35/person. The total seasonal value for beach-goers was estimated in the range of $800 million - $1 billion for US population using Great Lakes beaches (cited in Krantzberg et al., 2006). Song et al. (2010)

estimated that the average value of a site per trip to a specific Great Lakes beach site in Michigan is $47 ranging $38 - $58.

In the absence of more recent information of these activities in the Great Lakes in Canada and the US, to calculate the total economic contributions of beaches and lakefront use, the present study used inflation-adjusted average value from a range of values estimated by Krantzberg et al. (2006) for Canada and inflation-adjusted average value from a range of values estimated by Shaikh (2006) as cited in Krantzberg et al. (2006) for the US.

Following this approach, the economic contribution of Canada's beaches and lakefronts around the Great Lakes is estimated to be $235 million and $1.1 billion per year for Canada and the US, respectively.

It should be noted that in addition to likely errors associated with adjusting the original numbers, the assessment made here likely underestimated the actual contributions of these activities, as the numbers estimated are only for beach use excluding other lakefront activities (e.g swimming, picnicking, spending leisure time).

Wildlife Viewing

The Great Lakes watershed includes some of North America's more fascinating wildlife. The Great Lakes watershed/region is important for many species of resident birds for breeding, feeding, and resting, particularly waterfowl and birds that nest in colonies and millions of migratory birds that pass through during spring and fall.[64]

Because of the variations of the Great Lakes different varieties of fish and other aquatic wildlife can be found in each lake. Highly visited birding locations within 5 km of the shoreline occur around all five Great Lakes. The Lake Michigan hosts a wide range of bird populations, including water birds (e.g. ducks, geese, robins, eagles). Similarly, many bird species (e.g. hawks, owls) are commonly seen in Lake Superior.[65] Swans, ducks, geese, hawks and other waterfowl are among the wildlife that inhabit in Lake Ontario (Live Science, 2013, May 3). Birding sites are abundant around Lake Ontario, most of Lake Erie (e.g. Long Point Park), and lakes Michigan and Huron[66], with fewer along the Canadian shores of lakes Huron and Superior, where population is sparser and road access to shorelines is limited (Allan et al., 2015).

[64] https://www.nwf.org/en/Educational-Resources/Wildlife-Guide/Wild-Places/Great-Lakes.

[65] A small population of endangered whooping cranes (one of only two crane species in North America) is reported to be seen on the lake's north shore. Duluth's Hawk Ridge, (the lake's north shore), hosts as many as 10,000 migrating birds of prey each day during the fall migration season (Live Science, 2013, May 3)..

[66] Around Saginaw Bay, a bay within Lake Huron located on the eastern side of the U.S. state of Michigan, waterfowl and shorebirds, Caspian terns and black-crowned night herons are seen year round. In May, visitors can also see pike spawning in the open water. Magee Marsh along Lake Erie in northwest Ohio attracts a variety of birds during their spring migration and about 100,000 human visitors annually (Zuzelski and McCole, Undated).

A number of studies highlighted the high significance of wildlife viewing for Canada and the US. However, estimation of the economic values generated by wildlife watching specifically for the Great Lakes is sparse. Moreover, the estimates are largely available for birdwatching and exclude other wildlife watching activities.

From the Canadian perspective, EC (2000) also reported that Ontario residents, on average, spent CAD263/year or CAD16/day on wildlife viewing. The Federal, Provincial, and Territorial Governments of Canada (2014) found that Ontarians spent CAD176 million on birding annually. The average participant spent 139 days birding annually, spending CAD11/day.

From the US perspective, the US FWS (2014) estimated 23 million participated in at least one type of wildlife-watching activity including observing, feeding, or photographing fish and other wildlife and spent $11.5 billion in the Great Lake states in 2011.[67] Austin et al. (2007) estimated birding activities for the Great Lakes and found that there were about 17 million bird watchers in the Great Lakes states and 5 million in the Great lakes basin in the US. Out of 5 million bird watchers, 2 million are estimated to be visiting the Great Lakes once per year on average implying about 2 million birding trips to the Great Lakes annually.[68]

Kerlinger (unspecified) estimated annual spending by active bird watchers in the US averages between $1,500 and $3,400 with travel being the major expenditure.

Pertaining to consumer surplus, EC (2000) estimated that the consumer surplus associated with wildlife viewing in Ontario was CAD88/yearly or CAD8/daily, in 1996 dollars. Reviewing literature spanning 1967 to 1998, Rosenberger and Loomis (2001) found that the consumer surplus for wildlife watching activity was in the range of $2 - $162/person/day in 1996 dollars. Rosenberger (2016) estimated the mean consumer surplus of wildlife viewing for Canada and the Midwestern US at $13/day and $52/day, respectively.

From the Great Lakes context, using the contingent valuation method, Hvenegaard (1989) estimated that bird-watching expenditures were CAD224/trip, or CAD66/day, for trips to Point Pelee National Park, Ontario, in 1987. Birders staying for a day incurred average expenses of approximately CAD54/day, CAD75/day for a 2-3 day stay, and CAD74/day for stays ≥4 days. The willingness to pay (or "net economic value") was estimated to be in the amount of CAD256/trip or $76/day.

Based on an average surplus value of $50/trip (calculated from a range of $40 – $153 per trip) generated by birding, Austin et al. (2007) estimated that the total surplus value of birding on the US side of the Great Lakes is about $100 million annually.[69]

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[67] Includes away-from-home activities of at least 1 mile and around-the-home activities. Secondary watching, such as incidentally observing wildlife while pleasure driving, is not included. For details, see US FWS (2014).
[68] Nationally, about 69% of trips are estimated to sites associated with lakes and streams and 47% of trips are to sites associated with marshes, wetlands, and swamps.
[69] The estimation excluded birders living outside the Great Lakes region.

As most of the values reported in the literature were not Great Lake specific, to calculate the total economic contributions of wildlife viewing on the US side of the Great Lakes, the present study the wildlife viewing values estimated by Austin et al. (2007) and adjusted for inflation. For Canada, the present study concluded that the existing literature did not provide information on wildlife watching expenses on the Canadian side of the Great Lakes. Therefore, the study refrained from estimating the wildlife watching activities for Canadian side of the Great Lakes due to a lack of a suitable proxy to reliably estimate the expenses that could be used in parallel to the wildlife watching numbers provided for the US side of the Great Lakes.

Following this approach, the economic contributions of bird watching around the Great Lakes in the US is estimated to be $121 million/year. It should, however, be noted that the estimated values were, to some extent, underestimations of the actual contributions, as it only includes bird watching and excludes other wildlife watching activities as well as the relevant values generated by non-residents and foreign participants.

Ecosystem Services

Healthy ecosystems in the Great Lakes support sustainable industries, local economies as well as benefit people across Canada and the US. The Great Lakes ecosystem contains habitats such as forests, marshes, wetlands, and dune communities that allow for over 3,500 species of plants, including over 170 fish species, mammals, and amphibians to inhabit the basin.[70] The northern parts of the Great Lakes region contain dense coniferous and northern hardwood forests, while the southern parts contain largely grasslands and prairies.

Table 7: The Great Lakes Basin - Binational coastal wetland area

Lake/River	Area (Ha)
Lake Superior	26,626
St. Marys River	10,790
Lake Huron	61,461
Lake Michigan	44,516
St. Clair River	13,642
Lake St. Clair	2,217
Detroit River	592
Lake Erie	25,127
Niagara River	196
Lake Ontario	22,925
Upper St. Lawrence River	8,454
Total	**216,546**

Source: Environment Canada (2006)
Note: Identified coastal wetland area within the Great Lakes and connecting rivers up to Cornwall, Ontario.

The Great Lakes wetlands ((marsh, swamp, bog and fen) are located near and along the many lakeshores (e.g. Matchedash Bay on Georgian Bay (Great Lakes Fact Sheets, Environment

[70] Ibid. footnote 20.

Canada (Unspecified)). In the Great Lakes Basin, more than 216,000 hectares of coastal wetlands have been identified of which almost 50% is found in the Lake Huron and Lake Michigan sub-basins (see Table 7).

Through maintaining these complex ecosystems and biodiversity, the Great Lakes provide invaluable services to society - some are captured with the corresponding direct benefits while some are indirect/intrinsic. Examples of direct benefits of healthy ecosystems are commercial fishing and recreational fishing/activities. On the other hand, Indirect ecosystem services include but are not limited to natural local climate regulations, flood protection, erosion control and sediment retention, soil formation, nutrient cycling, waste treatment, water regulation, and stored carbon.[71,72] The intrinsic values of ecosystems and biodiversity, which is the focus of discussions of this sub-section, are harder to define because they are much more intangible (Krantzberg et al., 2008, 2006).

The EPA estimates that an acre of wetlands holds as much as 1 million gallons of floodwater and reduces flood peaks by as much as 60%. Based on extant literature, Ducks Unlimited (undefined) reported that the value of total ecosystem services (clean water, flood protection, fish and wildlife, habitat, etc.) derived from wetlands is $10,573 per acre per year.

The shores of Lake Michigan differ considerably on the north and south sides of the lake. The northern shore is heavily forested, sparsely populated, and home to the world's largest freshwater dune system, while the southern shore is dominated by industrial/agricultural production.

In summer, the Lake Michigan help moderate temperatures by absorbing warm air and cooling the summer heat and create the perfect environment for growing fruits like apples, cherries and grapes usually found much further south (e.g. the Western shore of Lake Michigan is known as the "fruit belt").

Marshes, tallgrass prairies, forests and sand dunes provide habitats for wildlife on Lake Michigan. The Lake Superior region is home to many common native plant species such as white pine, and Flowering Rush (a shoreline aquatic plant), and nearly 60 orchid species. As there is no major city on its shores, the land around Lake Huron remains rich in natural resources and heavily forested such as Huron-Manistee National Forests, which boast 10,000 acres of pine, aspen and hardwood forest and is also home to some 7,000-year-old petrified trees that are underwater. The Lake Erie region has a large concentration of concord grapes facilitated by its rich soil. Lake Ontario's climate is conducive to fruit trees and the area has become a major growing area for apples, cherries, peaches, pears and plums.

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[71] For a detailed discussion on specific ecological services, see Marbek (2010b).

[72] It is imperative to recognize that all the economic and other benefits derived by society are somehow linked to a healthy ecosystem nurtured by the Great Lakes basin. For instance, healthy ecosystems ensure suitable habitats for fish populations and thus enable commercial harvesters and recreational anglers to fish.

While there is a a growing recognition that such natural services have real economic value, as of now, literature providing the values of the (indirect) ecosystems services and biodiversity distinctively for the entire Great Lake Basin, is very limited due to the lack of guidance/methods, information and/or the complexity around predicting the future (e.g. knowledge of local weather and climate patterns) and time and resources (Environment Canada, 2001). However, a few studies (Kreutzwiser, 1981; IJC Study Board, 2006) attempted to provide estimates of the intrinsic values of ecosystem services either for the Canadian economy or for some rivers and some portion of major lakes (e.g. the Great Lakes) in Canada.

A few studies have attempted to evaluate the value of some of the afore-mentioned specific ecological services provided by the Great Lakes, following different methodologies and primarily from a Canadian or provincial perspective. Yap, Reid, de Brou, and Bloxam (2005) estimated health damages of about $7 billion per year of the total economic damage of around $10 billion per year, which some studies cited as benefits (i.e. avoided costs), associated with reduced air pollution through gas regulation services provided by Lakes. In terms of waste treatment, Brox, Kumar and Stollery (2003) estimated the WTP for different changes in water quality in the Grand River Watershed in Ontario. The study found that households have average WTP in the range of $6 - $11 per month for minor and major changes in water quality. The study calculated a present value of $1,869/household as the WTP for a one-time investment in a capital project for water quality improvements. In terms of evaluating wetlands' value in providing habitat and/or habitat protection, using a meta-analysis approach on 39 wetland valuation studies, Woodward and Wui (2001) estimated an average value of $1,364/hectare. Kazmierczak (2001) estimated the value of habitat and species protection to be $844/hectare. Using the benefit transfer approach, Costanza et al. (1997) estimated a global average of the habitat ecosystem service of $691/hectare. Krantzberg et al. (2008, 2006) cited that wild unprocessed biodiversity in Canada was worth $70 billion, which included values of nutrient cycling, flood control, climate control, soil productivity, forest health, genetic vigour, pollination and natural pest control.[73]

Literature providing relevant values for the entire Great Lakes basin is still limited. Wilson (2008) estimated that the Lake Simcoe watershed's non-market ecosystem services were worth $975 million ($2,948/hectare/year). Wetlands are worth an estimated $435 million per year ($11,172/hectare) because of their high value for water regulation, water filtration, flood control,[74] waste treatment, recreation, and wildlife habitat. The ecosystem service attributed to habitat is valued at $6,234/hectare of wetland in Lake Simcoe's basin. Expanding this approach, the International Lake Ontario-St. Lawrence River Study Board (2006) (cited in Marbek (2010b)), calculated a value of $2,184/hectare of wetland for all Canadian Great Lakes restoration projects.[75]

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[73] Costanza et al. (1997) estimated the value of the world's ecosystem services and natural capital and found a median value of $33 trillion, which was deemed to be a minimum due to simplicity in the methodology adopted.
[74] It should be noted that the Great Lakes themselves are a main cause of floods. Recently, however, flooding has become a larger problem for Ontario, not from the Lakes themselves, but within the watershed (Marbek, 2010b).
[75] This value may not reflect actual benefits from specific sites due to several reasons, such as productivity of site and proximity to people. For details, see the International Lake Ontario-St. Lawrence River Study Board (2006).

The Great Lakes wetlands filter and recharge freshwater, help prevent erosion and flooding, provide carbon storage, waste assimilation and metabolism, habitat for fish, wildlife, protected species and plants. They are also locations for recreation, education and research (Environment Canada, 2006).[76] The benefits of the Great Lakes wetlands extend outside of the region in consideration of the fact that the value of unprocessed biodiversity in Canada (approximately 70 billion cited in Krantzberg et al. (2006)) is dependent on the viability of the individual ecosystems located in the different provinces. For example, many bird species that depends on them are migratory and travel from wetland to wetland. Long Point Park at Lake Erie is a case in point which is recognized as a biosphere reserve by the United Nations and a world-renowned refuge and stopover for migrating birds in fall and spring (Krantzberg et al., 2006).

The International Joint Commission (IJC) Study Board (cited in David Suzuki Foundation (2008)) estimated the annual value for wetlands habitat services in the Great Lakes basin at around $548 million, or $5,830 per hectare, based on the average annualized wetland habitat restoration costs for a group of relevant Great Lakes Sustainability Fund projects.

Wilson (2008) found that the annual total value for waste treatment of nitrogen and phosphorus by wetlands in the Lake Simcoe watershed is an estimated $83.7 million or $2,148/hectare (based on a range of values from $1,061 to $3,235/ha/year). The study also determined the soil carbon storage of wetlands in Lake Simcoe to be 125 – 312 tonnes per hectare, depending on the type of wetland, and estimated an annual value in the range of $559 - $1,388/hectare, per year. The annual value of the carbon storage is an estimated $21.9 million, based on the average damage cost of carbon emissions ($52/tonne of carbon). Moreover, wetlands sequester between 0.2 to 0.3 tonnes of carbon per hectare each year, which was valued at $14/hectare.

Evaluating 17 ecosystem services grouped into six categories (water quantity and quality, climate change, biodiversity, material benefits, social wellbeing, and environmental integrity), Voora and Venema (2008) estimated that forests and wetlands account for 80% - 96% of the total ecosystem service values by land cover. In terms of evaluating wetlands' value in providing habitat and/or habitat protection, Pattison, Boxall, Adamowicz (2011) found that over a five-year period Manitobans would be willing to pay $296-$326/household per year depending on the level of wetland retention and restoration program improvement.

The Great Lakes basin provides important erosion control services for society, although the water in the Lakes themselves is one of the main causes of erosion to the surrounding shorelines. Two of the main economic benefits related to erosion control are the public benefit of reduced sedimentation and avoided private property damage.

[76] For a detailed assessment of the value of ecosystem services of 10 main biomes from a global perspective, see de Groot et al. (2012).

Pertaining to the public benefit of reduced sedimentation, the cost of replacement method is usually used to provide a monetary estimate of this benefit of decreased water turbidity of the water source caused by increased sedimentation. In the Great Lakes context, the mean cost of sediment removal for municipal water treatment facilities in southern Ontario was estimated to be $28.57/tonne of sediment (Fox and Dickson, 1990).[77]

In terms of avoided private property damage, the International Lake Ontario St. Lawrence River Study Board (2006) (cited in Marbek, 2010b) found that on Lake Ontario, around 600 homes are at imminent risk of damage from erosion and flooding. The David Suzuki Foundation (2008) valued shoreline protection of Sauble Beach, Lake Ontario, beach front and dunes at $6 million. Kriesel (1988) estimated that the average WTP as $80,283 to increase the number of years from 1 to 21 years until the distance between the house and the lake is zero.

Krantzberg et al. (2008, 2006) cited that wild unprocessed biodiversity in Canada was worth $70 billion, which included values of nutrient cycling, flood control, climate control, soil productivity, forest health, genetic vigour, pollination and natural pest control.

