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Socio-Economic Impact of the Presence of Asian Carp in the Great Lakes Basin

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Executive Summary

"Socio-Economic Impact of the Presence of Asian Carp in the Great Lakes Basin" provides a detailed socio-economic analysis of the potential economic impact to Canada of the establishment of Asian carp in the Great Lakes.

The Great Lakes – Superior, Huron, Michigan, Erie and Ontario - 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. With the exception of Lake Michigan, they straddle the Canada-United States border, and form a basin that is home to more than 11 million people, including 98% of Ontario's residents and over 60 aboriginal communities (Ontario Ministry of Natural Resources, 2010).

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 world-class commercial and recreational fisheries, numerous recreational activities and commercial transportation, and provide both tangible and intangible benefits to residents of Canada and of the United States.

The Lakes and their watersheds are facing threats from Asian carp, an Aquatic Invasive Species (AIS) in North America that is responsible for significant impacts on native species and associated human activities, through ecological damage, habitat alterations and direct competition for resources. This threat has attracted the attention of the governments of Canada, the United States, the province of Ontario, a number of states, as well as First Nations, the general public, industry associations and non-governmental environmental organizations.

In 2010, the Government of Canada renewed $4 million in funding to facilitate an AIS monitoring system and to meet AIS assessment needs, such as research funding, biological risk assessment, and regulatory policy development. In 2012, Fisheries and Oceans Canada (DFO) received $17.5 million over five years to protect the Great Lakes from Asian carp, under its Great Lakes Asian Carp Program. This study is a result of the risk assessment initiative.

DFO undertook the study to supplement the bi-national (Canada -US) Ecological Risk Assessment (DFO, 2012) to address the Asian carp threat to the Great Lakes, which was led by the Centre of Expertise for Aquatic Risk Assessment, DFO. This study also supports the AIS objectives under DFO's "Sustainable Fisheries and Aquaculture" strategic outcome.

The methodology adopted for the study's analysis is the Total Economic Valuation technique. This methodology has been used for both valuation of activities on the Canadian side of the Great Lakes basin, and for Net Present Valuation for discounting purposes. 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. For the purposes of estimating the impact to Canada, the study has excluded Lake Michigan. In alignment with DFO (2012), it was assumed that following the arrival of Asian carp, it would take 7 years for the impact to emerge in areas where the carp were present. Therefore, as the socio-economic study uses 2011 as the base year, it uses an adjusted base of 2018 from which to consider the 20 year and 50 year impacts.

The study used secondary source information, and was benefitted greatly from: (i) community profiles around the Great Lakes, primarily from Statistics Canada; (ii) the bi-national Ecological

Risk Assessment (DFO, 2012), including supplementary reports; (iii) a workshop held on March 29, 2012, jointly organized by the Great Lakes Fisheries Commission and Policy and Economics, Central and Arctic Region, DFO;[1] and (iv) expert opinion exchanged between a group of science experts involved in the Ecological Risk Assessment and economists involved in analyzing this socio-economic study of the presence of Asian carp in the Great Lakes.

In selecting the scenario for the impact assessment, the study followed DFO (2012) and assumed that in the absence of additional preventive measures, Asian carp will arrive, establish populations, survive, and spread throughout the Great Lakes, due to the availability of suitable food, thermal and spawning habitats, and the high productivity of embayments in the Great Lakes basin. Since there is no feasible way to separate out the impact of an introduction of Asian 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 Asian carp, holding other variables unchanged.

Based on a literature review, the study identified the following major activities for the development of the baseline: (i) water use; (ii) commercial fishing; (iii) recreational fishing; (iv) recreational hunting; (v) recreational boating; (vi) beaches and lakefront use; (vii) wildlife viewing; and (viii) commercial navigation. It estimated the annual value of economic contribution of these activities in and around the Great Lakes basin at $13.8 billion dollars (see the attached matrix). Of that total, expenditures made and imputed values/prices for these activities comprised $13.4 billion (96.9%), while consumer surplus made up the remaining $0.4 billion (3.1%).

The study recognized that the Great Lakes basin provides invaluable services to society through maintaining ecosystem health and biodiversity. Those intrinsic values are, however, difficult to quantify, because they are much more intangible than other benefits, such as commercial fish harvesting (Krantzberg et al., 2006). The study found a similar challenge in quantitatively capturing the benefits of option and non-use values based on the existing set of information. However, these 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 considerable benefit to the economy as a whole. Freshwater fisheries have contributed substantially to preserving traditional aboriginal life-styles in the study region. Socially, the Lakes' beaches and shorelines provide a "sense of place" and unique source of community pride, and serve as key measures for public perceptions of environmental quality. The Lakes also provide opportunities for research and educational activities that result in a better understanding of the ecology.

The study estimated that the total present (economic) values of commercial fishing, recreational fishing, recreational boating, wildlife viewing, and beaches and lakefront use were $179 billion and $390 billion, in 20 years and 50 years, respectively, starting in 2018 (see Table below).[2]

[1] 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, Ontario Ministry of Natural Resources, and Department of Fisheries and Oceans.

[2] The estimations of the economic contributions of the Great Lakes discussed in this report 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' opinions.

Table: Estimated Present Values of Affected Activities in the Great Lakes in 20 and 50 Years by Activity

List of Activities	Base Year 2018 ($Million)	20 Years ($Billion)	50 Years ($Billion)
Commercial Fishing	$227	$5	$10
Recreational Fishing	$560	$12	$26
Recreational Boating	$7,291	$153	$333
Wildlife Viewing	$218	$5	$10
Beaches and Lakefront Use	$248	$5	$11
Total	**$8,544**	**$179**	**$390**

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

The study examined the risks presented by Asian carp to these values and found that the establishment of Asian carp in the Great Lakes would cause moderate to high damage to commercial fishing, recreational fishing, recreational boating, wildlife viewing, and the beaches and lakefront use sectors/activities during the periods covered, with the exception of the 20 year period for Lake Superior, where the damage would be low to moderate. Asian carp would likely have either negligible or no impact on recreational hunting, water use, commercial navigation, and oil and natural gas extraction activities.

Over time, the introduction of Asian carp to the Great Lakes basin could change the domination of lake ecosystems from native fish species to Asian carp, with the potential to damage the public 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 introduction of Asian carp species 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 Asian 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 generated by activities in and around the Great Lakes basin should not be directly compared with those provided in the extant literature, because of differences in methodology followed by different studies. Methodologies varied in terms of scope, estimation procedures, time periods considered, and industries covered. Variances in estimations also arose due to considerations of whether to include both Canada and the US, and to secondary multiplier effects (indirect and induced) in appraising the baseline values, as well as the impacts.

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 20 and 50 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 quantitative scale of ecological consequence that could directly link between ecological and socio-economic impacts, which could be applied to assess socio-economic impacts more accurately in a quantitative manner; 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 Asian 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), 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 Computable 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 border[3] and are the world's largest freshwater system. The Great Lakes basin, including watersheds,[4] 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 17,000 kilometers (10,200 miles), long enough to reach nearly halfway around the world.[5] More than 11 million people – including 98% of Ontario's residents and over 60 aboriginal communities - live within the Great Lakes basin (Ontario Ministry of Natural Resources [OMNR], 2010).[6]

The Great Lakes and their watersheds are facing significant threats from the increasing number of aquatic invasive species[7] (AIS) that are weakening/threatening the health of the lakes, and affecting both activities linked to the lakes and the utilities they generate for the economy.[8] Asian carp, AIS from the North American perspective, are well-known to be responsible for significant impacts on native species and associated human activities, through ecological damage, habitat alterations and direct competition for resources.[9]

The threat of Asian carp to the Great Lakes has attracted the attention of Canada, the province of Ontario, national and state governments of the United States (US), First Nations, the general public, industry associations and environmental non-governmental organizations.[10] Stakeholders (e.g. citizens 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

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

[4] From west to east, the Great Lakes are Superior (82,100 sq. km), Huron (59,600 sq. km), Erie (25,700 sq. km) and Ontario (19,000 sq. km) (Environment Canada [EC], 1990). Lake Superior is the largest of the Great Lakes and the largest lake in Canada. Lake Huron is the lake in the middle. Lake Erie is the shallowest of all the Great Lakes. Lake Ontario is the smallest Great Lake by area. Lake Michigan (57,800 sq. km) is entirely within the US.

[5] http://binational.net/ourgreatlakes/ourgreatlakes.pdf.

[6] St. Lawrence River is a primary drainage conveyor of the Great Lakes Basin which crosses the Canadian provinces of Quebec and Ontario and. It also forms part of the international boundary between Ontario and New York in the US. 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 eight US states.

[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; GLFC, 2005).

[8] 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).

[9] For a detailed discussion, see Chapter 1.

[10] The US is investing in the Great Lakes through the US Great Lakes Restoration Initiative (GLRI) where combating invasive species is one of the five targeted initiatives. In February 2010, the U.S. Government launched an Asian Carp Control Strategy Framework dedicating $78.5 million, funded primarily through the US GLRI ($2.2 billion over 5 years, including $475 million in 2010), to control the spread of Asian carp to the Great Lakes. For details, see GLFC (2010) and USA: GLFC - Legislative Priority Fact Sheet (2010).

Asian carp in the Great Lakes.

The Government of Canada's Budget 2010 renewed approximately $4 million in funding from 2005 through the Aquatic Invasive Species Program, to facilitate an AIS monitoring system and to meet assessment needs, such as research funding, biological risk assessment, regulatory policy development. Additionally, in 2012, the Fisheries and Oceans Canada (DFO) allocated $17.5 million over five years to protect the Great Lakes from Asian carp under its Great Lakes Asian Carp Program. The funding has been directed to four key activities: prevention, early warning, rapid response, and management and control.

As part of the Government of Canada's initiatives, a bi-national (Canada -US) ecological risk assessment to address the Asian carp threat to the Great Lakes, led by the Centre of Expertise for Aquatic Risk Assessment (CEARA), DFO, has been carried out.[11] A necessary follow-up to the biological risk assessment is an assessment of the socio-economic impact of the establishment of Asian carp in the Great Lakes Basin, in order to provide decision-makers with information regarding the economic value that may be at risk and to assist in developing options that may be considered for prevention. The outcomes of this study will support the AIS objectives under DFO's "Sustainable Fisheries and Aquaculture" strategic outcomes.[12]

Objectives of the Study

The goal of this study is to provide a detailed socio-economic analysis of the economic impact to Canada of the establishment of Asian carp in the Great Lakes. The specific objectives of the study are to: (i) provide estimates of the economic value generated by the Great Lakes for Canada; and (ii) examine the economic impact/cost of the presence of Asian Carp in the Great Lakes for Canada.

Organization of the Study

The rest of the study is organized as follows: Chapter 1 presents an overview of the Great Lakes; Chapter 2 reviews the literature relevant to assessing the economic impact of the establishment of Asian carp in the Great Lakes; Chapter 3 presents the methodology adopted in the study; Chapter 4 presents the baseline values of activities in and around the Great Lakes by sector; Chapter 5 presents the social and cultural values associated with the Great Lakes; Chapter 6 presents a scenario based on the biological risk assessment; Chapter 7 presents the socio-economic impact assessment; and Chapter 8 draws conclusions.