There is no existing literature on the potential economic value of intrinsic services provided by the Great Lakes, due to the lack of spatially and temporally intensive data, coherent approach (Steinman et al., 2017), and the uncertainty around predicting the future (e.g. knowledge of local weather and climate patterns). Despite the difficulty of quantifying, the economic value of intact, healthy wetlands along the Great Lakes is substantial.

While the present study did not estimate and place any monetary values on ecosystem services, the study discussed the relevant literature that quantified some of the ecosystem services in an attempt to highlight the importance of such ecosystem services and to communicate important information to complement quantitative information provided for other activities in the study.

Option Value

The Great Lakes resources provide some sort of option and insurance for future generations because it provides them with the possibilities of commercial/recreational activities in the future. There may also be medicines available in the flora and fauna. Neither economic theory nor empirical literature provides adequate information to quantify the option values. It should, however, be noted that assets with less perfect substitutes are likely to have larger option values. The Great Lakes and associated unique biodiversity characteristics might be a case in point (Marbek, 2010b).

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[77] Using data from over 400 large US utilities, Holmes (1988) estimated that the average cost of turbidity related treatment activities to be $279.10/MG. The study also found that a 1% increase in sediment loading increases water treatment costs by 0.05%.

Research Value

The Great Lakes Basin also provides opportunities for research and educational activities that inform and benefit others and provide a better understanding of the ecology. Although, estimating the economic value of these uses is difficult, their contribution cannot be overlooked. There are a number of public outreach programs being implemented by different levels of government in both Canada and the US to improve public awareness, understanding and appreciation of the values of the ecosystems. Such programs also provide an opportunity to educate the public about activities that are carried out and about the negative impacts that human activities sometimes have on these ecosystems.

Non-Use Value

As mentioned in Chapter 1, society, and in particular, people residing in and near the Great Lakes region, derives substantial non-use value from the services provided by the Great Lakes.[78]

In terms of non-use values of the resources embedded in the Great Lakes, a few studies (e.g. Dupont, 2003; Rudd, Andres, & Kilfoil, 2016) have estimated non-use values of some species native to the Great Lakes, for different areas of Canada and the US, using direct stated preference methods (contingent valuation, discrete choice experiments). The total non-use value for the Great Lakes has not been studied so far due to the lack of extensive data. Moreover, neither has there been any applicable study that could serve as proxy values for the Great Lakes. However, some specific estimates of non-use values have been conducted in the Great Lakes context.

Loomis (1987) found that non-use values were approximately 73 times as large as the corresponding use values of Mono Lake, California. Whitehead et al. (2009) found that 23% of non-users of recreational benefits of the Saginaw Bay coastal marsh in Michigan reported positive WTP for those benefits. Given that protection of an additional 1,125 acres of coastal marsh was perceived as adding total additional value of $3,596/acre, the non-recreational or passive values to the public were estimated to be $1,969/acre, over the lifetime of the resident.

Using 1980 recreational use and survey data on 218 resident Colorado households, Walsh et al. (1984) estimated separate WTPs for option, existence and bequest values for increments of wilderness designated land. The study found that the three components of non-use value have a relatively equal weight, with existence and bequest values each being slightly more than option value, as follows: option value - USD10 million; existence value - USD12 million; and bequest value - USD13 million.[79]

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[78] Although, in theory, non-use values are divided into existence and bequest value, the empirical studies do not always make the distinction and calculate them together as non-use values.

[79] The preservation value estimates omit non-residents who are also expected to have some positive preservation

Dupont (2003) estimated that passive users of recreational activities in Hamilton Harbour, Ontario, had WTP for improvements as follows: $21 for swimming, $11 for boating, and $12 for fishing. These estimated non-use values excluded existence and bequest values of these activities by active users, and other ecological benefits valued by both groups. Reviewing relevant literature, Apogee (1990) provided additional estimates of non-use values associated with water quality and concluded that the non-use component was 50% of TEV.

Biodiversity itself also provides substantial non-use value, which may roughly be captured by people's WTP to preserve endangered species. Bishop et al. (1987) estimated the taxpayers' WTP for the striped shiner (designated as an endangered species) to be in the range of $10 - $14. Aggregating all of Wisconsin's taxpayers, the WTP was estimated to be USD29 million, which was almost 20% of the estimated direct use value of all of Wisconsin's sport and commercial fisheries in the Great Lakes ($154 million). Because this fish has no identified use value to society, this WTP can be interpreted as the total non-use value. These values give an indication of the magnitude of non-use values associated with Great Lakes resources.

Although, as indicated, it is a significant challenge to capture the benefits of non-use values, almost all the literature noted that even if non-use values might be insignificant at the individual level, aggregated values for an entire economy are significant. For example, Freeman (1979) stated that the total non-use values might fall in the range of 60% - 80% of TEV. While the total non-use value for the entire Great Lakes Basin has not been studied so far, the studies discussed above shed some light on the magnitude of non-use values associated with the resources.

Economic Contribution – At a Glance

Based on the methodology adopted in Chapter 2 and the subsequent calculations in the current chapter, Table 8 shows the estimated economic value of the activities in and around the Great Lakes in Canada and the US adopting the TEV framework.

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values for Colorado wilderness designation. For example, the residents of the state reported that they were willing to pay an additional $21/household annually to protect $125 million acres of wilderness in other states.

Table 8: At A Glance - Economic Contributions ($Million) of the Great Lakes by Country/Sector/Activity in 2014

Sector Impacted				Canada		The US	
				Value/ Expenditure	Consumer Surplus	Value/ Expenditure	Consumer Surplus
Use Values	Current Uses	Direct	**Extractive**				
			Commercial Fishing	$230	NA	$145	NA
			Recreational Fishing	$471	$84	$2,000	$1,000
			Hunting	NA	NA	$22	$9
			Non-Extractive				
			Recreational Boating	$2,300	NA	$4,900	NA
			Beaches/Lakefront Use	$235*	--	$1,100*	--
			Wildlife Viewing	NA	NA	$121*	--
		Indirect	Ecosystem Services	Not Quantified	Not Quantified	Not Quantified	Not Quantified
	Future Uses		Option Values	Not Quantified	Not Quantified	Not Quantified	Not Quantified
			Research Values	Not Quantified	Not Quantified	Not Quantified	Not Quantified
Non-Use Values			Existence Values	Not Quantified	Not Quantified	Not Quantified	Not Quantified
			Bequest Values	Not Quantified	Not Quantified	Not Quantified	Not Quantified

Source: Fisheries and Oceans Canada Staff calculation, Policy and Economics, Central and Arctic Region.
*Note: NA – Not available; * Includes consumer surplus.*

There are some associated private values held by people who live near or who visit the Great Lakes, usually captured in the literature as "aesthetic and amenity values". For example, while the carbon storage and nutrient cycling services of wetlands are public goods, there is also a private benefit to homeowners from living near the wetland (Marbek, 2010b). There is a growing economic literature (e.g. Johnston et al., 2001; Earnhart, 2001; Pompe, 2008) pertaining to the implicit prices people are willing to pay to benefit from environmental amenities. This study excludes aesthetic and amenities values from the overall calculation of the economic values in order to avoid double-counting problems, as these values overlap some of the benefits of recreational activities (e.g. recreational fishing and boating).[80]

Please note that while qualitatively assessed, as appropriate, due to insufficient information, the above-mentioned impact did not include (re)-distributional impact of activities and hence may have overestimated to some extent. However, on the other hand, the estimations of the economic contributions of the Great Lakes discussed in this chapter may also be viewed as conservative estimates. There were some underestimations of values in some sectoral activities due to: (i) lack of complete information required to provide defensible estimates; (ii) adjusting estimation variables where significant variations and uncertainties exist in the literature; and (iii) using reasonable proxies based on literature review and experts' opinions. For example, if candidate proxies showed significant variations, the study adopted the lower values to avoid overestimation of the economic contributions of the activities/sectors.

[80] For a discussion on the effect of an aquatic invasive species on lakefront property values, see Zhang & Boyle (2010).

Finally, the estimates presented here are based on information provided in extant literature, with adjustment, that employed a variety of methodologies for valuation, which limits comparability. Methodologies varied in terms of scope, estimation procedures, time periods considered, and industries covered. Therefore, the baseline values estimated by impacted activities in and around the Great Lakes for Canada and the US should not be directly compared and also with those provided in the extant literature.

Chapter 4: Social and Cultural Values of the Great Lakes

In addition to economic contributions discussed in Chapter 3, the Great Lakes provide considerable subsistence, social, cultural, and spiritual benefits to regional residents and contribute significantly to the economy as a whole. No comprehensive quantitative information/data was available on such benefits derived from the Great Lakes Basin. However, this chapter presents a qualitative discussion of the socio-cultural values of the Great Lakes Basin.

Aquatic environments in the Great Lakes have influenced and supported the livelihoods of regional residents, particularly, around 120 Aboriginal bands (a group of status Indians) that inhabited in the Great Lakes region over history. Currently, there are 75 First Nation communities living along the Great Lakes in Canada (Rashidi, 2014).[81]

Throughout the province of Ontario, Aboriginal peoples have constitutionally-protected Aboriginal and treaty rights to fish for food, and for social and ceremonial purposes. Aboriginals in Ontario engage in subsistence fishing and do not require a license for subsistence fishing (Boudreau & Fanning, 2016). Aboriginal fisheries are found primarily on the Great Lakes (as well as on Lake Nipissing, Lake Nipigon, and lakes of northwestern Ontario) (Ontario, 2015).

According to Kappen et al. (2012), there are twenty seven (27) recognized federal tribes in the US portion of the Great Lakes Basin. Of the total, twelve (12) are part of negotiated treaty settlements with the US Government to secure the tribes' rights to continue and uphold traditional way-of-life practices on the lands. The other fifteen (15) tribes within the Great Lakes Basin either continue to practice subsistence fishing on their reservations or have historically engaged in subsistence fishing. There are three (3) main treaty organizations in the basin: Chippewa Ottawa Resource Authority (CORA), the Great Lakes Indian Fish and Wildlife Commission (GLIFWC), and the 1854 Treaty Authority. There are also five (5) non-treaty tribes that practice subsistence fishing.

First Nations communities living along the Great Lakes rely on natural resources for their livelihood and gain invaluable traditional ecological knowledge by establishing unique relationship with their surrounding environments. Subsistence harvests identified in the Great Lakes Basin included fishing, hunting, gathering of wild rice[82], and agriculture. For some groups, such as, the Algonquians (e.g., Chippewa/Ojibwe, Ottawa), fishing was important and more reliable than agriculture because of their location. Fishing takes place either close to shore in

[81] The major tribes that have occupied the Great Lakes area include Anishinabe, Chippewa/Ojibwe, Cree, Dakota/Sioux, Huron, Iroquois, Menominee, Mesquakie/Fox, Miami, Missouri, Mohican/Mahican, Oneida, Ottawa, Potawatomi, Suak/Saques/Sac, Winnebag (Great Lakes Information Network, n.d; Hele, 2008).

[82] A cereal grass that grows in shallow lakes and streams and is harvested in the fall.

one of the Great Lakes or onshore in tributaries that run into the Great Lakes (Kappen et al., 2012).

Following the State of Michigan hook and line regulations and obtaining a Great Lakes subsistence license from the LTBB Natural Resources Department, tribal members in the State interested in fishing the Ceded waters of the Great Lakes for subsistence can harvest up to 100 lbs of fish per day via gill net, impoundment net, hook and line, or spear. Subsistence harvesters may have seasonal or geographic restrictions depending on the time of year and location of the harvests (Odawa Natural Resource Department, 2009).

LTBB of Odawa Natural Resource Department (ONRD, 2016) reported in its 2015/2016 Annual Harvest Report that, in 2016, six of its tribal members obtained subsistence fishing licenses, with two reported harvests. In 2016, subsistence fishers reported harvesting 50 lbs of walleye and 28 lbs of yellow perch.[83]

The Michigan Department of Natural Resources (MDNR, 2017) releases data compiled by the CORA concerning fishing in the 1836 Treaty-ceded waters of the Great Lakes. CORA represents 5 tribes in Michigan that practice subsistence fishing. MDNR found 24 different fish species weighted over 34,000 lbs were caught for subsistence fishing in 2016 including lake trout, whitefish, walleye, yellow perch, and salmon.

The GLIFWC represents 11 tribes in Minnesota, Wisconsin, and Michigan, all of which engage in subsistence fishing. While it does not keep comprehensive records on all subsistence fishing, the GLIFWC (2016) monitors spear and net fishing for inland waters. This fishing does not occur on the Great Lakes themselves but primarily on Mille Lacs Lake, which is west of Lake Superior. In the 2011, 681 tribal members engaged in spearing and/or netting and 3,261 permits were used on Mille Lacs Lake. Another 6 members fished smaller lakes in the area and caught 45,380 fish representing 14 species with a total weight of 83,579 pounds. About three-quarters of the fish caught were walleye.

One of the two tribes in the 1854 Treaty Authority practices subsistence fishing. Commonly targeted fish reported included lake and brook trout, whitefish, cisco, walleye, and pike.

Based on data compiled by CORA for the period 2006-10, Kappen et al. (2012) reported that the subsistence catch in Michigan waters in Lake Michigan were 11,357 pounds of fish on average, followed by Lake Superior with 4,752 pounds, St. Mary's River with 1,479 pounds and Lake Huron with 1,383 pounds. The major species caught in Michigan waters in Lake Michigan were walleye, whitefish, and sucker. In Lake Superior, salmon (1,313 pounds) and whitefish (1,142 pounds) were the only species for which more than 1,000 pounds were landed. In St. Mary's River and Lake Huron, whitefish was the most numerous fish caught for subsistence.

[83] The aggregate harvest was difficult to quantify due to the difference in reporting between pounds of fish and number of fish harvested.

Native Americans (e.g. in the area west of Lake Michigan, south and west of Lake Superior) who lived away from freshwater resources also relied on subsistence hunting and agriculture. Harvesting wild rice is ingrained in the customs, folklore, and religious beliefs of the Chippewa tribes in the Great Lakes. Native Americans traditionally also harvested plant and plant by-products (e.g. calamus) for a variety of uses such as food, medicine, raw materials (e.g. fishing gear), charms to dyes and decorative arts. While the capturing of wildlife was practiced throughout the Great Lakes region, subsistence hunting and trapping (e.g. ducks, geese, cormorants, swans, pigeons) is more important source of diet for tribes in the eastern Great Lakes Basin because of the location (Kappen et al., 2012).

Quantitative information on the economic values of subsistence harvests from the entire Great Lakes Basin is largely absent for both Canada and the US. However, the significance of subsistence harvests has been documented in a few studies (e.g. Kappen et al., 2012; Ashcroft et al., 2006; Derek Murray Consulting Associates, 2006; Meyers Norris Penny, 1999) conducted in other regions in Canada.

For example, using a production cost model, Kappen et al. (2012) estimated the annual household activity valuation for subsistence fishing at $15,665 in Michigan, $16,471 in Minnesota, and $14,921 in Wisconsin. A survey in the early 1980s of the Cross Lake community in Manitoba estimated over 103,000 kg of fish harvested for personal consumption in one year with a food replacement value of about CAD657,000 (Manitoba Water Stewardship, 2004).

For many communities, subsistence fish harvesting also helps maintain and reinforce family ties and traditions, and therefore is important for cultural reasons. Aboriginal Traditional Knowledge has been gathered by Aboriginal peoples through generations of depending on water resources which greatly help guide fisheries management planning and activities in Ontario. Because of the inherent compatibility of the fisheries with traditional indigenous livelihoods, participation in this industry allows First Nations harvesters to participate in the modern economy without losing their cultural identity (Romanow, Bear & Associates Ltd., 2006).

In addition to providing a food source through subsistence harvesting and cultural benefits (e.g. Annual Mother Earth Water Walk), subsistence harvest provides significant social benefits, particularly to Aboriginal communities, through the distribution of food among communities and those in the community unable to fish or hunt, providing linkages to traditional lifestyles and ancestors, and socialization. It is part of the tribes' cultural identity and an indication of their status as sovereign entities (Kappen et al., 2012).

The social impacts of commercial fishing are significant in terms of both employment and cultural significance. These non-economic benefits are not only substantial, but also may even exceed the benefits of subsistence as a food source. Subsistence harvesting also contributes to traditional knowledge (GSGislason & Associates Ltd., 2006).

Socially, Great Lakes beaches and coasts provide a unique source of community pride, as they encourage diversified recreational activities. Families enjoy festivals, picnics and outdoor theatre at Great Lakes waterfront venues and parklands. Ontario’s provincial parks, including 30 operating along the Great Lakes, attract 10 million visits every year. Over 100,000 annual visits are made to new provincial park visitor centres on Lake Superior, Georgian Bay and the French River (Ontario's Great Lakes Strategy, 2016). The beaches and coasts are the basis for the key public perception measure of environmental quality.

The Great Lakes nature holds spiritual significance to many residing nearby the resources, especially indigenous communities. Practices of fishing, hunting and trapping reflected great spiritual sense. The Great Lakes are also considered a world underwater heritage resource, with the world’s best freshwater collection of more than 4,700 shipwrecks from the 1700s to recent times (Ontario's Great Lakes Strategy, 2016).