[11] DFO (2012).

[12] For details, see http://www.dfo-mpo.gc.ca/fm-gp/sustainable-durable/index-eng.htm.

Chapter 1: A Brief Overview of the Study Area

Socio-Demographic Profile[13]

In 2006, Ontario had a population of 12 million people, which was 38% of Canada's total population (see Annex 1). Of the total population in Ontario, 2% (242,490) are of aboriginal identity, as compared to 4% for Canada.[14]

Of Ontarians 15 years of age and older, 22% do not have a diploma or degree, as compared to 24% for Canada as a whole. The percentage of the province's population of 15 years of age and older with a high school certificate or university diploma or degree is higher as compared to Canada (51% while the national figure was 48%).

The employment rate for Ontario is 94%, as compared to 93% for Canada overall. Manufacturing, business services and retail trade sectors employ most of the total experienced labour force age 15 years and over. The median of earnings of persons 15 years and over who work an entire year full-time in Ontario is $44,748, which was higher than the national average of $41,401.

A Brief Overview of the Great Lakes[15]

The Great Lakes hold 20% of the world's fresh surface water and 95% of North America's fresh surface water. They contain 22.8 quadrillion litres (or (22.8×10^{15}) litres) of water, of which only 1% is renewable (Krantzberg et al., 2006). The Great Lakes provide drinking water to more than 8.5 million or 70% of Ontario residents (OMNR, 2010) and to 40 million people living in Canada and the US (OMNR, 2011). The Lakes support thousands of wetlands, and a variety of landscapes, plants, fish and wildlife (e.g. over 150 native species of fish and more than 50 native plant communities) (OMNR, 2011).[16]

The Great Lakes also directly impact the lives of approximately 40 million people living in the Canadian provinces and US states that directly border them (OMNR, 2011). They support world-class commercial and recreational fisheries in both Canada and the US, provide recreation, serve as platforms for 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.

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[13] The socio-demographic profile summarized in this section is primarily based on 2006 Community Profiles prepared by Statistics Canada. For a detailed presentation of statistics, see Annex 1.
[14] For detailed information on aboriginal identity population by sexes, age groups, median age, see Annex 2.
[15] For a detailed discussion on the importance of the Great Lakes to activities/sectors, see the respective section in the study.
[16] Great Lakes coastal wetlands are highly productive and diverse communities of plant and animal life. For example, about 20 species of mammals, 28 species of amphibians, and 27 species of reptiles have been associated with the marshes of Lake Erie. See http://www.ec.gc.ca/eau-water/default.asp?lang=En&n=678C2760-1.

The Great Lakes basin is home to 98% of Ontario's population and supports 40% of Canada's economic activity (EC, 2010). More than 80% of the power generated in Ontario depends on the Great Lakes. Manufacturing industries accounted for 38.2% of total water intake from the Great Lakes basin and 14.0% from the St. Lawrence River basin (Statistics Canada, 2005). The Lakes support 25% of Canada's agricultural capacity and 45% of its industrial capacity (EC, 2010).

AIS Threats to the Great Lakes

The Great Lakes basin is facing significant threats from an increasing number of AIS. The AIS have historically been introduced to the Lakes through several vectors/sources of transmission and dispersion, including canals and international ship ballast water.[17] Commercial ships traveling only within the Great Lakes system facilitate the inter-lake spread of AIS through ballast water. Other known pathways include the aquaculture industry, aquarium trade, the live-food fish industry, recreational boating, sport fish stocking, bait bucket transfers, canals and waterways, and various horticultural practices.[18]

In the past, AIS have severely damaged the Great Lakes and economic activities dependent on the Lakes, such as commercial and recreational fisheries. Other major activities significantly affected include beach and lakefront use, wildlife watching, recreational boating, and hunting. The vital changes experienced within Great Lakes ecosystems due to the introduction of AIS have been documented for decades (e.g. DFO, 2012; Marbek, 2010a). The major affected areas in the ecosystem services are nutrient availability, water clarity, and productivity, which result in negative impacts to the environment and to biodiversity, as well as to the surrounding economy and infrastructure.[19]

Asian carp are well-known to be responsible for significant impacts on native species through both direct competition for resources and alterations to habitat. Asian 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).

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

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[17] 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) provides robust protection against ship-mediated biological invasions.
[18] For a detailed discussion, see EC (2010, 2004), DFO (2004), Great Lakes Fisheries Commission [GLFC] (2009), Rixon, Duggan, Bergeron, Ricciardi and Macisaac (2005).
[19] For a detailed list of changes, see http://nsgl.gso.uri.edu/michu/michui05009.pdf.

populations in that watershed.[20] Canada is highly vulnerable to Asian carp threats, as the species has a pathway to the Great Lakes from the Mississippi River through the Chicago Ship and Sanitary Canal (CSSC) via the Chicago Area Waterway System (CAWS).[21]

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[20] In a November 2005 statement to the House Subcommittee on Fisheries and Oceans, GLFC reported that 42% of threatened and endangered species in the US are at risk primarily because of AIS.

[21] Asian carp was introduced in the 1970s to control algae and suspended matter in catfish farms. Floods in the early 1990s overwhelmed the farms and released Asian carp into local waterways into Mississippi River basin (Krantzberg and de Boer, 2008).

Chapter 2: Literature Review

While a continuous effort has been made to improve the understanding of the impacts of AIS in the Great Lakes for the US economy (e.g. Felts, Johnson, Lalor, Williams, and Winn-Ritzenberg, 2010; Thomas, 2010; Austin, Anderson, Courant, and Litan, 2007; Leigh, 1998; and Ainsworth, 1977), until recently, comparatively less attention has been paid to measuring the impacts for Canada. Therefore, the extant literature provides very limited information for Canada. This section provides a summary of the extant literature that examines the economic aspects of invasive species threatening the Great Lakes from Canadian and/or US perspective.

Felts, Johnson, Lalor, Williams, and Winn-Ritzenberg (2010) examined the policy implications of AIS for the City of Milwaukee, and proposed that appropriate AIS policies balance the ecological responsibility, minimize economic damage by AIS, maximize Milwaukee's economic vitality, and political feasibility. The report also concluded that in the short-term, the primary focus should be preventing AIS introductions from ships entering the Port of Milwaukee, while in the long-term, AIS management should also focus on managing and removing established AIS.

Using a bio-economic simulation model, Thomas (2010) conducted a cost-benefit analysis of preventative management for zebra and quagga mussels in the Colorado-Big Thompson system. The study showed that the boat inspection program was very effective, and almost entirely eliminated the possibility of invasion of the reservoir system. However, the benefits of reduced control costs to infrastructure were unlikely to exceed the costs of the boat inspection program, because the probability of invasion was likely to be low, even without the boat inspection program. The study also noted the following important limitations: (i) many benefits were omitted from the analysis; (ii) the scope of the analysis was limited; and (iii) the uncertainty inherent in the bio-economic model.

Employing specific improvements and aggregate improvement approaches, Austin et al. (2007) conducted a study to determine the costs and likely ecological impacts of restoring the Great Lakes,[22] and to estimate the economic benefits of those ecological impacts. The first approach identified the specific improvements in the environment expected from restoration, and then added up the individual estimates. The second approach estimated the increase in property values in all the areas likely to be affected by the restoration initiative.

Following those approaches, Austin et al. found that ecological restoration initiatives generated a present-value of the long-term economic benefits of over USD50 billion to the US economy.[23] In

[22] The restoration measures evaluated included: (i) preventing the introduction of new AIS; (ii) improvement of habitats; (iii) improvement of the quality of drinking water; (iv) cleanup of "areas of concern" (AOCs); (v) addressing non-point sources of pollution; (vi) eliminating certain toxic pollutants (e.g. discharges of mercury, PCBs, dioxins, and pesticides); (vii) establishing a sound information base about the Great Lakes ecosystem; and (viii) assuring the sustainable development of the Great Lakes.

[23] Of the recommended five-year cumulative cost of USD20 billion, the Great Lakes Regional Collaboration Strategy (2005) recommended an allocation of USD694 million to prevent new introductions of AIS into the Great Lakes, and to halt the spread of existing AIS within the basin. The specific recommendations are (five-year cost estimates are provided in parentheses): (i) elimination and/or control of AIS spread by ships and barges (USD66 million); (ii) federal, state and local government measures preventing the introduction of AIS through the basin's canals and waterways (USD225 million) and through the trade and potential release of live organisms (USD85 million); (iv) establishment of an AIS management program (USD220 million); and (v) outreach and education programs (USD98 million).

addition to these long-term economic benefits, the study estimated additional short-term benefits in the form of multiplier effects within the range of USD30 to 50 billion, primarily to the regional economy. However, the estimation did not capture the benefits of the development of new technologies and industries that would be generated by the investment in Great Lakes restoration.

Leigh (1998) evaluated the cost-effectiveness of alternate control strategies, and determined the economic value of enacting the ruffe control program for the Great Lakes fishery. Based on biometric changes that were projected to occur, the study showed that early control of a non-indigenous fish species such as ruffe, could result in significant returns on investment. Instituting a ruffe control program would, under a moderate-case projection of benefits, yield an estimated net public savings of USD513 million for the US over five decades up to 2050.

Using both market models of supply and demand and Structured Expert Judgement (based on relevant scientific research and their professional opinions), Rothlisberger, Finnoff, Cooke, and Lodge (2012) examined the impact of invasive species from ocean-going vessels on wildlife watching, raw water use, and commercial and sport fishing in the Great Lakes from the US perspective. Compared to a scenario of no ship-borne invasions, the study found that in the US waters, median damage aggregated across multiple (ecosystem) services was USD138 million/year, broken down as follows: commercial fishery - USD5.3 million; sport fishing - USD106 million (with a greater degree of uncertainty in impact distributions); and raw water use[24] - USD27 million (median additional operating costs aggregated over all Great Lakes facilities). The study also noted that the negative impact of invasive species on sport fishing alone might be as high as USD800 million, with a 5% probability.

Employing the hedonic property-value method, Zhang & Boyle (2010) found that as Eurasian watermilfoil (an invasive aquatic weed) infested in selected Vermont lakes, adding to the total macrophyte (an aquatic plant that grows in or near water) growth, property values could diminish by less than 1% to as high as 16%, with incremental increases in the infestation level.

Braden, Won, Taylor, Mays, Cangelosi, and Patunru (2008) estimated the economic benefits of remediation of an AOC in the Sheboygan River, Wisconsin, using hedonic analysis and a survey-based method. Hedonic analysis found that for owner-occupied homes within a 5-mile radius of the Sheboygan River AOC, the overall estimated loss of property value was USD158 million (8% of market value). The impacts were proportionally greatest for properties closest to the AOC. A survey-based method yielded a mean estimate of USD218 million (10% of property value) in willingness to pay (WTP) for full cleanup of the AOC.

Results of a separate study (Braden et al., 2008) focusing on an AOC on the Buffalo River, New York, showed that after controlling for numerous structural, community, and spatial effects, single-family residential property prices south of the river were depressed due to their proximity to the AOC by USD118 million (5.4% of total market value). Considering only the area for which the market study showed price discounts, the survey-based estimates revealed a WTP for full cleanup of the AOC of approximately USD250 million (14% of median-based market value).

On the Canadian north shore of Lake Erie, using contingent valuation methodology (a methodology used to estimate economic values of ecosystem and environmental services) on 703 users of the public marsh at Long Point and Point Pelee in 1978, Kreutzwiser (1981) found that recreational users spent a total of $119,000 to receive wetland benefits that were estimated

[24] Includes nuclear power plants, fossil fuel power plants, municipal water plants and industrial facilities.

to have a contingent value of $213,000 and generated directly and indirectly $225,000 in local spending (e.g. travel, food, accommodation) per year implying a return of 179%.

As indicated above, literature assessing the (net) economic impact of AIS in the Great Lakes for the Canadian economy is substantially less as compared to that for the US. Most of the Canadian studies (e.g. Genesis Public Opinion Research Inc., 2007; and EC, 2000) were undertaken from either a provincial or national perspective, and remarkably few studies (e.g. DFO, 2008; Krantzberg et al., 2008, 2006) highlighted the economic contributions of the Great Lakes for Canada by activity and/or area. The present study will discuss the pertaining literature by activity in Chapter 5.

Chapter 3: Methodology Adopted

This study aims to evaluate the socio-economic impact of the presence of Asian Carp in the Great Lakes Basin in Canada. This was done in two steps: Firstly, baselines values (by sector and aggregated) of all the economic activities in and around the Great Lakes have been estimated which provided the foundation for a quantitative discussion of the magnitude of values that might be impacted. It should be noted that while developing the baseline values the study deferred from speculating whether a particular activity would be impacted or not by the presence of Asian carp.; Secondly, the results from the bi-national ecological risk assessment (henceforth DFO (2012)) which was discussed below and in Chapter 6 in details) led by CEARA, DFO, have been used to determine the activities 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:

$$TEV = Use\ Value + Non\text{-}use\ Value$$

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.[25]

In order to estimate the economic value of the Great Lakes to Canada and the impact should

[25] See Matrix 1 for details.

Asian carp establish in those lakes, the study includes estimates of: (a) the expenditures at market values, and (b) the consumer surplus generated by major activities, based on information obtained from extant literature.

The analysis was carried out as follows:

1. A situational overview of the study area was provided.
2. The scenarios and available options were considered.
3. Available information was interpreted and quantified to convert into values, whenever feasible, based on a feasible time horizon for the analysis.
4. Information was analyzed for the biological and economic impacts for each option.
5. The values were adjusted using the present value approach.[26]

AIS can lead to significant ecosystem alterations, including general reductions in biodiversity (DFO, 2012) and accelerated extinction rates of native species. The full effects and consequences of AIS sometimes take decades to emerge (Wilson, 1992).[27] In alignment with DFO (2012),[28] this study assumes that following the arrival of Asian carp, it would take seven (7) years for the impact to be felt in the area where they are present. Therefore, the time periods considered for impact assessments begin in 2018, and are for intervals of 20 years and 50 years as the study uses 2011 as the base year.

The study extrapolated baseline values to the base year of 2011 using the inflation rate, given that the data pertained to different years. For the socio-economic impact 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 3%. This rate represents the social opportunity cost.[29] 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 Statistics Canada. The scenario followed for the study and the assumptions made were based on information derived from DFO (2012) which incorporated existing, ongoing, and new research results to inform the potential for Asian carp arrival, survival, establishment, spread and

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[26] Due to significant uncertainties involved with some of the variables, such as impacts over time, the PVs were presented as a range of values, providing upper and lower limit estimates.
[27] 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.
[28] Sources are discussed in detail later in this chapter under "data sources".
[29] 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).

impact in the Great Lakes. As discussed in Chapter 2, while the extant literature provides very limited data on AIS for the Canadian side of the Great Lakes, 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 impact was unavailable, the study used proxies based on rational judgment from the findings of studies in comparable situations with appropriate adjustment(s) as necessary, or made a qualitative assessment of the impact.

One of the major challenges encountered by the study was that the biological risk assessments expressed consequences that could not be unambiguously linked to socio-economic impact analysis. 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 the ecological risk assessment, the study greatly benefitted from expert opinion exchanged through personal communications between a group of science experts involved in the ecological risk assessment and economists involved in the socio-economic study of the presence of Asian carp in the Great Lakes. This discourse helped to provide a defensible foundation for the socio-economic impact assessment.

Since there is no feasible way to separate out the impact from the presence of Asian carp into the Great Lakes and 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 Asian carp, holding other variables unchanged. For instance, the study projected that the reductions in native fish populations would be solely caused by Asian 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.[30]

It is also important to recognize that projections of the extent and degree of impact caused by AIS are problematic because scientists rarely find opportunities to predict impact in relatively undisturbed environments. Consequently, because of the inherent uncertainties, the socio-economic impact reported in the study is mostly speculative, providing the best estimates from available research. Furthermore, since the ecological risk assessment 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 the ecological risk assessment.

Scope of the Study

The scope of this socio-economic study aligns with the scenario provided by the DFO (2012), particularly in terms of the impact of the presence of Asian carp, and includes:

a. an overview of the Great Lakes;

b. a range of estimates of the economic value of the Great Lakes to Canada;

c. a review of relevant literature, to gauge the extensiveness of the research and data availability on the issue being addressed, and to adopt an appropriate methodology. The literature particularly focused on the types of activities considered, the methodology

[30] 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.

adopted and the results;

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

e. a description of the baseline scenario, 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 and the future trend, non-market value (e.g. ecosystem value), a profile of local demographics, and a description of the current level of protection already in place for the period of analysis chosen for the study. The baseline scenario provided a comprehensive socio-economic and ecosystem value of the study area;

f. identification and documentation of the major activities, environmental elements, and stakeholders that would be affected by the presence of Asian carp;

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

h. sensitivity analyses based on discount rate and other uncertainties to be identified in the analyses; and

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

Chapter 4 - Baseline Values of Activities around the Great Lakes

This chapter provides the situational overview, estimating the economic values to Canada generated by the major activities in and around the Great Lakes. As stated in Chapter 3, the values in aggregate provide a baseline value of the major activities from which the impact of Asian carp in the Great Lakes is estimated.

Based on relevant literature, the study identified the following major activities for the development of the baseline: (i) water use; (ii) commercial fishing; (iii) recreational fishing; (iv) recreational hunting; (v) recreational boating; (vi) beaches and lakefront use; (vii) wildlife viewing; and (viii) commercial navigation. In order to estimate the economic values of the above-mentioned 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 3).

The following portion of the chapter provides a detailed discussion of the methods applied and then estimates the economic values of activities around the Great Lakes in Canada.

Water Use

Canadians consistently rank water as this country's most important asset (Renzetti, Dupont and Wood, 2011). Water withdrawn from the Great Lakes is used in neighbouring municipalities and supplied to homes, businesses, and institutions like schools and hospitals for a diverse range of activities, such as drinking, washing, gardening, fire-fighting and landscape irrigation. In the manufacturing and agricultural sectors, water is used as raw material to support the production of goods and services. Water is also used for electricity generation (heating/cooling), oil/gas extraction, and mining (e.g. cleaning ore, cooling drills).

The Great Lakes Commission (2010) categorized water use from the Great Lakes basin as follows: (i) public water supply; (ii) self-supply domestic; (iii) self-supply irrigation; (iv) self-supply livestock; (v) self-supply industrial; (vi) self-supply thermoelectric power; (vii) self-supply hydroelectric power; and (viii) self-supply other.

According to the Great Lakes Commission (2010), approximately 850.5 billion gallons of water was withdrawn from the Great Lakes basin per day in 2008, of which almost 24% was withdrawn in Ontario (203.24 billion gallons per day). Of the total withdrawal in Ontario, hydroelectric use accounted for 93%. The remaining 13,697.1 million gallons per day was distributed as follows: nuclear plants, 74%; fossil fuel power, 11%; industrial users, 7%; public water supply, 6%; domestic (residential, commercial, institutional) and agricultural users, 1%; and other,[31] 1%.[32] In Québec, of the total water withdrawals of 305.2 billion gallons per day from the St. Lawrence River basin, hydroelectric power accounts for 304 billion per day (99.6%). The remaining 14 billion gallons per day was distributed as follows: public supply (residential, commercial, and

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[31] Water used for purposes not reported in categories. Examples include but are not limited to, withdrawals for fish/wildlife, environmental, recreation, navigation, and water quality purposes.

[32] The estimated water consumption coefficients for Ontario are public supply 15%, domestic 15%, irrigation 78%, livestock 80%, industrial varies by plant/SIC code, nuclear and fossil fuel power 0.9% each based on reports of increased local lake evaporation due to discharge of heated water to lakes, and other varies by use.

institutional), 81%; industrial users, 9%; domestic supply, 5%; fossil fuel power, 3%; and agricultural users, 2%.

The valuations of water used from the Great Lakes basin provided in this section are based on consumption and withdrawal data primarily taken from the Great Lakes Commission (2010) and on water use values information compiled from literature review.[33]

Raw Water Use[34]

Twenty four million people drink water that is drawn from the Great Lakes every day (U.S. Environmental Protection Agency, 2003). The Great Lakes Commission (2010) estimated that Ontario's annual water withdrawal and consumption by public sector and self-supply domestic categories were 1,203 and 180 million m^3, respectively. In Quebec, total withdrawal and consumptive use were 1,618.8 and 161.7 million m^3, respectively (see Table 1).

Table 1: Estimated Raw Water Withdrawal and Consumption by Use/Lake/Province for the Year 2008

Name of the Lake	Public Sector (Mil. M^3/Year)		Self-Supply (Mil. M^3/Year)		Total (Mil. M^3/Year)	
	Withdrawal	Consumption	Withdrawal	Consumption	Withdrawal	Consumption
Ontario	**1,054.2**	**158.1**	**149.1**	**22.4**	**1,203.3**	**180.5**
St. Lawrence	100.9	15.1	15.8	2.4	116.7	17.5
Lake Ontario	643.8	96.6	88.7	13.3	732.4	109.9
Lake Erie	129.7	19.5	27.6	4.1	157.3	23.6
Lake Huron	116.6	17.5	14.7	2.2	131.2	19.7
Lake Superior	63.2	9.5	2.4	0.4	65.7	9.9
Quebec	**1,519.9**	**151.8**	**98.9**	**9.9**	**1,618.8**	**161.7**
St. Lawrence	1,519.9	151.8	98.9	9.9	1,618.8	161.7
Grand Total	**2,574.1**	**310.0**	**248.0**	**32.2**	**2,822.1**	**342.2**

Source: The Great Lakes Commission (2010)

In terms of the economic value of drinking water, Statistics Canada estimated that, in 2007, the operating and maintenance costs of treating 180.5 million cubic metres of raw intake water from the Great Lakes basin was approximately $260 million (Marbek, 2010b). Assuming that water revenue structures closely reflect the full cost of water production, the present study inflation-adjusted the 2007 value of $260 million to determine the present value of drinking water derived from the Great Lakes, as follows:

Estimated Value of Drinking Water in Ontario $(EV_{DW}) = C_{2007} * \pi_{(2011/2007)}$

Where C is the cost of water production and π is inflation rate.