Chapter 5: Socio-Economic Risk Assessment

For this study, the socio-economic risk assessments that are direct consequences of the ecological outcomes of the presence of Grass Carp have been considered. These socio-economic impacts are tied to the DFO (2017) and Cudmore et al. (2017) and form the basis for the socio-economic risk assessment.

DFO (2017) provided the scenario for the socio-economic risk assessment, both for the assessment of the risk as well as for estimation of baseline values. In order to estimate the socio-economic risk assessment of the presence of Grass Carp in the Great Lakes, the study also heavily relied on the overall probability of introduction and the consequence scale provided in DFO (2017).

In order to set the stage (scenario) for risk assessment, following DFO (2017), the study assumed that in the absence of added prevention and protection, Grass Carp will arrive, establish population, survive and spread due to the availability of suitable food, thermal and spawning habitats, and high productivity embayments in the Great Lakes basin. Moreover, Grass Carp are unlikely to be susceptible to most predators for very long relative to their lifespan given rapid growth rates and there are no known significant diseases or pathogens present in the Great Lakes basin that would prevent the survival of Grass Carp (DFO, 2017).

As stated in Chapter 2, in addition to the results extracted from DFO (2017) and Cudmore et al. (2017), expert scientific opinion was sought from a group of scientists involved in the DFO (2017) assessment, in order to establish a defensible foundation for the socio-economic risk assessment. The discussion largely focused on: (i) the activities/sectors that might be at risk; (ii) the risk over 10 years and 40 years using 2024 as the adjusted base year; and (iii) permissible ways to use the quantitative scales of the overall probabilities for the impact analyses.

The next section of this chapter provides a detailed discussion of the degree of damage caused by Grass Carp in the Great Lakes Basin by major activity impacted.

Commercial Fishing

The effects of Grass Carp on native fish species are documented to be complex and apparently depend on the stocking rate, macrophyte abundance, and community structure of the ecosystem (DFO, 2017; Cudmore et al., 2017; Shireman and Smith, 1983). Therefore, in order to assess the impact on commercial fishing and related activities, it was necessary to project the expected ecological consequences on native species commercially fished in the Great Lakes.

DFO (2017) and Cudmore et al. (2017) found that Grass Carp were capable of influencing interspecific competition for food with native fishes and invertebrate, changes in the composition of macrophyte, phytoplankton with substantial repercussions for the aquatic ecosystem. The other most common effects documented worldwide in pertinent literature include interference with the reproduction of other fishes, decreases in refugia for other fishes (Shireman and Smith, 1983), changes in trophic structure of aquatic systems (Bain, 1993). DFO (2017) and Cudmore et al. (2017) concluded that if Grass Carp became established in the Great Lakes with ample populations, a similar impact to those documented worldwide would be realized.

Grass Carp seem to directly influence native fish species through either predation or competition when food is scarce and indirectly affect other animal species by modifying preferred habitat (Chilton and Muoneke, 1992). Wittmann et al. (2014) performed a meta-analysis of ecological effects of Grass Carp and found overall negative impact to biota.

The removal of marcophytes by Grass Carp may result in adverse effects on the ecosystem (e.g. loss of nursery habitat for fish, reduction of the riparian cover, the bank stability (Conover et al., 2007; Dibble & Kovalenko, 2009). Areas with macrophytes in the Great Lakes, that could be consumed by Grass Carp, is estimated at a total wet weight biomass of 2.5 to 4.5 million metric tonnes (DFO, 2017). A meta-analysis (that included 48 data points from 13 studies) found Grass Carp stocking strongly reduced macrophyte abundance or density (Wittmann et al. 2014).[84] Moreover, Smokorowski and Pratt (2007) concluded that substantial decreases in structural habitat complexity are detrimental to fish diversity, simplify fish communities, and change species composition.

Grass Carp's diet comprises approximately 95% plant material.[85] Grass Carp has a preference for plants with soft tissues and long, thin morphology (Wiley et al. 1986, Pine and Anderson 1991 cited in DFO (2017)). More than 50 genera of food items, including aquatic macrophytes, algae, invertebrates and vertebrates, were reported to be eaten by grass carp (Dibble & Kovalenko, 2009).

Following depletion of preferred food items in one feeding ground, Grass Carp tend to move to other feeding ground. Therefore, within a few years of introduction, some plants (e.g. pondweed, hornwort, duckweed) disappear, and toxic plants and nuisance hydrophytes become more abundant (DFO, 2017).

Although Grass Carp are often used to control selected aquatic weeds, these fish sometimes

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[84] For details of the results of studies carried out on the effect of Grass Carp on aquatic vegetation, see DFO (2017).
[85] Adult Grass Carp predicted to be not in direct competition for food with Great Lakes fish species, as they consume large amounts of aquatic vegetation, unlike larval and juvenile Grass Carp that mostly feed on rotifers, zooplankton, insect larvae, and small fishes (Dibble and Kovalenko 2009). However, by 4 to 6 weeks post-hatch, plants dominate the diet of juvenile Grass Carp (Cudmore and Mandrak, 2004). Grass Carp can consume 40% of their body weight in aquatic vegetation in a single day. A 5-year-old (about 7.5 kg) Grass Carp would consume approximately 50 kg of vegetation per year, and a 10-year-old fish (about 16 kg) would consume approximately 90 kg/year (Jones et al., 2017).

feed on preferred rather than on target plant species (Taylor et al. 1984). Increase in phytoplankton populations is a secondary effect of Grass Carp presence. A single Grass Carp can digest only about half of the plant material that it consumes each day. The remaining material is expelled into the water, enriching it and promoting algal blooms. These blooms can reduce water clarity and decrease oxygen levels (Bain 1993).

Grass carp is also documented to consume the roots of bank plant when there is a lack of food and contribute to increases in turbidity, alkalinity of water, and levels of dissolved nutrients (Mandrak and Cudmore, 2004). This is highly detrimental to native fish species because submerged aquatic vegetation in the littoral zone and coastal wetlands provide important fish habitat and support a wide variety of resident and migrant fish species.[86] On the other hand, increase in turbidity can diminish light penetration and decrease the growth of submerged vegetation which, in turn, may reduce the ability of visual predators to forage (Curmore et al., 2017). As a result, early life stages of native fish species inhabiting coastal wetlands, nearshore littoral zones, and tributaries are more likely to be affected.

The changes in water quality parameters (increase in nitrite, phosphate concentrations) because of sediment resuspension and removal of macrophytes (Dibble & Kovalenko, 2009; Shireman and Smith 1983, Kirkagac and Demir 2004) may influence algal blooms (Shireman and Smith 1983) and reduce native fish diversity and population (Wetzel 2001).

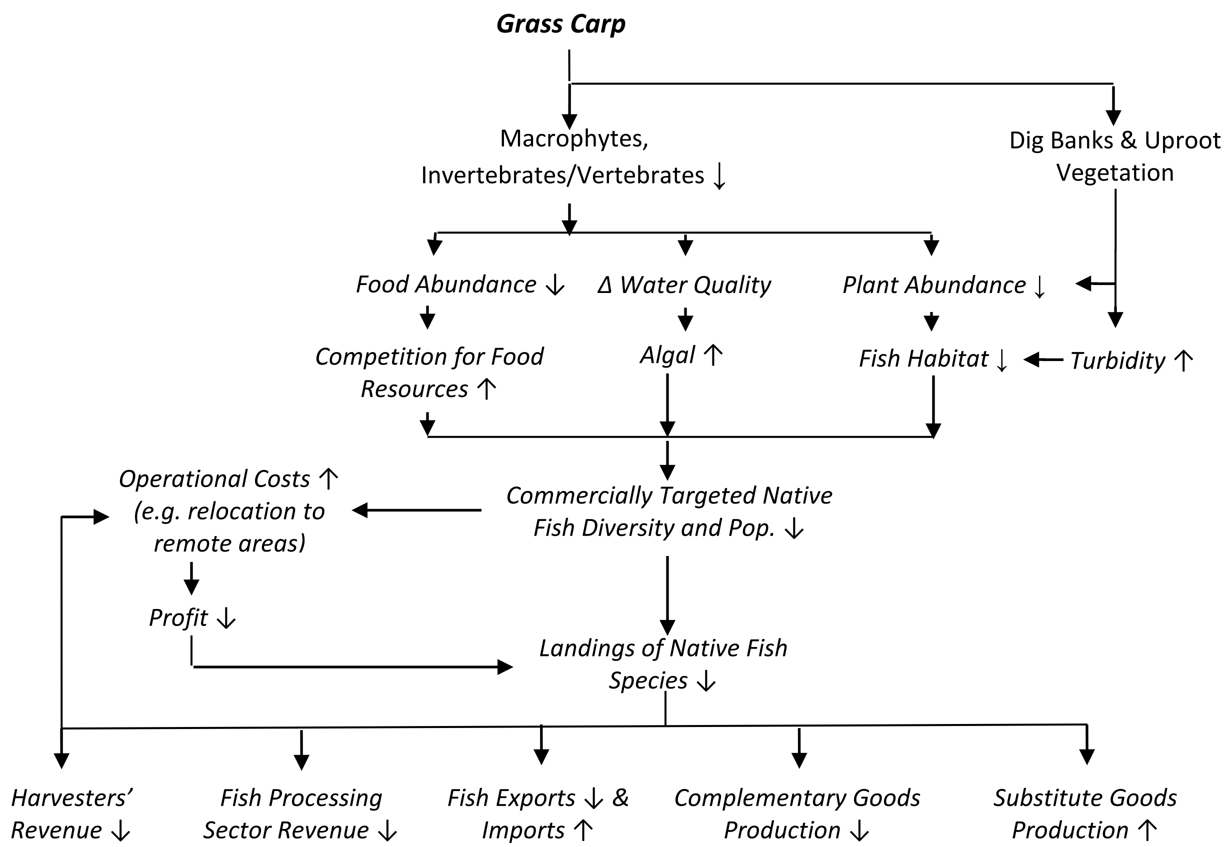
Grass Carp may also carry several parasites and diseases known to be transmissible or potentially transmissible to native fishes. As such, the species may have been indirectly responsible for the infection of native species.

Based on the habitat preferences and spawning needs, a literature review of the impact of Grass Carp on 136 fishes in the Great Lakes (including 18 non-native species) found high potential harmful consequences of reductions in vegetation and wetland habitat for 33 fish species, moderate for 33 fish species, and low or unknown for 70 fish species (Gertzen, Midwood, Wiemann, and Koops, 2017).[87] Fish species with low population numbers that rely on shallow, vegetated habitat may experience greater population-level effects, a loss of some populations, and a reduction in genetic diversity following Grass Carp introduction (DFO, 2017); Cudmore et al., 2017).

Based on the recent findings reported in DFO (2017) and Cudmore et al. (2017), the following flowchart shows the impact of presence of Grass Carp in the Great Lakes on commercial fishing and related activities:

[86] For example, vegetation removal by Grass Carp leads to higher predation on Rainbow Trout due to lack of cover, and changes in diet, densities, and growth of native fishes (Bain, 1993; Hubert, 1994). While knowledge of the spatial distribution of individual vegetation species is lacking, it has been found that more than 50% of the Great Lakes fish community uses aquatic vegetation for important life history needs (Gertzen et al. 2017).
[87] Of the 33 species classified as potentially experiencing high undesirable effects, 85% may experience consequences across all life stages, and the remaining species may experience consequences across at least two life stages.

Flowchart 1: Impact on Commercial Fishing Resulting from the Presence of Grass Carp



As shown in the flow chart, the presence of Grass Carp would increase costs and decrease revenues for commercial harvesters.

The presence of Grass Carp would also damage the commercial fishing industry through the expected impact on fishing revenue. The rationale is that Grass carp behavior and food habit is shown to alter the physical characteristics of aquatic habitats and alter water quality, degrade habitat by providing less desirable food or nesting sites for native species which may adversely affect growth and survival at multiple life stages, and reproduction. Less food availability would adversely affect the commercially targeted fish population, which would in turn reduce the catches of commercially fished species and harvesters' revenues/activities. The decrease in revenue would in turn reduce the level of gross profit and thereby create a circular flow of impact. From a demand perspective, the sector would also be adversely affected because of a reduced quality of native fish species, reflected through the smaller size of commercially targeted fish.

The presence of Grass Carp may also increase the operational costs of commercial fishing industry if harvesters have to travel further to remote sites to catch commercially harvested species, which would in turn reduce profit earned by harvesters. This may pose less incentive for harvesters to fish in the subsequent years which would in turn reduce profit further. This may create a circular flow of impact.

An analysis of harvest data for the year 2014 shows that 11,680 tonnes were harvested from the Canadian side of the Great Lakes that year, generating an estimated landed value of $30.2 million (see Annex 3A). Of the total harvest, Lake Erie accounted for 86% (10,024 tonnes), followed by Lake Huron with 10% (1,206 tonnes), Lake Superior with 2% (282 tonnes) and Lake Ontario[88] with 1% (168 tonnes). The major species harvested were perch (30%), rainbow smelt (23%), walleye (19%), white bass (16%) and lake whitefish (8%).

For the US side of the Great Lakes, an analysis of harvest data for the year 2014 shows that 6,795 tonnes were harvested from the Great Lakes that year, generating an estimated landed value of $22 million (see Annex 3A). Of the total harvest, Lake Erie accounted for 38% (2,546 tonnes), followed by Lake Michigan with 28% (1,931 tonnes), Lake Superior with 19% (1,255 tonnes), Lake Huron with 15% (1,042 tonnes), and Lake Ontario with 0.3% (21 tonnes). The major species harvested were lake whitefish (45%), perch (16%), and white bass (8%).

In order to estimate the impact of an arrival of Grass Carp in the Great Lakes, the study applied the analyses for ecological consequences reported in DFO (2017) and Cudmore et al. (2017) to recent five-year average market values for the time periods covered, and assumed that the ecological impact would similarly be transmuted to the species' populations and landings.

Table 9: Estimated Present Values ($000) of Market Values in Commercial Fishing in 10 (2033) and 40 Years (2063) by Lake

Variables	Superior	Huron	Erie	Ontario	Michigan	Total
Canada ($000)						
10 Years	-	$16,070	$226,790	$1,524	NA	**$244,383**
% of Total		*6.6%*	*92.8%*	*0.6%*	*NA*	*100.0%*
40 Years	-	$161,127	$1,123,801	$15,278	NA	**$1,300,206**
% of Total		*12.4%*	*86.4%*	*1.2%*	*NA*	*100.0%*
The US ($000)						
10 Years	-	$12,254	$45,383	$280	$44,227	**$102,144**
% of Total		*12.0%*	*44.4%*	*0.3%*	*43.3%*	*100.0%*
40 Years	-	$122,865	$224,883	$2,810	$312,016	**$662,574**
% of Total		*18.5%*	*33.9%*	*0.4%*	*47.1%*	*100.0%*

Source: Policy and Economics staff calculation, Central and Arctic Region, Fisheries and Oceans Canada.

On the Canadian side of the Great Lakes, based on the foregoing, the study anticipated that the total present value of impact on commercial fishing industry would be at $244 million in 10 years starting 2024 (see Table 9).[89] Of the total, the present value of impact on Lake Erie commercial fishery would be at $227 million (93% of total), followed by Lake Huron with $16 million (7%), and Lake Ontario with $2 million (1%) in 10 years starting 2024 (see Table 9). The

[88] Lake Ontario's commercial harvest comes primarily from the Canadian waters of Lake Ontario east of Brighton, including the Bay of Quinte and the St. Lawrence River http://www.mnr.gov.on.ca/en/Business/GreatLakes.

[89] For details on estimation of impact, see Chapter 2: Methodology Adopted.

impact on commercial fishing in Lake Superior was anticipated to be negligible. The certainties associated with these estimates were ranging from very low to low.[90]

Table 9 also shows that for the forty year interval ending in 2063, for the Canadian side of the Great Lakes, the total present value of impact on commercial fishing industry would be at $1.3 billion (see Table 9). Of the total, the present value of impact on Lake Erie commercial fishery would be at $1.1 billion (86% of total), followed by Lake Huron with $161 million (12%), and Lake Ontario with $15 million (1%). The impact on commercial fishing in Lake Superior remained negligible.

For the US side of the Great Lakes, the study anticipated that the total present value of impact on commercial fishing industry would be at $102 million in 10 years starting 2024. Of the total, the impact on commercial fishing industry in Lake Erie was estimated at $45 million (44% of total), followed by Lake Michigan with $44 million (43%), Lake Huron with $12 million (12%), Lake Ontario with $280K (0.3%). The impact on commercial fishing in Lake Superior was anticipated to be negligible. The certainties associated with these estimates were ranging from very low to low.

For the forty year interval ending in 2063, for the US side of the Great Lakes, the total present value of impact on commercial fishing industry would be at $663 million (see Table 9). Of the total, the present value of impact on Lake Michigan would be at $312 million (47% of total), followed by Lake Erie with $225 million (34%), Lake Huron with $123 million (19%), and Lake Ontario with $3 million (0.4%). The impact on commercial fishing in Lake Superior remained negligible.[91]

As indicated in DFO (2017) and Cudmore et al. (2017), the extent of the impact on commercial fishing in a specific lake depends on the size/depth of the lake to some extent. For example, 30% of the whitefish population spawns in Lake Erie. As it is the shallowest of all the Great Lakes, the impact on native fish species is anticipated to be higher because of more interaction between Grass Carp and native fish species.[92] Moreover, some species (e.g. lake whitefish) have already been declining for some time because of other pernicious forces in place (e.g. zebra mussel). Any further decline exacerbated by Grass Carp could render commercial fishing operations unsustainable, abolishing the commercial fishing industry from Lake Erie (which accounted for 86% of the catches in 2014), and subsequently from the entire Great Lakes.