[33] Since consumptive use means the volume of water depleted due to human activity and provides a suitable indicator of the sustainability of human water use (the State of the Great Lakes 2009), consumptive data rather than withdrawal data has been used for valuation in this study. For a detailed presentation on estimated water uses and values by sector, lake and province, see Annex 3.
[34] Raw water use includes Public Water Supply and Self-Supply Domestic for residential (e.g. drinking, food preparation, bathing), commercial and institutional purposes (e.g. hotels, restaurants, office buildings and institutions, both civilian and military, hospitals, schools). For details, see Great Lakes Commission (2010).

To calculate the value of water consumption from the Great Lakes basin in Quebec, the study first calculated the unit costs of raw intake water from Statistics Canada's estimate of the operating and maintenance costs of water intake from the Great Lakes basin in Ontario, and then applied the unit costs to consumption data for Quebec as follows:

Estimated Value of Drinking Water in Quebec $(EV_{DW}) = Q_{2011} * UC_{2007} * \pi_{(2011/2007)}$

Where *Q* is consumption, UC is the unit cost of water production and *π* is inflation rate. Following this approach, the total economic contributions of the Great Lakes raw water consumption is estimated to be in the amount of $531.7 million/year (Ontario - $280.4 and Quebec - $232.8).

Industrial Water[35]

Water from the Great Lakes is also used as input in a variety of industrial sectors. Using data for 2000, the Great Lakes Commission (2010) estimated that Ontario's industrial users withdrew 1,275.6 million m^3 of water from the Great Lakes and consumed 80.4 million m^3 each year. In Quebec, total withdrawal and consumptive use were 173.4 and 17.3 million m^3, respectively (Table 2).

Table 2: Estimated Industrial Withdrawal and Consumption of Water by Province/Lake for the Year 2008

Name of the Lake	Industry (Mil. M^3/Year)	
	Withdrawal	Consumption
Ontario	**1,275.6**	**80.4**
St. Lawrence	222.2	14.0
Lake Ontario	317.3	20.0
Lake Erie	249.3	15.7
Lake Huron	262.8	16.6
Lake Superior	224.0	14.1
Quebec	**173.4**	**17.3**
St. Lawrence	173.4	17.3
Grand Total	**1,448.9**	**97.7**

Source: The Great Lakes Commission (2010)

Pertaining to industrial water use value, using data for Canadian business sector industries for the period 1981-1996, Dachraoui and Harchaoui (2004) estimated that the shadow price[36] of water intake was $0.73/$m^3$ and varied significantly across industries. The value is reported to be slightly lower than that estimated for the top seven water using industries ($0.76/$m^3$).[37]

[35] Self-Supply for manufacturing (e.g. metals, chemicals, paper and allied products) and mining sectors (e.g. extraction/washing of coal and ores, crude petroleum). Brine extraction from oil and gas operations is excluded. For details, see Great Lakes Commission (2010).
[36] The monetary value assigned to a good or service when the market price is unavailable or incomplete.
[37] These are agriculture, mining, paper, primary metal, refined petroleum and coal products, chemical and utility.

In order to estimate the value of water provided to industrial facilities in the Great Lakes, the present study multiplied the consumption data provided by the Great Lakes Commission (2009) with the average value of water intake estimated by Dachraoui et al. (2004), after adjusting for inflation, as follows[38]:

Estimated Value of Industrial Water $(EV_{IW}) = Q_{2011} * (V_{1996} * \pi_{(2011/1996)})$

Where Q is consumption, π is inflation rate, *and* V is the average value of water intake. Following this approach, the economic contributions of the Great Lakes water consumption by industrial sector in Canada is estimated to total $96.4 million/year (Ontario - $79.3, Quebec - $17.1).

Agricultural Water[39]

In the agricultural sector, water from the Great Lakes basin is used by farms as input into the production process, livestock watering and irrigation. About one-third of the land located in the Great Lakes basin is used for agriculture. This amounts to nearly 25% of the total Canadian agricultural production (including dairy, grain, corn, livestock, and a variety of orchards, vineyards and other specialty crops) being supported by the Great Lakes. [40]

The Great Lakes Commission (2010) estimated that the agricultural sector withdrew a total of 110.3 million gallons per day of water for irrigation and livestock uses from the Great Lakes basin. The following table provides water withdrawal data for irrigation and livestock purposes by province and lake:

Table 3: Estimated Agricultural Water Withdrawal and Consumption by Use/Lake/Province 2008

Name of the Lake	Irrigation (Mil. M^3/Year)		Livestock (Mil. M^3/Year)		Total (Mil. M^3/Year)	
	Withdrawal	Consumption*	Withdrawal	Consumption*	Withdrawal	Consumption*
Ontario	**101.2**	**78.9**	**50.9**	**40.7**	**152.0**	**119.6**
St. Lawrence	3.2	2.5	8.2	6.5	11.4	9.1
Lake Ontario	24.5	19.1	7.5	6.0	32.0	25.1
Lake Erie	44.0	34.3	18.3	14.6	62.3	48.9
Lake Huron	28.9	22.5	16.8	13.4	45.7	36.0
Lake Superior	0.5	0.4	0.2	0.2	0.7	0.6
Quebec	**12.7**	**11.5**	**26.4**	**21.1**	**39.1**	**32.6**
St. Lawrence	12.7	11.5	26.4	21.1	39.1	32.6
Grand Total	**113.9**	**90.4**	**77.2**	**61.8**	**191.1**	**152.2**

Source: The Great Lakes Commission (2010).
*Note: * Staff estimation, Policy and Economics, Fisheries and Oceans Canada, based on consumption coefficient data provided in The Great Lakes Commission (2010).*

[38] Due to absence of data on water consumption for multiple years, the study assumed that the water consumption level in 2011 remained the same as that in 2000.
[39] Includes self-supply irrigation (e.g. water applied for growing crops and pastures, the maintenance of parks and golf courses) and self-supply livestock (e.g. water used by horses, cattle, sheep, fish hatchery). For details, see Great Lakes Commission (2010).
[40] See http://www.great-lakes.net/econ/busenvt/ag.html#overview.

In terms of the value of water used for these agricultural sector purposes, a few studies (e.g. Dachraoui and Harchaoui, 2004; Bruneau, 2007) provided estimates of the value of water used for these purposes in the southern Saskatchewan region of Canada. Using an economic rent approach, Gardner Pinfold (2006), estimated that the average short-run and long run values of water use to be $\$0.06/m^3$ and $\$0.014/m^3$, respectively, in the South Saskatchewan River basin area. Samarawickrema and Kulshreshtha (2008) estimated that the short-run and long-run estimates of irrigation water use range from $\$0.017$ - $\$0.088/m^3$ and $\$0.010$ - $\$0.068/m^3$, respectively, in a number of sub-basins in the South Saskatchewan River basin.

Using a residual imputation method, Bruneau (2007) estimated the values of water withdrawn for a variety of reasons (e.g. irrigation, livestock) in the South Saskatchewan River basin. The values presented in the study (20 to 100 times more than the average household pays) showed the value-added per unit of water used in livestock production, under the assumption that livestock owners, faced with a water shortage, would be forced to reduce their herds.[41] Therefore, the values may be treated as the maximum WTP of the owners to obtain water and as upper estimates, as the entire net value was attributed to water input and excluded other unmeasured inputs also critical to production (Bruneau, 2007). Using data for Canadian business sector industries for the period 1981-1996, Dachraoui et al. (2004) estimated that the shadow price of water intake for agricultural and related service sector was $\$0.46/m^3$.

Estimates of the value of water used in irrigation for a variety of crops in the Big Creek watershed in southern Ontario were provided by To (2006), cited in Marbek (2010b). Using the average market crop price received by producers from 2000-2004, the study calculated the loss in profitability in the short-term due to a decrease in water, assuming fixed costs. These estimates ranged from $\$3.79/m^3$ for ginseng, to $0.22/m^3$ for sweet corn.

Given that estimates of water use values for irrigation/livestock purposes vary by geographic location (Bruneau, 2007), and to maintain consistency in the estimation of the value of water used from the Great Lakes for other purposes discussed above (e.g. industrial use), the study at hand refrained from using value estimations from a few studies in other regions in Canada.

Therefore, to estimate the values of water withdrawn for irrigation and livestock from the Great Lakes, an inflation adjusted average ($\$1.10/m^3$) of the estimates of the short-run values of water for irrigation provided by To (2006) was used.[42] As a result, the estimated values should be considered as very conservative estimates of the water use values.

Estimated Value of Agricultural Water (EV_{AW}) = *Value of Irrigation Water* + *Value of Livestock Water*

(i) Value of Irrigation Water = $Q_I \times (V_{I2004} \times \pi_{(2011/2004)})$

(ii) Value of Livestock Water = $Q_L \times (V_{L2004} \times \pi_{(2011/1996)})$

Where Q is quantity, π is inflation rate, *and* V is water use value. Following this approach, the economic contributions to Canada of the Great Lakes water consumption by the agricultural sector is estimated to be in the amount of $164.7 million/year (Ontario - $131.9 (Irrigation $87.0, Livestock $44.9) and Quebec - $32.8 (Irrigation $11.5, Livestock $21.3)).

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[41] For Alberta, his estimates range from $\$25.72/m^3$ for milk cows to $\$122.29/m^3$ for pigs. For Saskatchewan, the values range from $\$26.36/m^3$ for milk cows to $\$136.78/m^3$ for pigs. For the entire South Saskatchewan River basin, the average value of water was estimated to be $\$46.33/m^3$.

[42] Assuming that the average value of $\$0.96/m^3$ was based on data for 2004, the value is adjusted to the 2011.

Commercial Fishing

The Ontario Ministry of Natural Resources (OMNR) is responsible for regulating Ontario's commercial fishery. There are more than 500 active commercial fishing licences in Ontario[43] and, in 2011, approximately 12,141t of fish were commercially caught from the Great Lakes, generating an estimated landed value of $33.6 million. OMNR (2010) estimated that, in 2008, Ontario's commercial licence holders caught nearly 14,808t of fish, for which the dockside/wholesale[44] value was $29.2 million. Once the fish has 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 in 2008 was in the range of $180 - $215 million[45], with an average value of $197.5 million. This implies that the value added to the landings by the processors resulted in a value more than six times higher than the dockside value.

However, neither the existing data nor the literature provides the total economic value (e.g. WTP) of commercial fishing generated for the Canadian economy.[46] 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 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 landed value for the year 2011, as follows:[47]

Estimated Market Value of Commercial Fishing (EV_{CF}) = $LV * M/D$

Where *LV* is landed value; *M* and *D* are market and dockside prices. Following this approach, the economic contributions of commercial fishing in the Great Lakes to the Canadian economy is estimated to be $226.5 million per year.[48]

Recreational Fishing

There are a number of sources (e.g. Austin et al., 2007; DFO, 2008; EC, 2000) that estimated the value of recreational fishing in the Great Lakes, employing different methodologies, such as survey question sequencing or Nested Logit models. For Canada, the most relevant and recent information on expenditures incurred for recreational fishing estimated in DFO (2008) employs

43 Ontario Ministry of Natural Resources. (2010, March 5). *Great Lakes Fisheries*. Retrieved on December 21, 2011, from http://www.mnr.gov.on.ca/en/Business/GreatLakes/2ColumnSubPage/STEL02_173913.html#Commercial_Fisheries.