As the commercially harvested fish species are impacted by the presence of Grass Carp in the

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[90] As stated in the Methodology Section, certainties associated with the impact assessment provided here are determined based on the certainties reported in DFO (2017) and Cudmore et al. (2017) and the assumption made in Chapter 3 that the certainties associated with the socio-economic assessment must be less than or equal to those of ecological risk assessment.

[91] A sensitivity analysis was performed replacing 5-year average market values by data for the most recent year available (2014) and found differences in estimated present values of total impact (both Canada and the US) in the amount of $15 million in 10 years and $71 million in 40 years starting 2024.

[92] Centre of Expertise for Aquatic Risk Assessment Team, Great Lakes Laboratory for Fisheries and Aquatic Sciences, DFO, personal communication, June 4, 2012.

Great Lakes Basin, it is anticipated that all sectors associated with commercial fishing through forward and backward linkages would be proportionally impacted (e.g. food processing and export sectors). For example, the detrimental impact on the commercially harvested freshwater species would damage the freshwater fish processing sector (captured in market value), reduce (increase) international exports (imports) of freshwater fish and fish products, increase pressure on the freshwater fish species sourced from other jurisdictions in Canada, and to some extent, hamper the competitive environment in the food sector in the regional economy and in Canada overall.

From an export perspective, the major freshwater species internationally exported from Canada were perch, whitefish, pickerel, trout, pike and smelt in 2016; together these species represented 78% (14,034 tonnes) of the total freshwater export (17,940 tonnes) and 84% (CAD125 million) of the total freshwater exported value ($150 million).[93] In 2016, Ontario exported 16,146 tonnes of freshwater fish product that yielded a total export value of $130 million. Exports of freshwater species from the Great Lakes, particularly whitefish, pickerel, mullet and pike, face competition from harvests elsewhere in Canada, international competitors, aquaculture production, and other related products.

From an export perspective, the major freshwater species internationally exported from the US were carp, catfish, eel, tilapia, and trout in 2016; together these species represented 90.7% (3,188 tonnes) of the total freshwater export (3,513 tonnes) and 92.3% (USD10.6 million) of the total freshwater exported value (USD11.5 million).[94]

The impact of Grass Carp in the Great Lakes would possibly trigger some (re)distributional effects in terms of production and employment, which might hamper the competitive environment. This is due to the presence of substitute products to freshwater species from the Great Lakes, which provide competing protein choices to fish at restaurants and supermarkets. For example, when the commercial fishing industry is impacted in a manner that adversely affects both the quality and price, consumers always have the potential to switch away from freshwater fish products to favorably priced substitute products (e.g. fish harvested from inland lakes in other provinces, marine fish, chicken and beef). The higher demand for substitute products will result in higher levels of production, value added and employment in the substitute sectors and lower levels of production, value added and employment in commercial fishing sector as well as complementary sectors.

An increased abundance of Grass Carp might have the potential to create income-generating opportunities, which might partially offset loss to commercial fishing industry due to the reduced abundance of commercially harvested native fish species. Although some consumers prefer locally harvested and processed fish, so far, however, the commercial value of Grass Carp has been reported to be quite low and much less than that of the native fish they would

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[93] http://www.inter.dfo-mpo.gc.ca/NSR/Home.

[94] 703t of carp, eel, catfish, and trout, worth USD3 million, were exported through US customs districts located in the Great Lakes states (NOAA 2017; NOAA Commercial Fisheries Statistics).

replace.[95] Grass Carp's potential to become a commercially fished species in future is perceived to be low in both Canada and the US. On the demand side, North American consumers have a negative view for carp as food and, on the supply side, particularly, in the US, they are numerous in rivers (with water quality issues) and streams in the Midwest of the US, and in consequence, have little value (about 5 cents a pound). Moreover, unlike silver and bighead carp, Grass Carp are bottom feeders which impact the flavor of the meat and, thereby, have even lower demand as food (Varble and Secchi, 2013).

It is noteworthy that given the immense size of the Great Lakes and its complex ecosystems and food webs, a proper forecast on the magnitude of socio-economic risk of Grass Carp, as well as the timeline for that risk to emerge on native fish abundance, is quite challenging. Thereby, the economic risks discussed above are conservative estimates and anticipated to be, by and large, proportional to the ecological consequences reported in DFO (2017) and Cudmore et al. (2017). For example, if the actual rate of arrival/migration differs from the predicted rate in DFO (2017) and Cudmore et al. (2017), both magnitude and realization of risk time will differ markedly.

Finally, the study assumed symmetric impact of the presence of Grass Carp on all species which is linear over time. Lauber, Stedman, Connelly, Rudstam, Ready, Poe, Bunnell, Höök, Koops, Ludsin and Rutherford (2016) found that since Grass Carp live in littoral zones and affect nearshore areas that support warmwater and coolwater fishes, the fish species most likely to be affected are Largemouth Bass, Northern Pike, Yellow Perch, and most other centrarchids. Smallmouth Bass would be less affected, and Walleye and salmonids would be minimally affected. Due to absence of a detailed ecological impact by species, such asymmetry of impact could not be incorporated in the economic risk assessment.

Recreational Fishing

In order to estimate the impact of Grass Carp's presence on recreational fishing in the Great Lakes, it was necessary to determine how angler days would be reduced due to a deterioration of angler day quality.

The rationale is that the presence of Grass Carp would damage the recreational fishing through the expected impact on native fish diversity and population (described in details in the commercial fishing section above). The reasoning is that if catch rates were reduced by decrease in native fish diversity and population,[96] demand for trips would likely decrease, which would in turn lead to a decrease in angling days, and hence a decrease in the recreational fishing activities in the Great Lakes, measured by a decrease in expenditures related to recreational fishing and consumer surplus.

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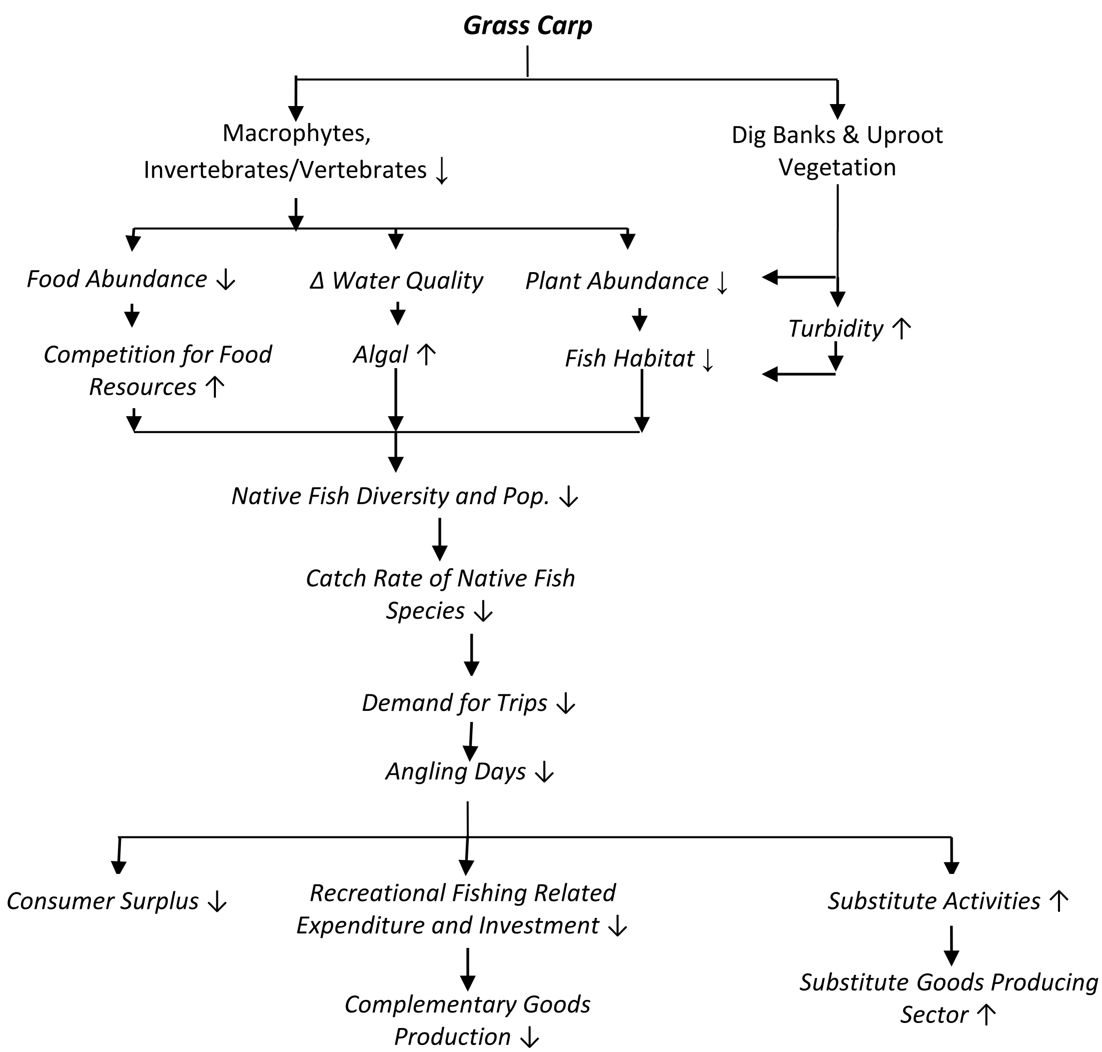
[95] Centre of Expertise for Aquatic Risk Assessment Team, Great Lakes Laboratory for Fisheries and Aquatic Sciences, DFO, personal communication, June 4, 2012.

[96] Employing nested logit framework, Melstrom and Lupi (2013) found that the fishing trip decisions are strongly influenced by the catch rates of the most popular Great Lakes fish species.

Based on the results reported in DFO (2017) and Cudmore et al. (2017), the presence of Grass Carp in the Great Lakes would damage recreational fishing activities as follows:

Flowchart 2: Impact on Recreational Fishing Resulting from the Presence of Asian Carp



In the absence of additional measures to prevent the presence of Grass Carp to minimize the damages to the recreational fishing activities on the Canadian side of the Great Lakes, the study estimated that in 2024, based on values for the subsequent 10-year time period, the total present value of impact of the recreational expenditures and consumer surplus would be approximately $345 million (expenditure - $293 million; consumer surplus - $52 million) with very low to low certainty[97] (see Table 10). Of the total, Lake Erie accounted for $168 million (57%), followed by Lake Huron with $95 million (32%), and Lake Ontario (including St.

[97] Certainties associated with the impact assessment provided here are determined based on the certainties reported in DFO (2017) and Cudmore et al. (2017) and the assumption made in Chapter 3 that the certainties associated with the socio-economic assessment must be less than or equal to those of ecological risk assessment.

Lawrence) with $81 million (27%). Lake Superior is predicted to have negligible impact.

Table 10: Canada - Estimated Present Values ($Mil.) of Risk of Recreational Fishing Expenditures and Consumer Surplus in 10 (2033) and 40 (2063) Years by Lake

Variables	Superior	Huron	Erie	Ontario	Michigan	Total
Expenditure/Investment						
10 Years	-	$79	$143	$70	NA	**$293**
40 Years	-	$795	$711	$700	NA	**$2,206**
Consumer Surplus						
10 Years	-	$16	$25	$11	NA	**$52**
40 Years	-	$161	$122	$114	NA	**$398**
Grand Total						
10 Years	-	$95	$168	$81	NA	**$345**
40 Years	-	$956	$833	$814	NA	**$2,604**

Source: Fisheries and Oceans Canada staff calculation, Policy and Economics, Central and Arctic Region.

The study also calculated that in 2024, based on values for the subsequent 40-year time period, the total present value of impact of the recreational expenditures and consumer surplus would be approximately $2.6 billion (expenditure - $2.2 billion; consumer surplus - $398 million) with very low to low certainty (see Table 10). Of the total, Lake Huron accounted for $956 million (43%), followed by Lake Erie with $833 million (37%), and Lake Ontario (including St. Lawrence) with $814 million (36%). Lake Superior is predicted to have negligible impact.

In terms of species caught in recreational fishing in the Great Lakes in Canada, DFO (2008) found that in 2005, the major species caught by anglers were perch (31.9%), bass[98] (23.2%), whitefish (8.1%), pike (5.0%), and trout[99] (9.0%) (see Annex 4E).

Table 11: The US - Estimated Present Values ($Mil.) of Risk of Recreational Fishing Expenditures and Consumer Surplus in 10 (2033) and 40 (2063) Years by Lake

Variables	Superior	Huron	Erie	Ontario	Michigan	Total
Expenditure/Investment						
10 Years	-	$135	$1,069	$74	$361	**$1,638**
40 Years	-	$1,352	$5,296	$738	$2,549	**$9,934**
Consumer Surplus						
10 Years	-	$93	$531	$47	$92	**$763**
40 Years	-	$930	$2,632	$467	$652	**$4,681**
Grand Total						
10 Years	-	$228	$1,600	$120	$454	**$2,401**
40 Years	-	$2,282	$7,927	$1,205	$3,201	**$14,615**

Source: Fisheries and Oceans Canada staff calculation, Policy and Economics, Central and Arctic Region.

In the absence of additional measures to prevent the presence of Grass Carp to minimize the

[98] Smallmouth, largemouth and rock bass.
[99] Rainbow, brown, brook and lake trout.

damages to the recreational fishing activities on the US side of the Great Lakes, the study estimated that in 2024, based on values for the subsequent 10-year time period, the total present value of impact of the recreational expenditures and consumer surplus at the Great Lakes Basin would be approximately $2.4 billion with very low to low certainty (see Table 11). Of the total, Lake Erie accounted for $1.6 billion (67%), followed by Lake Michigan $454 million (19%), Lake Huron $228 million (10%), and Lake Ontario $120 million (5%). Lake Superior is predicted to have negligible impact.

The study also calculated that in 2024, based on values for the subsequent 40-year time period, the total present value of impact of the recreational expenditures and consumer surplus at the Great Lakes Basin would be approximately $14.6 billion with very low to low certainty (see Table 11). Of the total, Lake Huron accounted for $7.9 billion (54%), followed by Lake Michigan $3.2 billion (22%), Lake Huron $2.3 billion (16%), and Lake Ontario $1.2 billion (8%). Lake Superior is predicted to have negligible impact.

It should be noted here that if recreational fishing on the Great Lakes is impacted, there is an impact on resident and non-resident anglers' expenditures and consumer surplus, and foreign expenditure that is associated with Great Lakes recreational fishing. The argument here is that foreign consumer surplus is not a benefit from a country's viewpoint, but the foreign expenditure is. The foreign expenditure would be lost if those visitors chose to spend their money in their own country instead of spending in the Great Lakes region.[100] Therefore, for this analysis, of the values presented above, the argument is that the residents' and non-residents' expenditure and consumer surplus, and foreigners' expenditure would partially be at risk if angling is impacted.[101]

Furthermore, as stated earlier, it is expected that damage to recreationally harvested fish species caused by Grass Carp in the Great Lakes basin would be followed by some relocation of expenditures of resident and non-resident to other sectors in the economy.[102]

Apart from recreational fishing, anglers also seek opportunities to enjoy other supplementary outdoor activities while on trips. The Canadian Tourism Commission (2006) found that relative to the average Canadian pleasure traveler, anglers were more likely to go boating, swimming and wildlife viewing while on trips. Anglers were especially more likely to have attended sporting events (e.g., professional sporting events, amateur tournaments) and attractions with an agricultural or western theme (e.g., agro-tourism, equestrian and western events). Reduced recreational fishing and related activities will have an economic impact to those whose

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[100] While it may be argued that there will still be some foreign expenditure associated with fishing at alternative sites and/or on alternative activities if there are some close substitutes. The possibility is considered to be low given that the entire Great Lakes is predicted to be impacted to a variety of extent.
[101] For details on expenditures by origins of anglers, please see Chapter 3 and Annex 4.
[102] For example, anglers may substitute away from fishing that are adversely affected to unaffected fishing types, particularly inland (Ready, Lauber, Poe, Rudstam, Stedman, and Connelly, 2016) or to other recreational activities to some extent such as hiking.

livelihood depends on the development of this sector.[103] The impacts on such subsidiary activities are anticipated to be notable and addressed separately, based on information availability, later in the respective sections of this chapter to avoid double-counting problem.

Finally, it should be noted that changes in expenditures and consumer surplus due to changes in catch rate depend on current catch rates at a site, the availability of alternative fishing sites, other factors (ready et al., 2012) and angler's behavior. In reality, anglers may respond to a decrease in the abundance of a fish species by substituting away from targeted species in affected lakes and switching to targeting other species or other waters or may decrease or even increase participation in recreational fishing.[104] The study adopted the ecological consequences reported in DFO (2017) and Cudmore et al. (2017) and assumed negative impact of the presence of Grass Carp on all species which is symmetric and linear over time. Therefore, the calculations of economic losses associated with potential declines in native fish population and eventually in catch rates due to the presence of Grass Carp presented in this sub-section may be biased to some extent.

Recreational Hunting

The presence of grass carp has been documented to be detrimental to bird species habitat because of their destructive nature on wetland plants (DFO, 2017; Curmore, 2017; Dibble and Kovalenko, 2009).

Grass Carp are consuming submerged aquatic vegetation and competing for food with several bird species, as well as by altering wetland nesting habitat. While knowledge of the spatial distribution of individual vegetation species in the Great Lakes is lacking, vegetation species that are important for waterfowl in the Great Lakes basin have been found to be consumed by Grass Carp to some extent.[105] Moreover, the removal of marcophytes can result in adverse effects on the ecosystem with a loss of a source of forage for birds (Conover et al. 2007)).

The relevant studies found in the literature mostly evaluated indirect impacts of Grass Carp on bird species (reduced mean biomass, abundance or concentration) that nest/feed in Great Lakes wetlands (Gasaway and Drda 1976, Johnson and Montalbano 1984, 1987, Leslie et al. 1987, McKnight and Hepp 1995). Gertzen et al. (2017) found that, of the list of bird species that use Great Lakes wetland habitat for important portions of their life, 18 bird species would have high impact and the remaining 29 species would have moderate impact.[106, 107]

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[103] For spatial correlations of five recreational elements of cultural ecosystem services (sport fishing, recreational boating, birding, beach use, and park visitation), see Allan et al. (2015).

[104] The rationale for increasing participation is that anglers will spend more time and spend more until they catch the targeted species or fulfil their targets.

[105] For details of the results of studies carried out on the effect of Grass Carp on aquatic vegetation, see DFO (2017).

[106] The findings are conditional on how quickly Grass Carp may reduce the density and diversity of macrophytes in wetlands, embayments, and nearshore areas, and how wetland birds may adapt or use other habitats.

[107] No study addressed grass carp impact on other vertebrates (e.g., aquatic mammals, reptiles, and amphibians). Many of these animals are highly dependent on vegetated habitats for food and protection from predators, and macrophytes that are critical to their survival.

According to Duck Unlimited (undefined)), the Great Lakes watershed has lost 62% of its original wetlands. Further destruction or degradation of habitat, including the coastal and inland wetlands and river corridors that Great Lakes bird species depend on may present a challenge for survival and may subsequently lead some of them towards species at risk.

In the absence of additional measures to prevent the presence of Grass Carp from the Great Lakes, reductions of bird species populations would decrease hunting opportunities and associated economic benefits from hunting expenditures. The hunters' consumer surplus associated with these activities would also be jeopardized to some degree, relative to the extent of deterioration of wetlands and bird species habitat caused by the destructive nature of Grass Carp.

Unlike commercial and recreational fishing, since recreational hunting is not directly linked to ecological consequences found in DFO (2017) and Cudmore et al. (2017), the impact and certainty analyses could not be quantified without additional information. However, it is anticipated that there would be some relocation of expenditures by resident Canadians to other sectors in the economy due to the expected damage to hunting activities. For example, if recreational hunting is no longer feasible, people's recreational activities may shift to other areas such as hiking.

Recreational Boating

The presence of Grass Carp may benefit the recreational boating activities in the form of reduced cost for vegetation control effort.[108]

The Grass Carp has been used in the US as a way of controlling and managing aquatic plants because of their foraging activities as well as alteration of water transparency, disturbance of the sediment, and deposition of fecal matter (Dibble and Kovalenko, 2009). While limited information is available on the direct impact of Grass Carp on non-targeted plants, it has been inferred that the presence of Grass Carp may facilitate recreational boating activities in the Great Lakes to some degree. The rationale is that marinas and boat owners may have to spend less time and money on vegetation control assuming absence of additional measures to prevent Grass Carp from the Great Lakes.

Since recreational boating is not directly linked to ecological consequences found in DFO (2017) and Cudmore et al. (2017), the impact and certainty analyses could not be applied to quantify the impact on this sector.

[108] Based on discussions with subject matter experts at the workshop "Socio-Economic Risk Assessment of the Presence of Grass Carp in the Great Lakes Basin" held on February 11-12, 2015.

Wildlife Viewing

Changes in water quality parameters (increase in nitrite, nitrate, phosphate concentrations) because of sediment resuspension and collapse of mechanisms responsible for maintenance of the vegetated state due to removal of macrophytes by Grass Carp are reported in a number of studies (e.g. Dibble & Kovalenko (2009), Shireman and Smith (1983), Kirkagac and Demir (2004)). This may provide a breeding ground for enteric bacteria, including some pathogens which can produce dangerous toxins and may influence algal blooms (Shireman and Smith 1983). Therefore, it may be anticipated that the presence of Grass Carp would increase algal build-up capacity in the Great Lakes, impact beach water quality (GLSC Fact Sheet 2009), pose increased health risk to Great Lakes users, and contribute to a decreased level of wildlife viewing activities around the Great Lakes basin.

In the absence of additional measures to prevent the presence of Grass Carp from the Great Lakes basin, viewers' expenditures and consumer surplus associated with these activities would be jeopardized to some degree, relative to the extent of deterioration of water quality and algal-related problems caused by the presence of Grass Carp.

Unlike commercial and recreational fishing, since wildlife viewing is not directly linked to ecological consequences found in DFO (2017) and Cudmore et al. (2017), the impact and certainty analyses could not be quantified without additional information. However, it is anticipated that there would be some relocation of expenditures by resident Canadians to other sectors in the economy due to the expected damage to wildlife viewing activities.

Beaches and Lakefront Use

The economic risk of the presence of Grass Carp to beach and lakefront use activities can be linked to the increased noxious smell and appearance of algae accumulated in nearshore waters or deposited on beaches.[109]

Since beaches and lakeshore activities are not directly linked to ecological consequences found in DFO (2017) and Cudmore et al. (2017), the impact and certainty analyses could not be applied to quantify the impact on this sector. However, it is likely that there would be some relocation of expenditures by beach users to other sectors in the economy due to the expected damage to beaches and lakefront use activities that the presence of Grass Carp would cause.

Ecosystem Services and Non-Market Values

There are a large number of coastal wetlands throughout the Great Lakes basin in both the US and Canada that would likely provide accessible spawning, nursery habitat to the suitable tributaries for Grass Carp (Cudmore et al., 2017; Cudmore and Mandrak, 2011). Cudmore et al.

[109] See wildlife viewing sub-section for a detailed discussion of the mechanisms.

(2017) reported that of the total area of 114,820 ha in the Great Lakes, about 24 wetlands with greater than 500 ha with an estimated low marsh area of 21,802 ha were suitable habitat for Grass Carp.

In Canada, there are 52 suitable spawning tributaries in the Great Lakes, unimpounded from mouth to at least 80 km upstream. More detailed analyses of tributary characteristics suggest that suitable spawning conditions for Grass Carp exist in at least 51 Canadian Great Lakes tributaries. In the US, there are 22 suitable spawning tributaries, unimpounded from mouth to at least 100 km upstream. More detailed analyses of Lake Erie tributaries suggest 7 out of 8 that would provide suitable spawning habitat (DFO, 2017).

While data is limited and the effects at the Great Lakes scale are unknown, available research suggests that Grass Carp could affect factors such as conductivity, turbidity, nutrient cycling, primary production, and dissolved oxygen (Cudmore et al., 2017). Wittmann et al. (2014) found significant cumulative effect of Grass Carp stocking on the overall abiotic environment.

Grass Carp populations with critical densities may nearly completely remove aquatic plants[110] (e.g. macrophytes, *cladophora, zygnema*) and influence macrophyte composition through selective feeding behaviour. A meta-analysis that included 48 data points from 13 studies found Grass Carp stocking strongly reduced macrophyte abundance or density (Wittmann et al. 2014).[111] The removal of marcophytes can result in adverse effects on the ecosystem with a reduction of the riparian cover, the bank stability (Conover et al. 2007)).

Areas with macrophytes in the Great Lakes, that could be consumed by Grass Carp, is estimated at a total wet weight biomass of 2.5 to 4.5 million metric tonnes (DFO, 2017). Of the estimated 2.5–4.5 million metric tonnes of aquatic vegetation in the Great Lakes at peak annual abundance (approximately August), complete elimination of vegetation was predicted to occur in less than 5% of areas and substantial reductions in peak aquatic biomass were predicted in many cases by the presence of Grass Carp (DFO, 2017; Gertzen et al. 2017).[112] Effects of the presence of Grass Carp may be greater within localized wetlands if Grass Carp (regardless of ploidy) aggregate in these areas (DFO, 2017).

Grass Carp is also known to consume terrestrial vegetation by digging into banks and uprooting riparian vegetation which might damage banks and cause erosion and increased turbidity in the adjacent waters (DFO, 2017; Cudmore et al., 2017) resulting in the loss of ecosystem services such as nutrient cycle control (DFO, 2017) and a non-functioning environment.

Aquatic vegetation in the Great Lakes provides ecosystem services such as provision of spawning and recruitment habitat for fish and bird species, high biological productivity, shore erosion protection, nutrient-cycle control, accumulation of sediment, supply of detritus (Herdendorf 1987), and mitigation of nonpoint source pollution (Mitsch 1992). Coastal

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[110] Ibid 86.

[111] For details of the results of studies conducted on the effect of Grass Carp on aquatic vegetation, see DFO (2017).

[112] A tipping point seemed to occur at a density of ten 13.2 kg Grass Carp/ha (DFO, 2017).

wetlands provide important nutrient sinks to help reduce eutrophication. Wetland using species in the Great Lakes are estimated to make up half of the fish biomass (Cudmore et al., 2017) and 60% of the dollar value of the fish landed commercially and 80% of the fish numbers harvested recreationally (Trebitz and Hoffman 2015).

Changes in water quality parameters, such as, increase in nitrite, nitrate, phosphate concentrations (Dibble & Kovalenko, 2009; Shireman and Smith 1983, Kirkagac and Demir 2004) are also predicted by the presence of Grass Carp which may influence algal blooms (Shireman and Smith 1983) and decreased ecosystem stability (Wetzel 2001).

The loss of such unique ecosystems and species may represent a loss to residents living close to such a unique natural resource and also to people around the world who value them for their own sake independent of use. In terms of quantifying economic values of the ecosystem services and non-market values predicted to be compromised, as the variability in ecosystem services might increase upon the presence of Grass Carp, firms/households may generally prefer to avoid risk or to be compensated for the changes caused by the presence of Grass Carp. The relevant literature on the study is scarce.

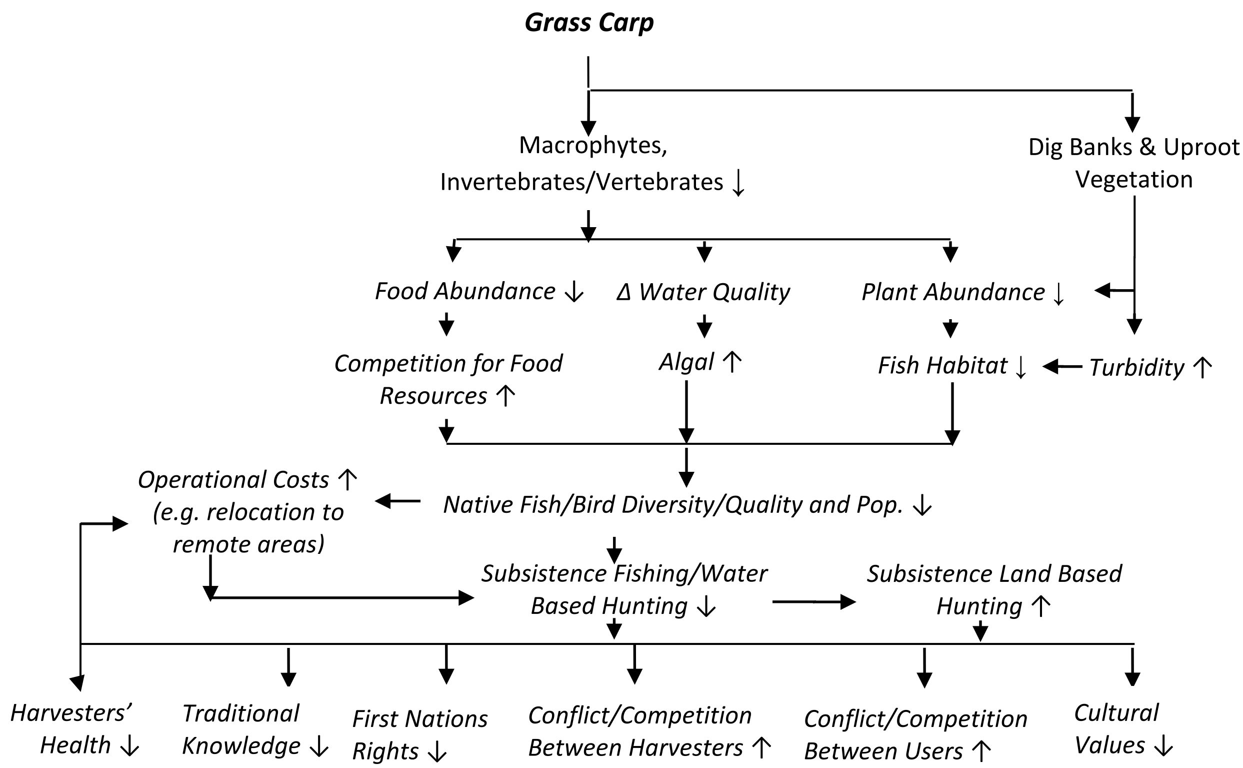
Whitehead (2006) estimated that the total value of protecting an additional 1,125 acres of Saginaw Bay coastal marsh, based on willingness to make a voluntary contribution, was $3,596/acre. Of the total value, recreational users were willing to pay in the amount of $1,627/acre and non-recreational or passive users were willing to pay $1,969/acre over the lifetime of the resident.

It is difficult and time consuming to quantify the damage to ecosystem services and non-market values caused by the damage to wetlands by the presence of Grass Carp in the entire Great Lakes Basin, due to methodological challenges, the lack of information and the uncertainty around predicting the future (e.g. knowledge of local weather and climate patterns). First of all, due to methodological difficulties, it is infeasible to quantify the damages to the services for the entire Great Lakes Basin. Secondly, it is extremely time intensive to quantify how much people will be willing to pay to avoid the damages or accept to be compensated for the damages to the services caused by the presence of Grass Carp. However, based on results reported in DFO (2017) and Cudmore et al. (2017), it may be inferred that there may be low to moderate risk on ecosystem services and non-market values in 10 years and extreme risk in 40 years starting 2023.

Social and Cultural Impact

Over time, the presence of Grass Carp in the Great Lakes basin could change the current lake ecosystems to ecosystems dominated by Grass Carp, and has the potential to damage the public image of these lakes regionally, nationally and internationally. These ecosystem impacts also directly affect the well-being of residents living close to such a unique natural resource and depend on their surrounding environment for subsistence, income generation and socio-cultural identity. For example, the Algonquian, Iroquoian and Sioux tribes have used the resources within the Great Lakes because they believe that those are the resources they have been given by their Creator to sustain themselves (Kappen et al., 2012).

Flowchart 3: Impact on Subsistence Fishing Resulting from the Presence of Grass Carp



As shown in the Flowchart 3, despite that Grass Carp population may present an opportunity for subsistence harvesters to harvest and harvesters are found to be adaptive to changing environment, a Grass Carp population may significantly damage subsistence harvests of native species from the Great Lakes and reduce the social, cultural and spiritual values of the lakes and of lake-related activities. Subsistence harvests may be impacted due to (i) change in ecosystem which may result in less native species as well as poor food quality for subsistence harvesters with negative impacts on subsistence harvesters and communities which may effectively extinguish First Nations rights (Rashidi, 2014); and (ii) gaining access to subsistence harvest may be impaired and/or may require travelling greater distances which will increase costs of harvesting. This will weaken/obsolete traditional knowledge and observations, and inter-generational transfer of knowledge and culture and change ways of life. Loss or degradation of fishing and other water based hunting may have an impact on traditional diets and may threaten food security and health of First Nation communities/individuals. The presence of Grass Carp may also encourage the increased level of (i) competition among subsistence harvesters/communities for fewer native fish species; and (ii) conflict and competition between subsistence harvesters and recreational anglers and commercial harvesters if changes causes fewer species availability. Quantitative assessments of these impacts are not feasible due to a lack of data.

Finally, Grass Carp may also consume wild rice *Zizania palustris,* a plant in the Great Lakes that is of conservation, rehabilitation and cultural value (DFO, 2017; US EPA 2012).

Due to comprehensive data on subsistence harvest, it is infeasible to quantify the social and cultural impact. However, based on results reported in DFO (2017) and Cudmore et al. (2017), it may be inferred that there may be low to moderate risk on subsistence fishing in 10 years and extreme risk in 40 years starting 2023 depending on the lake in question.

Chapter 6: Conclusion

The goal of this study was to provide a detailed socio-economic risk impact assessment of the potential risk that would stem from the presence of Grass Carp in the Great Lakes basin. The study, and in particular, the predicted risk that are provided, is intended to complement DFO (2017) in attempting to quantify the socio-economic impact of a potential Grass Carp establishment in the Great Lakes.