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

45 Supra note 41.

46 Austin et al. (2007) found the American Great Lakes commercial fishery was less than 2% as valuable as the recreational fishery sector.

47 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.

48 This estimation does not include commercial fishing in the St. Clair River due to data unavailability.

travel costs and expenditures for fishing trips to estimate the contributions of recreational fishing in the Great Lakes. Moreover, the consumer surplus value associated with recreational fishing that is not captured by expenditures is reported in EC (2000).

In terms of expenditures, DFO (2008) estimated that anglers spent a total of $214.6 million in Canada in direct recreational fishing expenditures in the Great Lakes in 2005, which was 25.1% and 8.7% of the totals of $856.2 million (weighted) and $2.5 billion direct expenditures on recreational fishing activities in Ontario/Quebec and in Canada, respectively.[49]

Table 4: Direct Recreational Fishing Expenditures ($Mil.) Made 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.*

In 2005, anglers invested $228.3 million in major purchases and investments that could be wholly attributable to recreational fishing in the Great Lakes. The investment accounted for 31.5% and 8.8% of the totals of $715.5 million (weighted) and $2.6 billion worth of purchases and investments made for recreational fishing in Ontario/Quebec, and in Canada, respectively.

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

Table 5: Major Purchases and Investments ($Mil.) 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**
Ontario	**$73.1**	**$300.7**	**$68.1**	**$147.0**	**$197.5**	**$28.7**	**$815.0**
Quebec**	**$41.2**	**$145.3**	**$56.4**	**$208.4**	**$101.5**	**$21.5**	**$574.3**
Canada	**$203.5**	**$873.6**	**$324.8**	**$606.4**	**$493.4**	**$83.8**	**$2,585.4**

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

The total direct expenditures and major purchases/investment of $443.0 million in recreational fishing in the Great Lakes accounts for 28.7% of the weighted total of $1.5 billion expended in Ontario and Quebec in 2005 (see Table 6).[50]

Table 6: Major Purchases/Investments and Direct Expenditures ($Mil.) by All Anglers, 2005

	Direct Expenditures	Major Purchases	Total
The Great Lakes	**$214.6**	**$228.4**	**$443.0**
St. Lawrence	*$13.2*	*$36.0*	*$49.2*
Lake Ontario	*$44.9*	*$48.0*	*$92.9*
Lake Erie	*$33.4*	*$50.8*	*$84.1*
Lake Huron	*$92.1*	*$69.2*	*$161.3*
St. Clair	*$13.9*	*$14.2*	*$28.1*
Lake Superior	*$17.1*	*$10.3*	*$27.4*
Ontario	**$1,031.5**	**$815.0**	**$1,846.6**
Quebec	**$378.9**	**$574.3**	**$953.2**
Weighted Total	**$856.2**	**$715.5**	**$1,571.7**
GL as a % of Weighted Total	**25.1%**	**31.9%**	**28.7%**
GL* as a % of Ontario	**19.5%**	**23.6%**	**21.3%**
GL as a % of Quebec**	**3.5%**	**6.3%**	**5.2%**
Canada	**$2,466.2**	**$2,585.4**	**$5,051.6**
GL as a % of Canada	**8.7%**	**8.8%**	**8.8%**

Source: Survey of Recreational Fishing in Canada 2005, DFO.
*Notes: * Excludes St. Lawrence; ** Includes St. Lawrence only.*

[50] Quebec is included, as a portion of investments/expenditures are made by anglers from Quebec.

Pertaining to the estimation of consumer surplus, following the contingent valuation methodology, based on 39 studies and 122 estimates for the US, Rosenberger & Loomis (2001) presented a range of estimates for consumer surplus of fishing to be USD3.03 to USD369.15. Apogee (1990) used a value of $70 in consumer surplus per angler-day for recreational fishing on the Great Lakes. 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 $10.89 - $39.37 for unspecified improvements to recreational fishing. The most widely used consumer surplus value associated with recreational fishing in Canada is reported by EC in 2000. Based on the results of a survey conducted in 1996, EC (2000) estimated the consumer surplus associated with recreational fishing to be $10.80 in 1996 dollars.

Therefore, to calculate the total economic contributions of recreational fishing in the Great Lakes to Canada, the present study added the inflation-adjusted expenditures on recreational fishing in 2005 estimated by DFO (2008) and the inflation-adjusted economic values estimated by EC (2000), as follows:

Estimated Value of Recreational Fishing (EV_{RF}) = *Expenditures in Recreational Fishing (E_{RF}) + Value of Consumer Surplus (CS)*

(i) Estimated Expenditures in Recreational Fishing (E_{RF}) = $I_{\mathrm{RF}2005} * \pi_{2011/2005}$

(ii) Value of Consumer Surplus $(CS_{RF}) = N_D * (V_{1996} * \pi_{2011/1996})$

Where I_{RF} is direct expenditure and investment in recreational fishing, π is inflation rate, N_D is number of angling days, and V is consumer surplus per day. Following this approach, the economic contributions of the recreational fishing industry around the Canadian side of the Great Lakes is estimated to be $560.3 million/year.[51]

Recreational Hunting

A few studies (e.g. Rosenberger, 2001; EC, 2000) provided estimates for Canada (and the US) of the number of hunters and the economic values of hunting activities. However, none of the literature estimated either the number of hunters or the benefits accrued by hunting activities (e.g. waterfowl) occurring specifically along the Great Lakes.

Austin et al. (2007) estimated that approximately 20,000 hunters and 200,000 hunting trips depend on Great Lakes ecosystems each year. 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. Applying USD32 per trip to 200,000 Great Lakes waterfowl hunting days, the report estimated a surplus value of hunting in the amount of USD6.4 million around the Great Lakes in the US.

Using meta-assessments of the literature based on 13 recreation demand studies carried out during 1967-1998, Rosenberger (2001) presented a range of USD3.8 - 249.9 consumer surplus

[51] The non-resident, non-Canadian (foreign) consumer surplus is not a benefit to Canada and therefore excluded from the calculations.

per waterfowl hunting day. Applying conjoint valuation approach analysis on waterfowl hunters in Louisiana,[52] Gan and Luzar (1993) estimated a WTP in the amount of USD395.77 to increase the daily duck bag limit from the currently mandated three ducks per day, with lower and upper limit estimates of USD326.66 and USD490.72, respectively.[53]

From the Canadian perspective, EC (2000) found that residents of Ontario spent $4.3 billion on nature-related activities in 1996, of which $200.6 million was spent on hunting wildlife. [54] The average hunter spent $639 during the year, or $37/day of participation. Quebec residents spent $285.6 million on hunting wildlife, of a total of $2.1 billion spent on nature-related activities. The average Quebec hunter spent $726 during the year, or $50/day of participation in hunting. Pertaining to the estimation of consumer surplus, the report estimated that the consumer surplus associated with hunting[55] was $219.7/yearly or $17.9/daily, in 1996 dollars.

As the above values are not Great Lake specific, to calculate the total economic contributions of hunting in the Great Lakes, the present study scaled down the hunting expenditures and the economic values estimated by EC (2000), [56] and adjusted for inflation as follows:

Estimated Value of Hunting (EV_H) = *Expenditures in Hunting* (E_H) + *Value of Consumer Surplus* (CS_H)

(i) Estimated Expenditures in Hunting (E_H) $= 0.265 * (Ontario_{I1996} * \pi_{2011/1996}) +$
$0.046 * (Quebec_{I1996} * \pi_{2011/1996})$

(ii) Value of Consumer Surplus $(CS_W) = 0.265 * [Ontario_{NH} * (Ontario_{V1996} * \pi_{2011/1996}) +$
$0.046 * [Quebec_{NH} * (Quebec_{V1996} * \pi_{2011/1996})$

where I is expenditure in hunting, π is inflation rate, N_H is number of hunters, and V is consumer surplus per year. Following this approach, the economic contributions of recreational hunting around the Great Lakes in Canada was estimated to be $105.7 million/year (Ontario - $85.5, Quebec - $20.2).

Recreational Boating

Several studies (e.g. Dutta, 1984; Hushak, 1999, Dupont, 2003) have assessed the economic values associated with recreational boating in the Great Lakes from both the Canadian and the US context.

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[52] Conjoint valuation approach analysis, widely used in marketing research, offers an alternative resource suited to outdoor recreational activities characterized as multi-attribute.
[53] The report found that the total WTP to have the number of hunting days extended and the daily duck bag limit increased from the currently mandated three ducks per day was $426.44.
[54] Of the total $200.6 million, approximately $64.1 million (32.0%) was spent on equipment used, 45 million (22.4%) on transportation, 28.4 million (14.2%) on food, 13.2 million (6.6%) on accommodation, and the remaining 49.8 million (24.8%) on other cost items, such as entry fees.
[55] Hunting prey included only waterfowl.
[56] The proportions of the total such expenditures (Ontario: 26.5% and Quebec: 4.6%) are calculated based on the proportions of recreational fishing expenditures by Ontario and Quebec residents that are Great Lake specific reported in DFO (2008).

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. Husak (1999) estimated that the total boating expenditures of Ohio's boat-owning households was USD2.6 billion during October, 1997 - September, 1998.[57] The Great Lakes Commission reported that there were about 4.3 million recreational boats 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. More than 910,000 boats are used primarily on Great Lakes waters.[58] Applying an input-output model, the Commission also estimated that expenditures on boats and boating activities in the Great Lakes states totaled nearly USD16 billion in 2003. With secondary effects, the number grew to USD19 billion in sales, USD6.4 billion in personal income, and USD9.2 billion in value added. These expenditures directly supported 107,000 jobs, which grew to 244,000 jobs with the inclusion of secondary effects. The U.S. Army Corps of Engineers (2008) estimated that 911,000 recreational boaters in the Great Lakes States spent USD3.68 billion/year on boating trips, and USD2.25 billion/year on boats, equipment and supplies. These expenditures resulted in the creation of 60,000 jobs and USD2.76 billion in personal income.

In the Canadian context, a few studies (e.g. Thorpe and Stone, 2000) have estimated that there were 1.2 million recreational boats in Ontario, of which approximately 780,000 (65%) were used in the Great Lakes.[59] Every year, more than 1.5 million recreational boaters travel the waters of the Great Lakes (OMNR, 2012, March). Using data from online surveys and publicly available information from Industry Canada, Genesis Public Opinion Research Inc. (2007) estimated that the total direct and indirect expenditures from recreational boating in Ontario was in the amount of $7.3 billion in 2006, but provided no specific estimate for the Great Lakes.

With respect to consumer surplus, Dupont (2003) estimated that the median WTP for improvements to Hamilton Harbour, Ontario, Canada, to support recreational boating was in the $8.20 to $43.27 range for passive and active boating users, respectively. Though no specific value was provided for boating, EC (2000) estimated that the consumer surplus associated with outdoor activities in natural areas[60] for Ontario residents was $146.6/yearly, or $9.7/daily, in 1996 dollars.

Therefore, to calculate the total economic contributions of recreational boating in the Great Lakes basin in Canada, the present study added inflation-adjusted expenditures estimated by Genesis Public Opinion Research Inc. (2007) (weighted by 65%) and the inflation-adjusted economic values estimated by Environment Canada (2000), as follows:

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[57] Employing three surveys, the study found that the mean WTP for dredging to remove contaminated sediments from the Ottawa River was $66.5 per year for the next 10 years or $539 as the present value of mean payments.