While additional secondary source information was used, the report heavily relied on DFO (2017), including the supplementary reports, provided a solid and defensible foundation for assessing the socio-economic impacts that would result from the presence of Grass Carp in the Great Lakes basin.

The study found that the Great Lakes basin provides invaluable services to society through maintaining ecosystem health and biodiversity - some are captured with the corresponding direct benefits (e.g. recreational activities) while some are indirect/intrinsic (e.g. climate control, non-use values). The intrinsic values of ecosystem health and biodiversity are hard to define, because they are much more intangible than direct benefits, such as commercial fishing (Krantzberg et al., 2008, 2006). However, it has been stated that the total non-use values might fall in the range of 60% - 80% of the total economic value (Freeman, 1979).

The Great Lakes provide considerable subsistence, social, cultural, and spiritual benefits to the people residing in the region and to Canada and the US as a whole. Freshwater fisheries have contributed substantially to preserving traditional aboriginal lifestyles in the study region. Socially, the Great Lakes beaches and shorelines provide a “sense of place” and a unique source of community pride and are the key public perception measures of environmental quality. The Great Lakes also provide opportunities for research and educational activities that result in a better understanding of the ecology.

In the absence of additional measures to prevent the presence of Grass Carp from the Great Lakes basin, the study estimated that, starting in 2024, the present value of impact on Great Lakes commercial fishing industry in Canada would be at $244 million and $1,300 million in 10 years and 40 years, respectively (see Table 12 and Annex 5A for Heat-Maps on risk and uncertainties[113]). The present value of impact on Great Lakes commercial fishing industry in the US would be at $102 million and $663 million in 10 years and 40 years starting 2024, respectively (see Table 12 and Annex 5B for Heat-Maps on risk and uncertainties).

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[113] Please note that heat-maps are developed only for commercial and recreational fishing based on the scales for the uncertainties and risk used in DFO (2017). For other activities predicted to be affected by the presence of Grass Carp (recreational boating, wild-life viewing, hunting, beaches and lakefront use), heap-map could not be developed, as they are not linked to ecological consequences found in DFO (2017) and, thus, socio-economic risk and (un)certainty could not be derived with precision.

Table 12: Estimated Present Values (USD Mil.) of Affected Activities in the Great Lakes in 10 Years and 40 Years by Country/Activity

Sector Impacted	Canada			The US		
	Baseline (2024)	10 Years (2033)	40 Years (2063)	Baseline (2024)	10 Years (2033)	40 Years (2063)
Commercial Fishing	$230	$244	$1,300	$145	$102	$663
Recreational Fishing	$556	$345	$2,604	$3,000	$2,401	$14,615
Hunting	NA	NA	NA	$31	NA	NA
Recreational Boating	$2,300	NA	NA	$4,900	NA	NA
Beaches/Lakefront Use	$235	NA	NA	$1,100	NA	NA
Wildlife Viewing	NA	NA	NA	$121	NA	NA

Source: Fisheries and Oceans Canada staff calculation, Policy and Economics, Central and Arctic Region.
Note: NA - Not available.

As for recreational fishing, starting in 2024, the present value of impact in Canada would be at $345 million and $2,600 million in 10 years and 40 years, respectively. The present value of impact on Great Lakes recreational fishing industry in the US would be at $2,400 million and $14,615 million in 10 years and 40 years, respectively.

The study also anticipated that the presence of Grass Carp in the Great Lakes would decrease beach/lake front use, wildlife viewing, hunting opportunities and associated economic benefits to some degree, relative to the extent of deterioration of wetlands and bird species habitat and deterioration of water quality and cladophora-related problems caused by the presence of Grass Carp. On the other hand, the presence of Grass Carp may benefit the recreational boating activities in the form of reduced cost for vegetation control effort. However, the impact on such activities could not be quantified as these activities were not directly linked to ecological consequences found in DFO (2017) and Cudmore et al. (2017).

The study recognized that during the period considered, there could be factors in the economy at work that might create counteracting forces on the impacts of Grass Carp on communities, businesses, and individuals. Therefore, the net economic impacts might be counterbalanced at the regional and national levels, while remaining significant for the stakeholders (e.g. communities, harvesters, users), when taking into account the (re)distribution of income and employment as a consequence of change in the scale of activities in and around the Great Lakes basin.

In terms of damage to ecosystem services, the study found that Grass Carp populations have the potential to nearly completely remove aquatic plants, influence macrophyte composition, damage banks and cause erosion and increased turbidity resulting in the loss of ecosystem services such as nutrient cycle control (DFO, 2017) and a non-functioning environment. It is difficult and time consuming to quantify the damage to ecosystem services caused by the damage to wetlands by the presence of Grass Carp in the entire Great Lakes Basin, due to methodological challenges, the lack of information and the uncertainty around predicting the future (e.g. knowledge of local weather and climate patterns). Despite the difficulty of quantifying, the economic value of damages to wetlands along the Great Lakes may perceive to be substantial.

From social and cultural aspects, the presence of Grass Carp in the Great Lakes basin has the potential to harm the well-being of residents living close to such a unique natural resource. Grass Carp species may significantly damage subsistence harvests of native species from the Great Lakes and reduce the social, cultural and spiritual values of the lakes and of lake-related activities. It may also create conflict and competition between subsistence harvesters and recreational anglers and commercial harvesters if changes cause fewer species availability. Quantitative assessments of these impacts are not feasible due to a lack of pertinent information.

The risk of the presence of Grass Carp in the Great Lakes Basin assessed in the study should be viewed as conservative estimates. First of all, as more non-native species are introduced, native species are increasingly disrupted and becomes more susceptible to future invasions (Simberloff and Von Holle 1999, Ricciardi 2001). Secondly, although not a known current practice, additional importation of live Grass Carp into the US could introduce non-native pathogens with unknown potential consequences (Cudmore et al., 2017). Thirdly, different species may adapt to changes in ecosystem that shifts or changes species' habitat. These unknowns and interrelated nature of ecosystems may cause additional impact, which were not captured in the present socio-economic risk assessment.

It should also be noted that the estimated baseline values and risk associated with activities in and around the Great Lakes for Canada and the US should not be directly compared and also with those provided in the extant literature due to methodological differences which limits comparability. Nonetheless, in the absence of more/better data, this study made an effort in identifying the value of certain activities in and around the Great Lakes in Canada and the US and the value of what might potentially be lost by the presence of Grass Carp.

While Grass Carp driven changes to ecosystems are well known, the mechanisms of impact of Grass Carp on ecosystem services is still emerging. While most research focuses the ecological implications of Grass Carp, relatively less research has been done on the implications for activities in and around the Great Lakes. Furthermore, the economic risk of Grass Carp is often neither properly captured nor incorporated into decision making and thereby may result in an ‘invisible tax’ (Pejchar and Mooney, 2009) on ecosystem services. In light of that, the study presents the economic risk assessment of Grass Carp to supplement the ecological risk assessment. The results of the study may be used to communicate to the public, resource managers, and decision makers in both Canada and the US, help set the priorities and assist in developing options for mitigation measures and/or prevention of Grass Carp in the Great Lakes Basin.

The study suffered from some limitations due to a lack of information, which focuses the areas for further research. While collecting and analyzing information for the purpose of this study, the most notable obstacles/limitations identified are[114]:

i. Lack of Great Lakes specific information by activity;

ii. This study does not take into account the dynamic and interrelated nature of ecosystems, the relationships between resource uses or changes in environmental conditions. The values by activity predicted in 10 and 40 years are based on the values by activity for the most recent year available assuming that the values will prevail for the time period covered if everything else is remaining the same. In reality, economic conditions (e.g. commercial fishing, recreational fishing) may change rapidly over time. That is, the study assumes the economic system as static and unresponsive to invasion which contradicts the reality for large-scale invasions when human behavior and economic systems respond to the effects of invasive species and can be as dynamic as ecological systems. Moreover, because of the presence of overlaps in some activities (e.g. recreational fishing and recreational boating) and/or complementarity and substitutability of goods/activities, results presented here must be considered within light of this static approach.

iii. Lack of a more explicit linkage between the ecological consequences proposed in DFO (2017) and Cudmore et al. (2017), and the socio-economic factors proposed in the current document. The study assumed linearity between ecological and socio-economic risk and uncertainty and drew conclusions based on the present values of the activities. A revision of the study based on quantified link between ecological and socio-economic consequences would provide a more accurate socio-economic risk assessment in a more precise manner.

iv. Lack of adequate information to provide an incremental/marginal analysis showing a quantitative estimate or a range of estimates of the socio-economic risk of some of the impacted activities for which only qualitative descriptions were provided in the current study.

These limitations have been mitigated to some extent through the adoption of assumptions and application of proxies from the extant literature, with appropriate adjustments as and when needed, within the existing time constraints. However, the appropriate remedy for these limitations would be further research. For example, in order to have a proper assessment of baseline value(s) and impact, a possible next step might be to undertake a comprehensive survey in the study area to obtain values (including willingness to pay and subsistence harvests) being generated by activity and by lake. Similarly, for forecasting, estimation methodologies such as multimarket General Equilibrium model[115], which try to identify parameters important to a decision or set of decisions in part to reflect welfare changes from complementarity and substitutability of key goods, may mitigate biases associated with forecasting.

[114] For sector/activity specific limitations identified in the study, please see the respective section.

[115] For a detailed discussion, see Lodge (2016).

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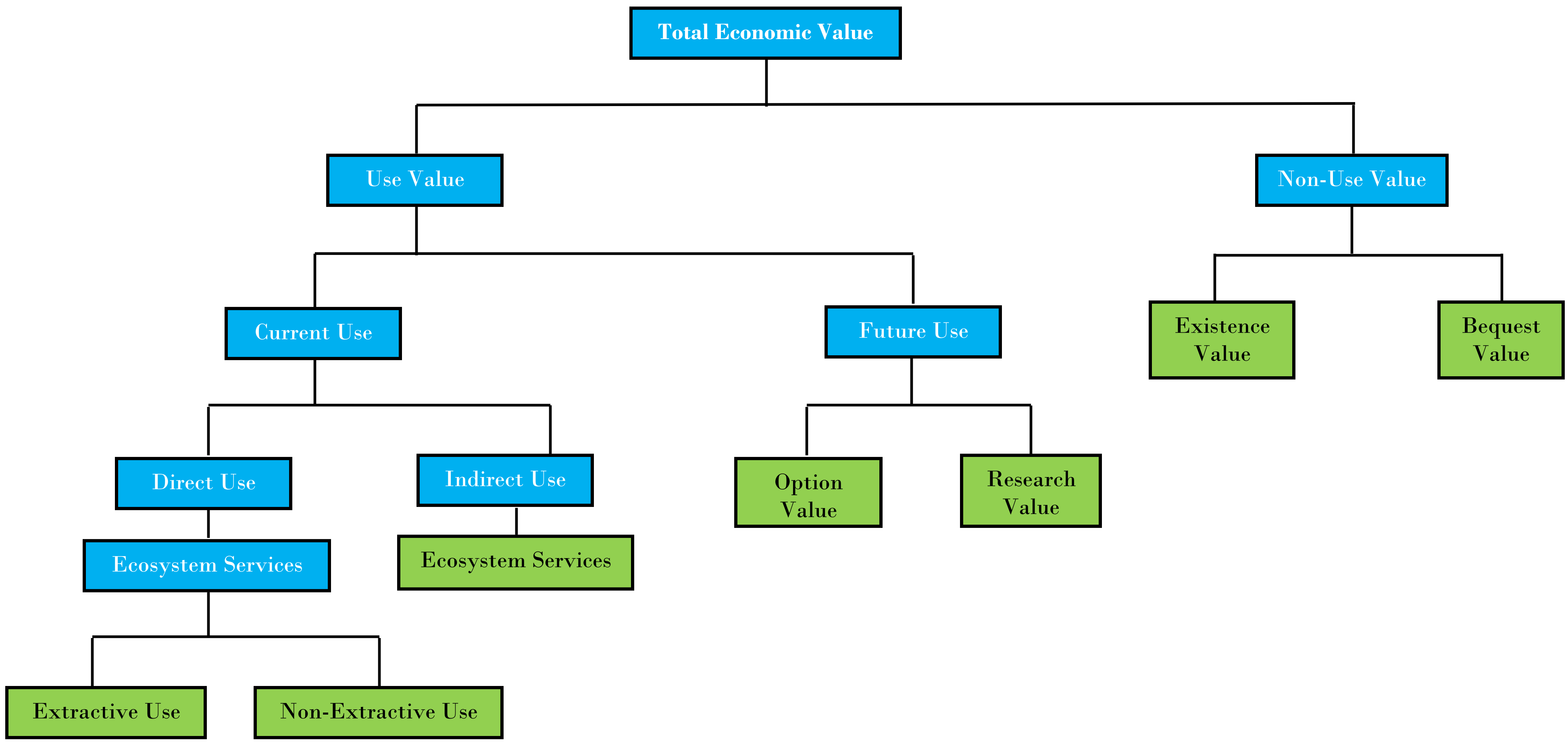
Matrix 1: Total Economic Valuation Flowchart



Definitions

Use Value: The value people derive from using a good.

Current Use Value:

Direct use: Directly consumable goods and services through ecosystem services.

Ecosystem services: Include provisioning services such as food, water (Millennium Ecosystem Services Assessment, 2005).

Extractives use: Extractive uses result in water level and/or commodities provided by the Great Lakes (e.g. commercial fishing).

Non-extractives use: Non-extractives uses do not cause water level and/or commodities provided by the Great Lakes (e.g. wildlife watching).

Indirect use: Indirectly consumable goods and services through ecosystem services.

Ecosystem services: Include provisioning services such as include regulating services (e.g. climate, floods, disease, water quality) and supporting services (e.g. soil formation, nutrient cycling) (Millennium Ecosystem Services Assessment, 2005).

Future Use Value:

Option value: The amount someone is willing to pay to keep open the option of future use of the resources (e.g. possibility of commercial/recreational fishing in the future). [116]

Research Value: Scientific research potential that may result in new discoveries/knowledge and/or new developments that have broader application in future. Some of the potential beneficial effects include new understanding of the biology and ecology of the area, new understanding of inter-specific interactions and competition, new chemicals/medicines with broader applicability.

Non-Use Value: The value people derive from a good/resource independent of any use people might make of that good/resource.

Bequest value: Conservation for future generations (e.g. future biodiversity). Bequest value takes into account people's WTP for future total use by their children and future generations.

[116] For a detailed discussion on option values, see Marbek (2010b).

Existence value: Existence value arises because people intrinsically value the existence of the Great Lakes regardless of its use. Existence value includes the benefits from knowing that the Great Lakes are being used by others as well as cultural values for an economy.[117]

[117] Existence and bequest values are non-market values that aim to assign a monetary value to goods and services that have no market price. Therefore, despite some limitations, the non-market evaluation remains an efficient method being widely used to capture the benefits quantitatively and to support and influence policies on marine environment. For a detailed discussions on difficulties in applying traditional non-market valuation techniques in a Canadian context, see Adamowicz et al. (1994).

Matrix 2: Summary of Empirical Studies Used for Valuation of Economic Activities in the Great Lakes basin

Name of the Author	Time Period and Area Covered	Method of Analysis	Conclusion/Information Used	Limitations noted and/or Adjustment Made for the current Study
Commercial Fishing				
Ontario Ministry of Natural Resources - Supplied Data	2010-2014 - Ontario Great Lakes		An average of 12,575t of fish were caught with a value of CAD33 million.	Converted from CAD to USD.
National Oceanic and Atmospheric Administration National Marine Fisheries Service Website	2010-2014 - US Great Lakes	All live weight data of landed finfish reported by US fishers.	An annual average of 7,792t yielding USD20.7 million were landed.	Added value not provided. Used OMNR 2015 ratio.
Recreational Fishing				
DFO 2008	2005 – Great lakes Basin in Canada	Recreational Fishing Survey on 16,000 households within Canada.	The total direct expenditures and major purchases/investment of USD365.9 million in recreational fishing in the Great Lakes based on travel costs and expenditures for fishing trips.	Adjustment has been made for inflation and converted from CAD to USD.
U.S. Fish and Wildlife Service 2014	2011 - US	A national outdoor recreation survey based on 30,400 households within the US.	The total direct expenditures and major purchases/investment of USD2.0 billion in recreational fishing in the Great Lakes based on travel costs and expenditures for fishing trips.	Did not provide expenditures by lake, so expenditures were extrapolated from the proportion of anglers by lake. Adjusted for inflation.
Rosenberger 2016	1958-2016 - North America	A database of 421 economic valuation surveys of outdoor activities.	The mean consumer surplus of freshwater fishing in Midwestern US and Canada were $48 and $18 per angler-day, respectively.	Mulitplied by mean-use days derived from DFO 2008 and U.S. Fish and Wildlife Service 2014 after adjusting for inflation.
Recreational Hunting				
U.S. Fish and Wildlife Service 2015	2011 - US	A national outdoor recreation survey based on 30,400	USD10.3 billion was expended on waterfowl hunting in the Great Lakes states.	Expenditures were provided at the state level. Used ratio from Austin et al. to derive Great Lakes level data. Adjusted for

		households within the US.		inflation.
Austin et al. 2007	2007 - US Great Lakes	Estimation.	5% of waterfowl hunting in the Great Lakes states occurs in the Great Lakes.	Ratio was an estimation.
Rosenberger 2016	1958-2016 - North America	A database of 421 economic valuation surveys of outdoor activities.	The mean use value of waterfowl hunting in Midwestern US was $35 per hunting-day in 2016.	Mulitplied by mean-use days derived from U.S. Fish and Wildlife Service 2015. Adjusted for inflation.
Recreational Boating				
U.S. Army Corps of Engineers 2008	2003 - US Great Lakes	Boater registration data and an independent online boater assessment survey.	Registered boaters spent 17 million boating days and expended USD3.8 billion in 2003.	Consumer surplus substantially varies between studies, so it was not included. Information may be outdated. Adjusted for inflation.
Krantzberg et al. 2006	2000 - Canada Great Lakes	Proporationate population estimate.	The estimated economic value of boating in the Great Lakes in Canada is CAD2.2 billion.	Adjusted for inflation. Converted from CAD to USD.
Beaches and Lakefront Use				
Krantzberg and de Boer (2006)	2004 – Canadian portion of the Great Lakes	Derived by proportionally scaling the value derived by Shaikh (2004) for the US	The estimated Willingness to Pay value was in the range of USD197 - USD247 million for Canadian Great Lakes beach-goers and USD800 million - USD1.0 billion for US Great Lakes beach-goers.	Adjustment has been made for inflation.
Wildlife Viewing				
Austin et al. 2007	2007 - US Great Lakes	Estimated birding-days and birding trip values based on available information	Estimated the total surplus value of birding on the US side of the Great Lakes is about $100 million annually.	Estimation derived based upon other estimations. Adjusted for inflation.