[58] See http://www.glc.org/advisor/00/recboating.pdf.

[59] Preliminary results from a recent survey on recreational boaters in Ontario being conducted by the OMNR and the Ontario Federation of Anglers and Hunters found that 29.4% of Ontario boaters surveyed use their boats on the Great Lakes or connecting waterways, while 73.8% used their boats on inland waters, which may include a portion of the Great Lakes Basin (Drake, A., Great Lakes Laboratory for Fisheries and Aquatic Sciences, DFO, personal communication, June 21, 2012).

[60] "Outdoor activities in natural areas" include sightseeing, photographing, gathering nuts, berries and firewood, picnicking, camping, swimming/beach activity, canoeing/kayaking/sailing, power boating, hiking/backpacking, climbing, horseback riding, cycling, off-road vehicle use, downhill skiing, snowmobiling and relaxing in an outdoor setting.

Estimated Value of Boating (EV_B) = *Expenditures in Boating (E_B) + Value of Consumer Surplus (CS_B)*

(i) Estimated Expenditures in Boating[61] (E_B) = $0.65 * (I_{B2006} * \pi_{2011/2006})$

(ii) Value of Consumer Surplus (CS_B) = $N_B * (V_{1996} * \pi_{2011/1996})$

where I_B is boating expenditure, π is inflation rate, N_B is number of boaters, and V is consumer surplus per year. Following this approach, the economic contributions of recreational boating around the Great Lakes in Canada is estimated to be $7.3 billion per year.[62]

Beaches and Lakefront Use

Literature relating to the benefits of beach and lakefront use along the Great Lakes is rich compared to that for other activities.

From the US perspective, using results from a survey of 1500 Chicago beach-goers in 2004, Shaikh (2004) estimated that the average day at the beach was worth approximately USD35 to an individual. The total seasonal value for beach-goers was estimated in the range of USD800 million - USD1.0 billion. Based on survey data for recreational use of ocean beaches, 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. Furthermore, the study estimated that the economic benefit of a 20% reduction in beach closings and advisories would be in the range of USD130–USD190 million per year.[63]

From a Canadian perspective, using survey data and the travel-cost method, Sohngen (1999) estimated that the recreational value of a day trip to Lake Erie beaches was in the range of $26 - $44. 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 $30.55 and $27.69, 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 $16.06 - $75.18 for swimming activities (Marbek, 2010b). Krantzberg et al. (2006) estimated the WTP value for Canadian Great Lakes beach goers to be in the range

[61] Expenditures include amounts expended for marinas and yacht clubs, intra-provincial automotive travel, at retail outlets, angler expenditures other than boats and intra-provincial transportation covered elsewhere, private wharf and boathouse construction other than at marinas and yacht clubs, boat insurance, boater and interested party expenditures and boating related tourism expenditures. For details, see Genesis Public Opinion Research Inc. (2007).

[62] The estimation of the baseline value of the recreational fishing in the Great Lakes excludes expenditures pertaining to the St. Lawrence River, as no estimation of expenditures or suitable proxies were found for recreational boating on the St. Lawrence. However, the Québec Marine Trade Association estimated that, of Québec's estimated 879,000 recreational boats, 813,075 boats (93%) are used on the St. Lawrence River.

[63] The low end of the range comes from multiplying 80 million swimming days by $1.50 per visit, whereas the high end of the range comes from multiplying 8 million swimmers by $23 per visitor. The study noted that the estimates were conservative based on available information for individual Great Lakes beaches or beaches in individual Great Lakes cities or states.

of $200 - $250 million, which was derived by proportionally scaling the value derived by Shaikh (2004) for the US.

To calculate the total economic contributions of beaches and lakefront use in the Great Lakes, the present study used inflation-adjusted average value from a range of values estimated by Krantzberg et al. (2006), as follows:

Estimated Expenditures in Beaches and Lakefront Use (E_{BL}) = $I_{BL} * \pi_{2011/2006}$

where I_{BL} is beaches and lakefront expenditure, and π is inflation rate. Following this approach, the economic contribution of Canada's beaches and lakefronts around the Great Lakes is estimated to be $247.8 million per year.

Wildlife Viewing

A number of studies highlighted and estimated the economic value of wildlife viewing for regions of the US and Canada. However, information on the economic values generated by wildlife watching specifically for the Great Lakes is sparse.

From the US perspective, the U.S. Fish and Wildlife Service (2001) estimated that there were 46 million bird watchers in the US, whose expenditures related to wildlife watching in the US were approximately USD32 billion for the year 2001. Using the contingent valuation method, the survey found that the net economic value for a wildlife watcher in their resident state was USD257/year or USD35/day of wildlife watching. Wildlife watchers who travel outside their state have a different demand curve and therefore have higher net economic values of USD488/year and USD134/day of wildlife watching. Kerlinger (unspecified) estimated that there were 10 million bird watchers in the US and that bird watching related expenditures were over USD20 billion per year in the US. The annual spending by active bird watcher averages between USD1,500 and USD3,400. Rosenberger and Loomis (2001) reviewed literature spanning 1967 to 1998 in the US and Canada, and covered 760 value measures estimated from 163 separate empirical research efforts spanning 21 recreational activities. The study found that the consumer surplus for wildlife watching activity was in the range of USD2.36 - 161.59/person/day.

Austin et al., 2007 estimated birding activities specifically 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. Surplus value generated by birding was found to be in the range of USD40 – USD153 per trip, with a weighted average value of about USD50/trip. Assuming 2 million traveling bird watchers each visit the Great Lakes basin once per year, the study estimated that the total surplus value was in the range of USD5 – USD10 million annually.[64]

From Canadian perspective, EC (2000) found that Ontario residents spent $410.9 million on wildlife viewing in 1996. On average, the wildlife viewers spent $263/year or $16/day of participation. For Quebec residents, wildlife viewing expenditures were estimated at $281.0 million in the same year. On average, Quebec residents spent $239, or $17/day of participation

[64] The estimation excluded birders living outside the Great Lakes region, and only included benefits solely associated with birding.

in wildlife viewing. [65] Pertaining to consumer surplus, the report estimated that the consumer surplus associated with wildlife viewing was $88.4/yearly or $7.5/daily, in 1996 dollars.

From the Great Lakes context, using the contingent valuation method, Hvenegaard (1989) estimated that bird-watching expenditures were $224/trip, or $66/day, for trips to Point Pelee National Park, Ontario, in 1987. The total expenditures for the year were estimated to be in the amount of $5.4 million, broken down as follows: travel 27.2%; food 26.3%; and accommodations,22.5%. The WTP (or "net economic value") was estimated to be in the amount of $256/trip or $76/day, and $6.3 million for the year.

As the values were not Great Lake specific, to calculate the total economic contributions of wildlife viewing in the Great Lakes, the present study scaled down the wildlife viewing expenditures and economic values estimated by EC (2000) and adjusted for inflation as follows:[66]

Estimated Value of Wildlife Viewing = *Expenditures in* Wildlife Viewing (E_W) + *Value of Consumer Surplus* (CS_W)

(i) Estimated Expenditures in Wildlife Viewing $(E_W) = 0.265 * (Ontario_{I1996} * \pi_{2011/1996}) + 0.046 * (Quebec_{I1996} * \pi_{2011/1996})$

(ii) Value of Consumer Surplus $(CS_W) = 0.265 * [Ontario_{NW} * (Ontario_{V1996} * \pi_{2011/1996}) + 0.046 * [Quebec_{NW} * (Quebec_{V1996} * \pi_{2011/1996})]$

where I is wildlife viewing expenditure, π is inflation rate, N_W is number of viewers, and V is consumer surplus per year. Following this approach, the economic contributions of wildlife viewing around the Great Lakes in Canada is estimated to be $217.5 million/year (Ontario - $196.7; Quebec - $20.9).

Commercial Navigation

The Great Lakes provide means of transporting goods from the industrialized core of North America. The Great Lakes-St. Lawrence Waterway extends 3,700 kilometers (2,300 miles) (Martin Associates, 2011), making it the largest inland waterway in the world (Canadian Shipowners Association, 2006). The waterway complements the region's rail and highway network and offers customers a cost-effective means of moving raw materials, agricultural commodities and manufactured products. It includes 110 system ports located in the eight Great Lakes states and the provinces of Ontario and Quebec. In 2010, a total of 322.1 million metric tons of cargo was "handled" (based on approximately 164 million metric tons of cargo "moved") by all US and Canadian ports and marine terminals on the Great Lakes-Seaway system (Martin Associates, 2011).

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[65] EC (2000) also reported that Canadians spent an estimated $1.3 billion on wildlife viewing in 1996. On average, participants spent $297/year, or $17/day of participation.

[66] The proportions (Ontario: 26.5% and Quebec: 4.6%) are calculated based on recreational fishing expenditures by Ontario and Quebec residents in respective jurisdiction reported in DFO (2008).

In the US, estimations of the economic contributions made by the Great Lakes - St. Lawrence Seaway System and the 16 major individual ports located on the US side of the border include USD3.4 billion of business revenue to firms providing transportation and cargo handling services, an additional USD1.9 million of local purchases and consumption expenditures, and USD1.3 billion in expenditures by the firms providing the cargo handling and transportation services (Krantzberg et al., 2006).

Martin Associates (2011) estimated that 32 US and Canadian Great Lakes-Seaway system ports contributed USD9.7 billion in personal income and generated 128,227 US jobs (direct, indirect and induced) in 2010. As a result of maritime activity on the Great Lakes-Seaway system, business revenue accrued in 2010 in the US was over USD18.0 billion.

According to Statistics Canada (2008), the Great Lakes region accounts for the majority of the total inbound tonnage from the US. In 2008, the total international shipping of commodities (coal, grain, iron ore, aggregates, salt, and petroleum products) handled (loaded and unloaded) in the Canadian portion of Great Lakes region was 44.3 million tonnes.

LECG (2004) conservatively estimated that, in 2003, over $2.2 billion of provincial gross domestic product (GDP) and over 18,000 jobs were generated by the Great Lakes/St Lawrence waterway Transport and Environment Canada (2004) estimated that the Great Lakes - St. Lawrence Waterway added $3.0 billion annually, and approximately 17,000 jobs, to the Canadian economy. Martin Associates (2011) estimated that the seaway provided an economic benefit of $3.7 billion in personal income and the generation of 76,608 Canadian jobs (direct and indirect) in 2010. As a result of maritime activity on the Great Lakes-Seaway system, in 2010, business revenue accrued was approximately $16.0 billion in Canada.

The Canadian Shipowners Association[67] reported an economic contribution of $4 billion (direct and indirect impact) from cargo handling, vessel services, and inland transportation services on this integrated waterway system in Canada.[68]

The present study calculated that the total value generated by commercial navigation in the Great Lakes in Canada is in the amount of $4.2 billion, by revising the estimate of the Canadian Shipowners Association for inflationary impact, as follows:

Estimated Value of Commercial Navigation (V_{CN}) = $V_{2008} * \pi_{2011/2008}$

where V is value of transportation services and π is inflation rate.

Oil and Gas

In 2009, there were 96 commercial oil and gas producers in Ontario. There were 1,200 active oil wells, 1,300 commercial natural gas wells and 500 private gas wells. Five hundred (500) of the

[67] The Canadian Shipowners Association (CSA) represents Canadian companies with domestically flagged vessels and advocates the development of marine policy, regulations and operational matters for ship owners operating vessels on the Great Lakes, St. Lawrence Waterway, the Arctic and the eastern seaboard of the United States and Canada. See http://www.shipowners.ca/.

[68] Canadian Shipowners Association (2011) retrieved on December 20, 2011, from http://www.shipowners.ca/index.php?page=impact-of-the-canadian-marine-sector.

gas wells were located offshore on Crown land under the Lake.[69]

Ontario Ministry of Natural Resources (2012) reported that about 88,000 cubic meters of crude oil with a wellhead value of $50 million was produced in Ontario in 2009. In 2008, approximately 240 million cubic meters of natural gas with a retail value of $80 million was produced in Ontario. All of Ontario's crude oil and natural gas production is consumed within Ontario.[70]

The study calculated the total value of oil and natural gas produced from the Great Lakes in the amount of $136.8 million as follows:

Estimated Value of Oil (V_O) = $V_{2009} * \pi_{2011/2009}$

Estimated Value of Natural Gas (V_G) = $V_{2008} * \pi_{2011/2008}$

Where V is value of resources and π is inflation rate.

Ecosystem Services

The Great Lakes provides invaluable services to society through maintaining ecosystems and biodiversity. Some of these are captured with the corresponding direct benefits to the Great Lakes economy. The intrinsic values of ecosystems and biodiversity are harder to define because they are much more intangible (Krantzberg et al., 2008, 2006). For example, the Great Lakes provide clean, breathable air by regulating gases (e.g. carbon dioxide) and protect the general maintenance of a habitable planet by regulating the local weather and climatic conditions of the region. These services are usually categorized in the literature as follows:[71] gas regulation; local climate regulation; water regulation; disturbance prevention; soil formation/retention; waste treatment; nutrient cycling; and habitat, refugium and nursery (Marbek, 2010b; Krantzberg et al., 2008, 2006).[72] Thus far, however, there has not been sufficient practical guidance provided on how to measure them.

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 $6.6 billion per year of the total economic damage of $9.6 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,

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[69] Ontario Ministry of Natural Resources. (2012, May 30). *Crude Oil and Natural Gas Resources*. Retrieved on June 28, 2012, from http://www.mnr.gov.on.ca/en/Business/OGSR/2ColumnSubPage/STEL02_167105.html.

[70] Ontario Ministry of Natural Resources (2012) reported that there was approximately 30 million cubic meters and 35 billion cubic meters of undiscovered resources of crude oil and natural gas remaining in Ontario, respectively. These are estimated to be the quantities equivalent to what has already been recovered over the years in Ontario. Most of the undiscovered resources of crude oil and natural gas lie on Crown land under Lake Erie, Lake Ontario, Lake St. Clair and Lake Huron.

[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, a healthy ecosystem ensures suitable habitats for fish populations and thus enables commercial harvesters and recreational anglers to fish.

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 $6.09 - $11.07 per month for minor and major changes in water quality. The study calculated a present value of $1,869 per 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 $1,363.79 per hectare. Kazmierczak (2001) estimated the value of habitat and species protection to be $843.55 per hectare. Using the benefit transfer approach, Costanza et al. (1997) estimated a global average of the habitat ecosystem service of $690.71 per 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 $6,234.14 per 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 $2,184.40 per hectare of wetland for all Canadian Great Lakes restoration projects.[75] Wetlands and other natural ecosystems fixate nutrients in their soils. Two of the main non-point source pollutants in the Great Lakes Basin are phosphorous and nitrogen (Marbek, 2010b). 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 per hectare (based on a range of values from $1,061 to $3,235/ha/year).

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 USD548 million, or USD5,830 per hectare, based on the average annualized wetland habitat restoration costs for a group of relevant Great Lakes Sustainability Fund projects.

Wilson (2008) 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 per 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 per hectare.

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.

[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).

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).[76]

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.

There is no existing literature on the potential economic value of natural local climate regulation by the Great Lakes, due to the lack of information and the uncertainty around predicting the future (e.g. knowledge of local weather and climate patterns).

Option Value

Neither economic theory nor empirical literature provides adequate information to quantify the option values. Thus, option value is excluded from the computation of the baseline 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).

Non-Use Value

As mentioned in Section 4, 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.[77]

In terms of non-use values of the resources embedded in the Great Lakes, a few studies have estimated non-use values 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.

In the US, Loomis (1987) found that non-use values were approximately 73 times as large as the

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[76] 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%.

[77] 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.

corresponding use values at 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, generating a present value of USD635/acre.

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 - USD10.2 million; existence value - USD12.3 million; and bequest value - USD12.5 million.[78]

From the Canadian perspective, Dupont (2003) estimated that passive users of recreational activities in Hamilton Harbour, Ontario, had WTP for improvements as follows: $20.5 for swimming, $10.9 for boating, and $11.7 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 (1987) estimated the taxpayers' WTP for the striped shiner (designated as an endangered species) to be in the range of USD10.2 - USD13.8. 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 (USD154 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.

Aggregated Economic Contribution

Based on the methodology adopted in Chapter 3 and the subsequent calculations in Chapter 4, the present study estimates that, in Canada, the value of economic contributions of the activities in and around the Great Lakes is in the amount of $13.8 billion dollars. Table 7 and Matrix 2 show the details on the values adopting the TEV framework discussed in Chapter 3.

[78] The preservation value estimates omit non-residents who are also expected to have some positive preservation 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 7: Economic Contributions ($Million) of the Great Lakes by Sector and Activity in 2011

			Sector	Value/ Expenditure	Consumer Surplus	Total
Use Values	Current Uses	Direct	**Extractive**	**$1,743**	**$79**	**$1,822**
			Industrial Water	$96	NA	$96
			Drinking Water	$532	--	$532
			Agricultural Water	$165	--	$165
			-- *Irrigation*	$99	--	$99
			-- *Livestock*	$66	--	$66
			Commercial Fishing	$226	NA	$226
			Recreational Fishing	$498	$62	$560
			Hunting	$90	$16	$106
			Oil and Gas	$137	NA	$137
			Non-Extractive	**$11,620**	**$350**	**$11,970**
			Recreational Boating	$6,994	$297	$7,291
			Beaches and Lakefront Use	$248	NA	$248
			Wildlife Viewing	$165	$53	$218
			Commercial Navigation	$4,214	--	$4,214
			Grand Total	**$13,363**	**$429**	**$13,792**
		Indirect	Ecosystem Services	Not Quantified	Not Quantified	Not Quantified
	Future Uses		Option Values	Not Quantified	Not Quantified	Not Quantified
			Research Values	Not Quantified	Not Quantified	Not Quantified
Non-Use Values			Existence Values	Not Quantified	Not Quantified	Not Quantified
			Bequest Values	Not Quantified	Not Quantified	Not Quantified

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

Of the total quantified direct use values of $13.8 billion, non-extractive use and extractive use values accounted for $12.0 billion (86.8%) and $1.8 billion (13.2%), respectively. Moreover, of that $13.8 billion total, expenditures made, as well as imputed values/prices for the activities in and around the Great Lakes, comprised $13.4 billion (96.9%) and the consumer surplus constituted the remaining $0.4 billion (3.1%).

The Great Lakes basin also provides opportunities for research activities that inform and benefit others and provide a better understanding of the ecology. Research is often integrated with education. Although, estimating the economic value of these uses is difficult, their contribution in this area cannot be overlooked. Public outreach programs can 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.

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; Earhhart, 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).

The estimations of the economic contributions of the Great Lakes discussed in this chapter should be viewed as conservative estimates. The conservative estimates are provided by: (i) adjusting estimation variables where significant variations and uncertainties exist in the literature; and (ii) using reasonable proxies based on literature review and experts' opinions. For example, if candidate proxies showed significant variations (e.g. proxies used for water use), the study adopted the lower values to avoid overestimation of the economic contributions of the activities/sectors. In addition, there were some underestimations of values in some sectoral activities due to lack of complete information required to provide defensible estimates, an issue further elaborated below.

Limitations/Gaps Identified in the Study

While undertaking an assessment of the economic contributions generated by the Great Lakes basin, the study found the following data gaps/limitations:

Water Use: Pertaining to water consumption from the Great Lakes, there were shortcomings in the study's analysis due to incomplete information, and that resulted in a failure to capture the full spectrum of the value of the consumed water to the economy. The study particularly suffered from incompleteness stemming from the use of proxies for the valuations of water used for residential, agricultural, and industrial purposes. For example, the study used Statistics Canada's estimates of operating/ maintenance costs of raw intake water from the Great Lakes basin, assuming that water revenue structures closely reflect the full cost of water production. For industrial water uses, the study used the shadow price of water intake for Canadian business sector industries from Dachraoui and Harchaoui (2004). Similarly, for agricultural water use, the study used the estimated value of water used in irrigation for Southern Ontario as proxy, both for Great Lakes water used for irrigation and for livestock. No Great Lakes specific data on the valuation of water used for those purposes was found. Furthermore, the study excluded consumer surplus values of water use from the assessment due to missing information on subject areas.

Heating and Cooling (including nuclear and thermal plants): The Great Lakes Commission (2010) estimated that Ontario's annual water withdrawal and consumption were 2,028 and 18 million m^3 by the fossil fuel power plants, and 13,990 and 126 million m^3 by nuclear power plants, respectively. In Quebec, fossil fuel power plants annually withdrew and consumed 65 and 6 million m^3, respectively.[79] In terms of the economic value of this water in the process of heating and cooling thermal power plants, the Industrial Water Use Survey found that Ontario's thermal power generating plants spent $9.1 billion on water intake operating and maintenance costs for the intake of 23,228 million m^3 of water in 1996. This expenditure results in an average intake cost of 0.39/m^3 (Marbek, 2010b).[80] Unfortunately, an estimate of the full benefits (e.g. avoided electricity production, avoided pollution costs) of this usage was not available and therefore, has been excluded from the baseline calculation of the present study.

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[79] No water was withdrawn from the St. Lawrence River by nuclear power plants in Quebec.
[80] Using cold lake water to cool buildings (e.g. Toronto's ENWAVE) is a new use of Lake Ontario water. The project had a capital cost of $230 million and resulted in the displacement of approximately 61 megawatts of electricity demand and 80 million kwh of electricity consumption (Marbek, 2010b).

Hydropower Production: The Great Lakes provide important low cost and clean electricity generation opportunities through hydropower production. Ontario Power Generation currently operates 65 hydroelectric stations (including a green power portfolio of 29 small hydroelectric plants) and 240 dams on 24 river systems, with the majority stationed throughout the Great Lakes basin. In total, hydroelectric generation produced 32.4 terawatt-hours of power in 2011.[81]

According to the Great Lakes Commission (2010), Ontario's annual water withdrawal from the Great Lakes basin under this category was approximately 262 billion m^3 (190 billion gallon per day). Marbek (2010b) reported that the Sir Adam Beck power plant on the Niagara River used in the range of 9 -11 billion m^3 of water each month, and produced $100 - $150 million worth of electricity. However, due to the absence of information on the hydropower generated by other plants (Long Sault and Moses Saunders) and the lack of a detailed cost structure of hydropower production, the present study excluded these benefits generated by the Great Lakes from the baseline values.