Annex 1: Map of the Great Lakes Basin

Source: www.atlas.gc.ca

Annex 2A: Selected Socio-Economic Indicators for the Great Lakes States

Indicators	Illinois	Indiana	Michigan	Minnesota	New York	Ohio	Pennsylvania	Wisconsin	US
Total population	**12,873,761**	**6,568,645**	**9,900,571**	**5,419,171**	**19,673,174**	**11,575,977**	**12,779,559**	**5,742,117**	**316,515,021**
Male	6,292,276	3,189,737	4,848,114	2,632,132	9,377,147	5,632,156	6,190,363	2,822,400	151,781,326
Median age	37	37	39	37	38	39	40	39	37
Population density (per square km)	90	71	68	26	161	109	110	41	35
Population 18 to 24 years	**1,249,849**	**665,721**	**998,253**	**505,477**	**1,985,605**	**1,102,450**	**1,243,213**	**559,675**	**31,368,674**
Less than high school graduate	169,425	113,959	137,223	64,011	257,748	157,687	156,073	67,174	4,503,448
High school graduate	349,450	204,562	280,324	132,569	509,475	342,726	395,168	174,317	9,321,843
Some college or associate's degree	575,813	289,051	489,074	247,949	924,095	498,495	548,814	261,780	14,459,475
Bachelor's degree or higher	155,161	58,149	91,632	60,948	294,287	103,542	143,158	56,404	3,083,908
Population 25 years and over	**8,600,178**	**4,316,273**	**6,652,665**	**3,632,992**	**13,435,795**	**7,817,508**	**8,814,112**	**3,873,119**	**211,462,522**
Less than high school graduate	1,038,317	524,854	693,457	274,773	1,930,117	849,597	950,001	347,428	28,229,094
High school graduate	2,308,309	1,494,302	1,988,382	946,686	3,588,894	2,669,316	3,207,989	1,239,523	58,722,528
Some college or associate's degree	2,475,681	1,256,861	2,178,934	1,186,288	3,320,660	2,258,567	2,134,085	1,208,472	61,558,628
Bachelor's degree or higher	2,777,871	1,040,256	1,791,892	1,225,245	4,596,124	2,040,028	2,522,037	1,077,696	62,952,272
Aboriginal population	**135,378**	**57,401**	**147,217**	**108,857**	**304,046**	**95,809**	**96,666**	**93,108**	**6,138,482**
Male	68,411	28,678	71,770	53,847	149,690	46,969	47,343	46,307	3,054,732
Median age	29	31	30	25	30	33	30	27	29
Aboriginal 25 years and over	**18,923**	**10,357**	**34,313**	**32,977**	**45,835**	**14,164**	**16,052**	**33,706**	**1,584,273**
Less than high school graduate	4,561	1,468	4,853	5,498	13,053	3,014	4,971	4,462	331,230
High school graduate	5,024	3,477	12,516	11,425	12,197	4,266	4,717	12,408	503,497
Some college or associate's degree	6,292	3,535	12,215	11,716	11,583	5,056	3,969	12,893	526,059
Bachelor's degree or higher	3,046	1,877	4,729	4,338	9,002	1,828	2,395	3,943	223,487
In labor force	**6,413,110**	**3,150,864**	**4,656,615**	**2,865,941**	**9,610,086**	**5,573,105**	**6,172,172**	**2,944,512**	**152,343,518**
Employed	5,820,209	2,898,701	4,190,823	2,702,896	8,810,126	5,107,620	5,675,239	2,756,034	139,593,533
Unemployed	592,901	252,163	465,792	163,045	799,960	465,485	496,933	188,478	12,749,985
Civilian employed 16 years or over	**6,395,690**	**3,147,834**	**4,652,874**	**2,863,915**	**9,586,527**	**5,564,805**	**6,167,295**	**2,942,008**	**151,328,054**
Agriculture, forestry, fishing and hunting, and mining	64,380	42,725	55,638	65,637	54,493	57,831	88,200	71,069	2,852,402
Construction	313,232	175,010	212,000	156,525	514,033	275,483	341,409	153,703	9,027,391
Manufacturing	765,301	569,228	776,736	382,798	600,408	831,030	729,883	532,873	15,171,260
Wholesale trade	184,522	79,429	106,578	81,498	229,075	147,353	168,873	76,802	3,968,627
Retail trade	668,523	349,322	498,455	318,240	1,000,895	625,036	703,923	325,573	16,835,942
Total households	4,786,388	2,501,937	3,841,148	2,124,745	7,262,279	4,585,084	4,958,859	2,299,107	116,926,305
Median household income ($)	57,574	49,255	49,576	61,492	59,269	49,429	53,599	53,357	53,889
Households with earnings	3,773,574	1,944,202	2,829,006	1,709,589	5,627,288	3,464,021	3,738,692	1,800,252	90,916,552
Median family income ($)	**71,546**	**61,119**	**62,247**	**77,055**	**71,913**	**62,817**	**68,158**	**68,064**	**66,011**
Median earnings for workers ($)	32,206	29,172	28,188	33,527	34,655	30,060	31,542	30,721	30,926
F/T, year round with earnings	4,234,359	2,094,262	2,865,017	1,898,758	6,506,716	3,696,416	4,170,130	1,943,435	102,063,280
Mean earnings ($)	63,560	52,755	57,177	62,086	68,860	55,417	59,386	54,693	59,736

Sources: (i) 2015 American Community Survey, the 2015 Population Estimates, and (ii) the US Census Bureau.

Annex 2B: Aboriginal identity population by Sexes, Age Groups, Median Age for the US and Great Lakes States

States	Total population	Aboriginal Population*	Aboriginal Population**	Non-aboriginal identity population
Population				
Illinois	12,859,995	139,840	75,460	12,720,155
Indiana	6,619,680	62,546	26,656	6,557,134
Michigan	9,922,576	153,104	71,545	9,769,472
Minnesota	5,489,594	117,564	73,101	5,372,030
New York	19,795,791	318,526	190,539	19,477,265
Ohio	11,613,423	101,965	31,847	11,511,458
Pennsylvania	12,802,503	107,484	45,343	12,695,019
Wisconsin	5,771,337	100,614	65,072	5,670,723
United States	321,418,820	6,623,941	4,010,885	314,794,879
Male				
Illinois	6,314,495	70,453	39,048	6,244,042
Indiana	3,261,865	31,323	13,740	3,230,542
Michigan	4,878,148	74,767	35,811	4,803,381
Minnesota	2,729,864	58,193	36,640	2,671,671
New York	9,611,513	157,441	96,284	9,454,072
Ohio	5,686,530	50,280	16,385	5,636,250
Pennsylvania	6,264,374	52,763	22,949	6,211,611
Wisconsin	2,867,600	50,205	32,819	2,817,395
United States	158,229,297	3,297,446	2,024,209	154,931,851
Median Age				
Illinois	37.7	31.4	31.4	-
Indiana	37.5	33	34	-
Michigan	39.7	31.1	34.1	-
Minnesota	37.9	26	27.6	-
New York	38.3	31.7	32.1	-
Ohio	39.3	33.9	36.9	-
Pennsylvania	40.7	30.5	30.2	-
Wisconsin	39	28	29.7	-
United States	37.8	30.2	30.7	-
Total population 16 years and over				
Illinois	10,244,199	104,444	29,453	10,139,755
Indiana	5,222,522	47,184	10,615	5,175,338
Michigan	7,983,626	113,670	27,442	7,869,956
Minnesota	4,347,568	79,042	25,120	4,268,526
New York	16,070,457	240,646	73,908	15,829,811
Ohio	9,295,051	78,044	12,967	9,217,007
Pennsylvania	10,431,544	78,895	16,805	10,352,649
Wisconsin	4,626,689	70,140	23,336	4,556,549
United States	256,152,291	4,844,357	1,494,467	251,307,934

Sources: US Census Bureau 2015 Population Estimates

*Note(s): * Includes American Indians and Alaskan Natives, including those of mixed race; ** Includes American Indians and Alaskan Natives, excluding those of mixed race*

Annex 2C: Selected Socio-Economic Indicators for Ontario and Quebec

Indicators	Canada	Ontario	Quebec
Total population	**35,151,728**	**13,448,494**	**8,164,361**
Male	17,264,200	6,559,390	4,016,755
Median age	41	40	41
Population density (per square km)	4	15	6
Population 15 to 24 years	**4,386,300**	**1,785,600**	**936,100**
Less than high school graduate	1,418,100	582,900	271,500
High school graduate	1,024,700	421,800	140,600
Some college or non-university degree	1,613,000	608,400	473,600
Bachelor's degree or higher	330,400	172,400	50,500
Population 25 years and over	**25,200,800**	**9,737,800**	**5,951,800**
Less than high school graduate	3,582,400	1,236,600	1,105,000
High school graduate	4,903,800	1,939,700	916,200
Some college or non-university degree	9,738,500	3,540,000	2,464,100
Bachelor's degree or higher	6,976,200	3,021,600	1,466,400
Aboriginal population	**911,700**	**234,500**	**96,300**
Male	440,700	112,900	47,800
Median age (For First Nations in ON and QC)	28	29	31
Aboriginal 25 years and over	**606,140**	**153,570**	**69,780**
Less than high school graduate	142,260	33,270	19,070
High school graduate	87,500	22,440	6,840
Some college or non-university degree	277,790	48,300	30,910
Bachelor's degree or higher	83,600	23,120	10,470
In labor force	**19,431,400**	**7,484,900**	**4,445,700**
Employed	18,068,500	6,994,600	4,129,900
Unemployed	1,362,900	490,300	315,800
Employed 15 years or over	**18,080**	**7,000**	**4,133**
Agriculture, forestry, fishing and hunting, and mining	616	114	88
Construction	1,385	504	236
Manufacturing	1,695	751	493
Wholesale trade	678	279	151
Retail trade	2,068	754	502
Median market income of above ($)	52,200	55,000	42,800
Persons or families with employment income	15,740,980	3,868,670	3,868,670
Median family market income ($)	**76,900**	**79,000**	**66,500**
Median employment income for workers ($)	33,180	33,170	30,940
Full-time employees	12,512,800	4,836,100	2,917,700
Median weekly wage ($)	960	962	874

Source: (i) 2016 Canadian community profile, Statistics Canada; and (ii) CANSIM

Annex 2D: Aboriginal identity population by Sexes, Age Groups, Median Age for Ontario, Quebec and Canada

Provinces	Total - Population	Aboriginal identity	First Nations*	Métis	Inuk (Inuit)	Multiple Aboriginal identities	Other Aboriginal identities	Non-Aboriginal identity
Total Population								
Ontario	12,651,790	301,430	201,100	86,015	3,360	2,910	8,045	12,350,365
Quebec	7,732,520	141,915	82,425	40,960	12,570	1,550	4,410	7,590,610
Canada	32,852,320	1,400,690	851,560	451,795	59,440	11,415	26,470	31,451,640
Male								
Ontario	6,181,445	145,020	96,620	41,755	1,475	1,420	3,745	6,036,425
Quebec	3,814,045	70,205	40,110	21,295	6,265	715	1,815	3,743,840
Canada	16,163,110	682,190	411,785	223,335	29,495	5,525	12,055	15,480,925
Median Age								
Ontario	40	31.2	29.6	34.8	25.2	27.9	35.9	40.2
Quebec	41.2	32.7	31.3	38.8	21.3	33.1	46	41.3
Canada	40.1	27.7	25.9	31.4	22.8	24.9	39.4	40.6
Total population 25 years and over								
Ontario	8,771,320	176,090	113,250	54,545	1,685	1,555	5,045	8,595,230
Quebec	5,499,490	85,325	48,145	27,480	5,420	965	3,310	5,414,165
Canada	22,935,455	754,065	435,900	267,340	27,330	5,695	17,800	22,181,395

Sources: Statistics Canada; Censuses of Population; 2011.
*Note: * First Nations peoples in Ontario include Algonquian-speaking Cree, Oji-Cree, Algonquin, Ojibwa, Odawa, Potawatomi and Delaware, plus the Iroquoian-speaking Six Nations (Mohawk, Oneida, Onondaga, Cayuga, Seneca and Tuscarora). Over 60% reported being a Treaty Indian or a Registered Indian and over one-quarter (27% or 55,885) of all First Nations people lived on a reserve.*

Annex 3A: The Great Lakes Landings and Landed Values of Commercial fisheries by Species/Lake/Country in 2014

Species	Erie	Huron	Ontario	Superior	Michigan	Grand Total
Canada						
Landings (kg)						
Yellow and White Perch	3,184,610	243,863	36,778	-	NA	**3,465,251**
Rainbow Smelt	2,659,414	-	-	-	NA	**2,659,415**
Walleye	2,136,546	84,541	12,745	180	NA	**2,234,012**
Lake Whitefish	49,660	719,378	30,427	98,422	NA	**897,886**
White Bass	1,900,175	441	1,128	-	NA	**1,901,745**
Others	93,680	157,906	86,860	183,708	NA	**522,154**
Total	**10,024,084**	**1,206,129**	**167,939**	**282,310**	**NA**	**11,680,462**
Landed Values (USD 000)						
Yellow and White Perch	$12,344	$995	$117	-	NA	**$13,457**
Rainbow Smelt	$1,218	-	-	-	NA	**$1,218**
Walleye	$8,935	$383	$60	$1	NA	**$9,379**
Lake Whitefish	$160	$2,706	$114	$328	NA	**$3,308**
White Bass	$2,197	$0	$1	$0	NA	**$2,199**
Others	$72	$150	$170	$282	NA	**$674**
Total	**$24,926**	**$4,234**	**$462**	**$611**	**NA**	**$30,233**
The US						
Landings (kg)						
Yellow and White Perch	1,023,713	13,552	20,435	5	21,340	**1,079,045**
Rainbow Smelt	-	-	-	3,595	36	**3,633**
Walleye	131	18,553	-	903	3,335	**22,923**
Lake Whitefish	15,787	733,256	-	712,190	1,561,289	**3,022,521**
White Bass	506,630	1,634	-	-	8	**508,272**
Others	999,744	274,863	48	538,507	345,410	**2,158,571**
Total	**2,546,005**	**1,041,858**	**20,483**	**1,255,200**	**1,931,419**	**6,794,965**
Landed Values (USD 000)						
Yellow and White Perch	$3,739	$76	$87	$0	$117	**$4,019**
Rainbow Smelt	-	-	-	$7	$0	**$7**
Walleye	$1	$106	-	$5	$16	**$127**
Lake Whitefish	$52	$3,594	-	$3,127	$7,840	**$14,613**
White Bass	$744	$2	-	-	$0	**$746**
Others	$913	$431	-	$858	$630	**$2,832**
Total	**$5,449**	**$4,209**	**$87**	**$3,997**	**$8,604**	**$22,345**
Grand Total						
Landings (kg)	***12,570,089***	***2,247,987***	***188,422***	***1,537,510***	***1,931,419***	***18,475,427***
Landed Values (USD 000)	***$30,375***	***$8,443***	***$549***	***$4,608***	***$8,604***	***$52,578***

Sources: (i) OMNRF; (ii) NOAA Fisheries, Fisheries Statistics Division

*Note: * Includes American Eel, Bigmouth Buffalo, Black Crappie, Bowfin, Brown Bullhead, Burbot, Channel Catfish, Chinook Salmon, Cisco, Common Carp, Freshwater Drum, Gizzard Shad, Lake Trout, Lepomis, Moxostoma, Mudpuppy, Northern Pike, Oncorhynchus, Pink Salmon, Pomoxis, Quillback, Rainbow Trout, Rock Bass, Round Whitefish, Sea Lamprey, Suckers, White Sucker.*

Annex 3B: Landings and Landed Values of Commercial Fishing in the Great Lakes by Lake during 2010-14

Lakes	2010	2011	2012	2013	2014	Total	5-Year Average
Canada							
Landings (kg)							
Erie	8,995,179	9,839,812	11,734,709	11,278,256	10,024,084	**51,872,040**	**10,374,408**
Huron	1,756,601	1,690,680	2,020,149	1,724,702	1,206,129	**8,398,262**	**1,679,652**
Superior	396,319	353,664	356,109	316,333	282,310	**1,704,735**	**340,947**
Ontario	190,365	202,642	180,507	158,601	167,939	**900,055**	**180,011**
Total	**11,338,465**	**12,086,798**	**14,291,474**	**13,477,893**	**11,680,462**	**62,875,092**	**12,575,018**
Landed Values (USD)							
Erie	$24,859,972	$28,075,877	$31,847,531	$25,071,027	$24,926,134	**$134,780,541**	**$26,956,108**
Huron	$4,285,309	$4,802,412	$6,482,456	$5,049,332	$4,234,195	**$24,853,705**	**$4,970,741**
Superior	$517,947	$464,337	$488,686	$493,410	$611,147	**$2,575,527**	**$515,105**
Ontario	$476,570	$588,968	$464,209	$364,966	$461,982	**$2,356,695**	**$471,339**
Total	**$30,139,798**	**$33,931,594**	**$39,282,882**	**$30,978,734**	**$30,233,459**	**$164,566,467**	**$32,913,293**
The US							
Landings (Kg)							
Erie	2,256,175	2,584,064	2,864,662	2,463,429	2,546,005	**12,714,335**	**2,542,867**
Huron	1,422,485	1,479,348	1,294,408	1,358,597	1,041,858	**6,596,697**	**1,319,339**
Michigan	2,880,192	2,711,856	2,602,555	2,066,781	1,931,419	**12,192,803**	**2,438,561**
Superior	1,516,891	1,527,528	1,722,065	1,320,518	1,255,200	**7,342,203**	**1,468,441**
Ontario	20,505	37,133	27,857	10,186	20,483	**116,164**	**23,233**
Total	**8,096,248**	**8,339,929**	**8,511,547**	**7,219,512**	**6,794,965**	**38,962,201**	**7,792,440**
Landed Values (USD)							
Erie	$4,626,313	$5,720,364	$6,544,315	$4,630,923	$5,448,932	**$26,970,847**	**$5,394,169**
Huron	$3,016,693	$3,663,271	$3,485,956	$4,577,357	$4,208,543	**$18,951,820**	**$3,790,364**
Michigan	$6,831,070	$7,193,410	$9,298,717	$8,309,881	$8,603,579	**$40,236,657**	**$8,047,331**
Superior	$2,691,983	$3,234,041	$3,600,453	$3,464,482	$3,996,948	**$16,987,907**	**$3,397,581**
Ontario	$75,872	$144,795	$92,912	$33,005	$86,885	**$433,469**	**$86,694**
Total	**$17,241,931**	**$19,955,881**	**$23,022,353**	**$21,015,648**	**$22,344,887**	**$103,580,700**	**$20,716,140**
Grand Total							
Landings (Kg)	***19,434,712***	***20,426,727***	***22,803,021***	***20,697,405***	***18,475,427***	***101,837,293***	***20,367,459***
Landed Values (USD)	***$47,381,729***	***$53,887,475***	***$62,305,235***	***$51,994,382***	***$52,578,346***	***$268,147,167***	***$53,629,433***

Sources: (i) OMNRF; (ii) NOAA Fisheries, Fisheries Statistics Division

Annex 4A: Direct Recreational Fishing Expenditures (CAD Mil.) Made on Canadian Side of the Great Lakes Basin by All Anglers by Lakes/Types, 2005

Name of the Lakes	Packages	Food & Accommodation	Fees*	Travel	Boating Expenses**	Other Expenses***	Total
Superior	$4.1	$5.2	$1.3	$3.3	$3.0	$0.1	$17.1
Huron	$5.9	$30.3	$7.5	$18.3	$29.4	$0.7	$92.1
Erie	$1.7	$7.9	$5.0	$7.6	$10.9	$0.2	$33.4
Ontario	$1.4	$11.4	$5.3	$10.0	$16.3	$0.7	$44.9
Lake St. Clair	$1.3	$2.9	$1.4	$2.8	$4.7	$0.8	$13.9
St. Lawrence	$0.8	$4.2	$1.2	$2.5	$4.0	$0.5	$13.2
Great Lakes	**$15.2**	**$62.0**	**$21.6**	**$44.5**	**$68.3**	**$3.0**	**$214.6**

Source: Survey of Recreational Fishing in Canada 2005, DFO.
*Notes: * Includes campsite, licences, and access fees; ** Includes household boat costs, boat rentals, and supplies*; ***** Includes expenses such as travel, guides.*

Annex 4B: Major Purchases and Investments (CAD Mil.) on Canadian Side of the Great Lakes Basin by All Anglers by Lake/Type, 2005

Name of the Lakes	Fishing Equipment*	Boating Equipment	Camping Equipment	Vehicles	Land/ Buildings	Other Investments	Total
Superior	$0.8	$1.1	$1.0	$3.6	$3.1	$0.7	$10.3
Huron	$8.2	$27.1	$6.6	$12.4	$12.2	$2.7	$69.2
Erie	$4.1	$36.3	$1.0	$4.0	$4.6	$0.9	$50.8
Ontario	$7.4	$28.9	$1.3	$3.7	$1.0	$5.7	$48.0
Lake St. Clair	$1.4	$5.6	$1.0	$4.2	$1.5	$0.5	$14.2
St. Lawrence	$2.0	$8.4	$0.8	$6.0	$18.5	$0.3	$36.0
Great Lakes	**$23.9**	**$107.3**	**$11.6**	**$33.8**	**$41.0**	**$10.8**	**$228.4**

Source: Survey of Recreational Fishing in Canada 2005, DFO.
*Notes: * Includes expenditures on fishing rods, reels, depth finders, etc.*

Annex 4C: Great Lakes Anglers (000's) and Days of Fishing on the US Side of the Great Lakes Basin by Type of Fish: 2011

	Anglers	Days of Fishing	Average Days per Angler
Black bass (largemouth, smallmouth, etc.)	559	4,830	9
Walleye, Sauger	584	5,612	10
Northern pike, pickerel, muskie, muskie hybrids	224	2,271	10
Perch	497	5,805	12
Salmon	379	5,297	14
Steelhead	198	3,092	16
Lake trout	215	3,573	17
Other trout	97	700	7
Anything	148	1,464	10
Other type of fish	179	1,722	10
Total	**1,665**	**19,661**	**12**

Source: 2011 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation

Annex 4D: Expenditures ($Mil.) on the US Side of the Great Lakes Basin by Anglers, 2011

States	Food and Lodging	Transportation	Other Trip Costs	Total equipment	Total Expenditures
Illinois	-	-	-	-	-
Indiana	-	-	-	-	-
Michigan	$165.8	$121.7	$185.1	$622.9	$1,095.5
Minnesota	-	-	-	-	-
New York	$90.8	$41.3	$132.1	$95.7	$359.8
Ohio	$74.1	$49.2	$89.3	-	$241.0
Pennsylvania	-	-	-	-	-
Wisconsin	$23.9	$21.5	$30.5	-	$86.4
Great Lakes Total*	**$373.7**	**$251.6**	**$459.7**	**$777.0**	**$1,867.1**

Source: 2011 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation
*Notes: * Total Great Lakes may slightly vary from other reported numbers due to suppressing numbers below the response threshold.*

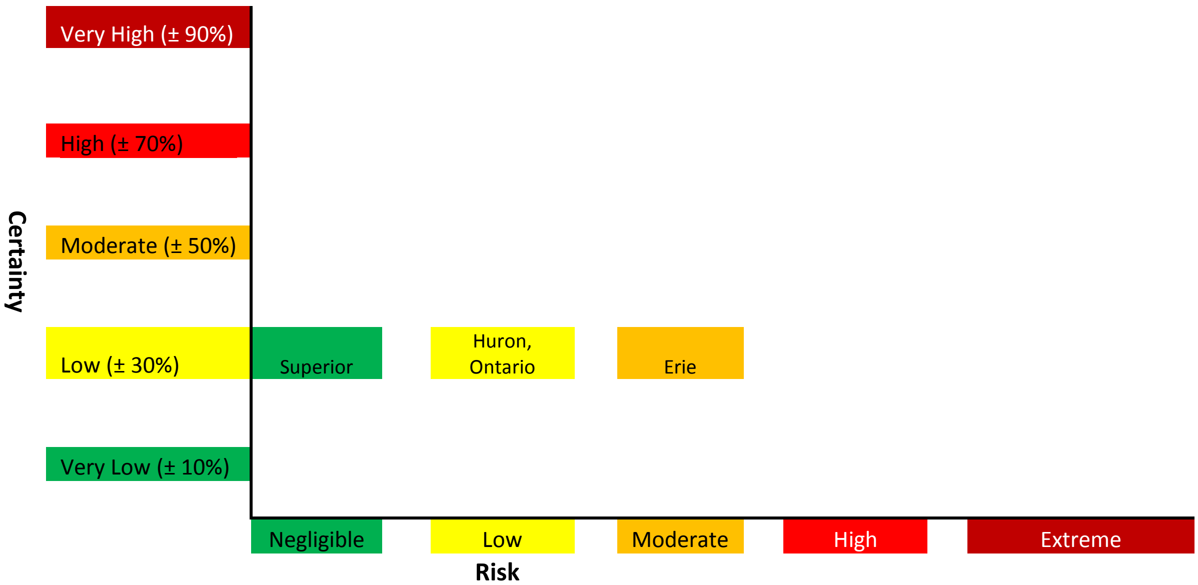
Annex 4E: Number of Fish Harvested All Anglers Who Fished on the Canadian Side of the Great Lakes, by Species and Lake, 2005

Name of the Species	Lake Ontario	Lake Erie	Lake St. Clair	Lake Huron	Lake Superior	St. Lawrence River	Great Lakes Basin	Species %
Walleye	287,888	303,442	338,751	336,457	530,328	125,542	1,922,410	8.1%
Pike	124,297	178,935	29,411	471,927	196,863	181,229	1,182,661	5.0%
Perch	872,121	3,567,973	1,608,046	754,588	48,852	699,235	7,550,815	31.9%
Muskellunge	1,293	567	102,457	12,314	671	4,894	122,196	0.5%
Whitefish	16,996	9,219	17,042	28,787	8,887	-	80,931	0.3%
Smallmouth bass	236,764	639,584	325,163	1,319,003	70,153	243,330	2,833,998	12.0%
Largemouth bass	162,112	161,795	111,008	349,287	7,900	134,513	926,614	3.9%
Rainbow Trout	286,366	60,744	2,703	331,965	15,764	13,728	711,269	3.0%
Brown Trout	58,373	6,726	809	13,091	223	-	79,223	0.3%
Lake Trout	65,417	40,065	659	175,956	47,809	4,832	334,736	1.4%
Brook Trout	11,830	1,015	330	27,660	964,391	-	1,005,225	4.3%
Splake	7,524	-	-	8,757	231	9,508	26,020	0.1%
Chinook	184,122	6,833	-	217,182	18,754	-	426,890	1.8%
Coho	57,478	2,703	272	41,800	7,131	-	109,384	0.5%
Sturgeon	-	338	482	-	-	-	820	0.0%
Catfish	192,557	118,420	139,306	55,158	1,986	122,691	630,119	2.7%
Crappie	468,881	185,900	173,418	133,100	-	17,042	978,342	4.1%
Rock Bass	242,585	291,598	234,938	797,926	3,424	148,308	1,718,779	7.3%
Sunfish	428,603	729,846	295,439	509,590	-	201,358	2,164,836	9.2%
Smelt	43,253	945	-	39,814	93,537	-	177,550	0.8%
Other fish	140,743	188,050	155,642	128,407	5,524	35,638	654,006	2.8%
Total	**3,889,202**	**6,494,699**	**3,535,878**	**5,752,768**	**2,022,429**	**1,941,848**	**23,636,825**	**100.0%**

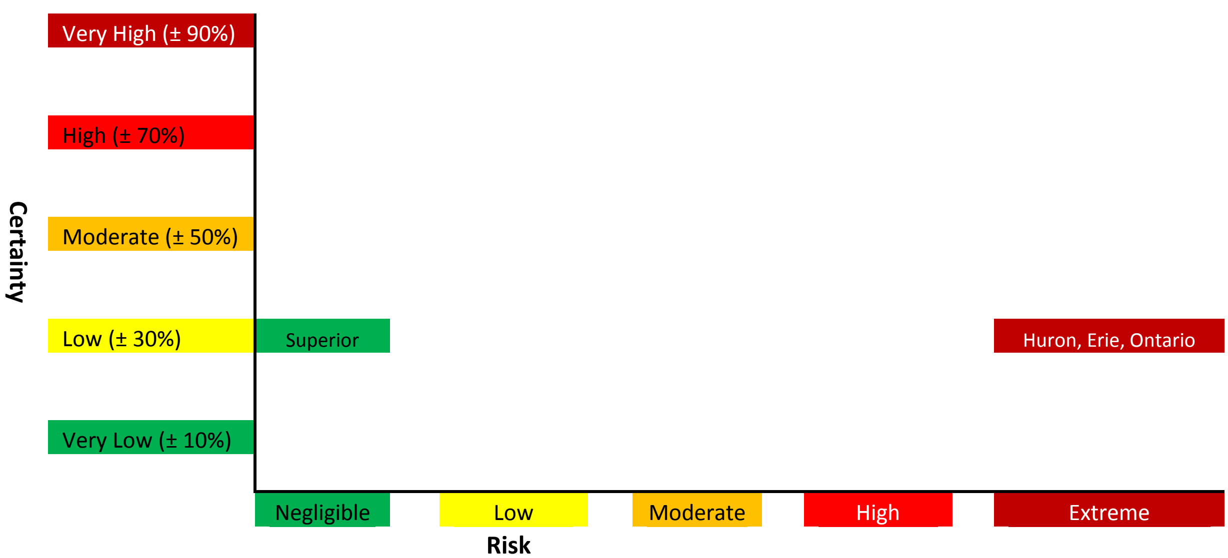
Source: DFO (2008)

Annex 5A: Heat-Map - Commercial and Recreational Fishing for Canada in 10 and 40 Years Starting 2024

(I): Commercial and Recreational Fishing by Lake for 10 Years

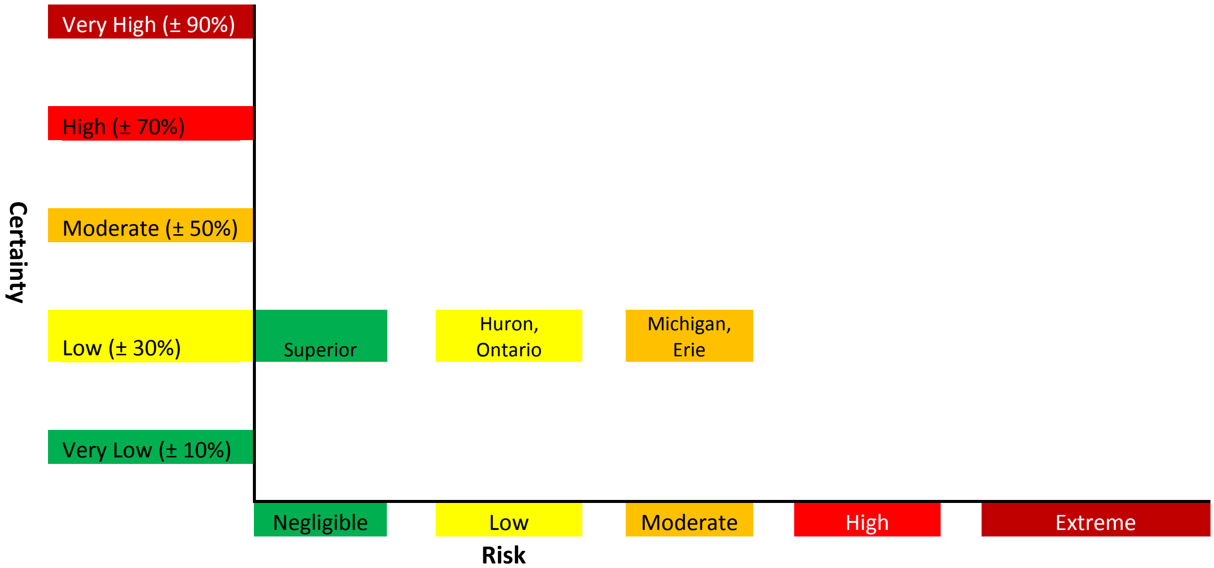


(II): Commercial and Recreational Fishing by Lake for 40 Years



Annex 5B: Heat-Map - Commercial and Recreational Fishing for the US in 10 and 40 Years Starting 2024

(I): Commercial and Recreational Fishing by Lake for 10 Years



(II): Commercial and Recreational Fishing by Lake for 40 Years