Self-Supply of Water for Other Uses: The Great Lakes Commission (2010) category of "self-supply of water used for other purposes" includes water used to maintain levels for navigation, for recreation, for fish and wildlife habitat creation and enhancement (excluding fish hatchery operations), flow augmentation/diversion, sanitation, pollution confinement, temporary or immediate emergency situations (e.g., fighting forest or peat fires), and other water quality purposes and agricultural activities/services other than those directly related to irrigation, such as, field drainage. According to the Great Lakes Commission (2010), Ontario's annual water withdrawal from the Great Lakes basin under this category was approximately 276 million m^3 (200 million gallon per day). Unfortunately, estimates of the values of these usages were not available and, therefore, were excluded from the baseline calculation of the present study.

Commercial Fishing: The economic contributions of commercial fishing were underestimated because of missing information on landings from St. Clair river basin. The estimation may also have differed from actual contributions because market price proxies were used to fill in the gap in market value/price data.

Recreational Hunting, Wildlife Viewing: The recreational hunting and wildlife viewing expenditures were not available for the Great Lake basin. As a result, the study scaled down residents' expenditures and consumer surplus values from Environment Canada (2000) and further adjusted 1996 survey data for current year. The estimated values therefore were, to some extent, underestimations of the actual contributions, as it excluded the relevant values generated by non-resident Canadians and foreign participants. Recent estimates of expenditure and consumer surplus values specific to the Great Lakes basin would allow for a better assessment of the economic contributions of this sector.

Recreational Boating: The recreational boating expenditures were not available for the Great Lake basin. Therefore, the study scaled down expenditures estimated for Ontario from Genesis Public Opinion Research Inc. (2007) and consumer surplus values from Environment Canada (2000), and made further adjustments for inflation. Moreover, unlike recreational fishing, expenses wholly attributable to recreational boating was not available. Therefore, due to the lack of lake-specific information and expenses wholly attributable to recreational boating, the estimates may have contained inaccuracy to some extent.

[81] See http://www.opg.com/power/hydro/.

Beaches and Lakefront Use: The beaches and lakefront uses data were not available for the Great Lake basin. As a result, the study used inflation-adjusted average value from Krantzberg et al. (2008), which was scaled down from a US estimate done in 2004. Moreover, no information was available on consumer surplus values of these activities in the Great Lakes. Therefore, the assessment made in the study likely underestimated the actual contributions of these activities. More recent Great Lakes-specific estimates of expenditure and consumer surplus values would have allowed for a better assessment of the economic contributions of this sector.

Aquaculture: Commercial cage aquaculture in Ontario mostly occurs in the North Channel of Lake Huron (Manitoulin Island) and in Georgian Bay.[82] Statistics Canada valued the aquaculture industry in Ontario in 2004 as having a gross output of $22.7 million, consisting of the sales value of products and services. Ontario's commercial aquaculture industry (Great Lakes and land-based) contributes about $65 million to the province's economy and produces over 4,500t of fish annually.[83] These numbers represent aquaculture in Ontario and not just from the Great Lakes, however the majority of aquaculture in Ontario occurs in Lake Huron. The Great Lakes play a vital role as one of the inputs used in the production process of the aquaculture industry. However, due to the absence of information on a detailed cost structure of aquaculture production, the study excluded the contributions of the Great Lakes to the development of the aquaculture industry from the baseline values.

Other Recreational Benefits: The Great Lakes provide additional benefits from a variety of other recreational uses, such as skiing and snowmobiling in the winter, and hiking, camping and golfing. Several studies (e.g. Environment Canada, 2000, Office of the Great Lakes, 2009, and Price Waterhouse Coopers, 2004) documented the benefits of such activities associated with tourism, with no attempts to separate the individual categories. For example, Environment Canada (2000) estimated that Ontario residents spent $2,851 million on "outdoor activities in natural areas" in 1996. Along with activities such as hiking and camping, the list of "outdoor activities in natural areas" also included sightseeing in natural areas, swimming/beach activity and power boating, which have been included in the present study as individual categories. Therefore, as it was not feasible to extract the values of individual activities, some recreational benefits have been excluded from the calculation of economic benefits in the study.

[82] The main species for fish farming industry in Ontario is rainbow trout. About 3,200t of rainbow trout are produced in Ontario every year, contributing more than $38.2 million to Ontario's economy annually (Ontario Ministry of Natural Resources, 2012).
[83] Rainbow trout is the only fish farming species produced at the Great Lakes sites. About 3,700t of rainbow trout are produced in Ontario every year, contributing more than $50.7 million to Ontario's economy annually (Ontario Ministry of Natural Resources, 2012, June 8).

Chapter 5: Social and Cultural Values of the Great Lakes

In addition to economic contributions discussed in Chapter 4, 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.

Harvesters of Great Lakes freshwater fish species and the communities involved in the harvests have long realized the importance of the resource to their communities, both for preserving traditional values and for subsistence purposes. Freshwater fisheries have contributed substantially to preserving traditional Aboriginal lifestyles in the study region, as fish harvesting is one of a few remaining primary economic activities providing a viable livelihood to support Aboriginal families and people. For many communities, commercial fishing helps maintain and reinforce family ties and traditions, and therefore is important for social and cultural reasons. 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).

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 (2009) reported in its 2008/2009 Annual Harvest Report that, in 2009, eight of its tribal members obtained subsistence fishing licenses, with four reporting harvests. Three gillnet permits were issued in 2009. In 2009, reported species harvested included whitefish, lake trout, salmon, menominee, and herring. The aggregate harvest by subsistence license holders was difficult to quantify due to the difference in reporting between pounds of fish and number of fish harvested. Quantitative information on subsistence harvests from the Great Lakes basin is largely absent in both Canada and the US. However, the significance of subsistence harvests of freshwater species has been documented in a few studies (e.g. Ashcroft, Duffy, Dunn, Johnston, Koob, Merkowshy, Murphy, Scott, and Senik, 2006; Derek Murray Consulting Associates, 2006; Meyers Norris Penny, 1999) conducted in other regions in Canada.[84]

In addition to providing a food source through subsistence harvesting, the harvest of freshwater

[84] For example, Ashcroft et al. (2006) cited some estimates of subsistence harvests from some studies. A survey done in 1984-85 by Murray and Clouthier estimated a provincial domestic harvest of 1.8 million kg for about 4,000 harvesters, or an average of 450 kg per harvester. Ashcroft et al. (2006) cited another survey undertaken on Lac la Ronge during the 1991-92 seasons. The survey estimated that 134 licenced domestic harvesters harvested a total of 36,318 kg, comprised mainly of suckers, whitefish and pike. Similarly, a survey in the early 1980s of the Cross Lake community in Manitoba indicated that over 103,000 kg of fish were harvested for personal consumption in one year. The food replacement value of this high quality protein had been estimated to be about $657,000 (Manitoba Water Stewardship, 2004).

species provides significant social benefits, particularly to Aboriginal communities, through the distribution of food among communities, providing linkages to traditional lifestyles and ancestors, and socialization. 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. The beaches and coasts are the basis for the key public perception measure of environmental quality.

Chapter 6: Scenario Based on Biological Risk Assessment

Historically, AIS have caused extensive damage to Great Lakes ecosystems, however it is difficult to precisely measure AIS populations and calculate their impacts with a high degree of certainty (Jude et al., 2004). There are some critical factors for determining the magnitude of AIS threats such as the species' reproduction rate, the species' ability to compete with other species, the quantities of biomass the species consumes. Mere arrival of Asian carp does not in itself amount to a major ecological threat, as the species must also demonstrate its ability to establish a self-sustaining population. If Asian carp establishes a healthy population, it has a strong likelihood of harming native plant and animal life, due to its large size and its ability to consume large quantities of native species' food sources (Lieberman, 1996).

For the AIS already established, the estimates of resulting damages could ideally be made from empirical analyses of key variables before and after the invasion, controlling all other factors that could simultaneously affect the response variables (Hoagland and Jin, 2006). For an invasive species like Asian carp that has yet to be introduced to the Great Lakes basin, such an analysis is not possible. It is therefore necessary to seek an alternative approach to the quantification of potential damages to the economy.

Ecologists are making significant efforts to identify concrete changes to the ecosystem caused by AIS. Assuming that only the current management measures are in place and all other things being equal, CEARA, DFO, evaluated the likelihood of arrival, survival, establishment, and spread of *Bigheaded carps (Bighead and Silver carps)* in the Great Lakes basin, and the magnitude of the ecological consequences, based on a qualitative scale and corresponding ranking of certainty, for up to 20 years and up to 50 years.[85]

Following Mandrak, Cudmore and Chapman (2011), DFO (2012) divided the risk assessment process into three steps.[86]

Firstly, it estimated the overall probability of an introduction of Asian carp (using estimates of likelihood of arrival, survival, establishment, and spread) as follows:

Probability of Introduction = Min [Max (Arrival, Spread), Survival, Establishment].

According to this formula, the overall probability of introduction was estimated sequentially by determining the highest ranking between 'Overall Arrival and Spread', incorporating the ranking to the ranks of 'Survival and Establishment', and finally taking the lowest rank of the three.

In the second step, the study determined the magnitude of the ecological consequences of an established population of Asian carp.

Finally, the results from step one and the magnitude of the ecological consequences were combined into a risk matrix to communicate an overall risk. Each lake was assessed at the 20 year and 50 year intervals.

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[85] 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.

[86] For details on 'likelihood as probability categories', 'description of ecological consequence ratings', and 'relative certainty categories', see DFO (2012).

The major findings of the ecological risk assessment of *Bigheaded carps* in connection to this socio-economic impact assessment study are as follows:

- Once having gained entry into the basin, most likely through the Chicago Area Waterway System (CAWS) into Lake Michigan, overall probability of introduction within the 20-year timeframe was very likely for lakes Michigan, Huron, and Erie, high for Lake Ontario (high certainty), and moderate for Lake Superior (moderate certainty);

- Bigheaded carps would survive and become established due to the availability of suitable food, and thermal and spawning habitats in the Great Lakes basin (particularly, in Lake Erie, including Lake St. Clair), and the high productivity embayments (shoreline indentations larger than a cove, but smaller than a gulf) of lakes Superior, Michigan, Huron and Ontario;

- The consequences of an established bigheaded carp population are expected to include changes in planktonic communities, reduction in planktivore (animals feeding primarily on plankton) biomass, reduced recruitment of fishes with early pelagic life stages, and reduced stocks of piscivores (fish-eating species); and

- A time lag is expected with respect to seeing the consequences of an established population of bigheaded carps in the Great Lakes.[87] Within 20 years, the magnitude of the ecological consequences was ranked moderate for all lakes, except Lake Superior, which was ranked low. Within 50 years, the magnitude of the consequences was ranked high for all lakes, except Lake Superior, which was ranked moderate. All ranks for consequences for all lakes in both time periods had moderate certainty. These ranks indicate the escalating consequences expected as the invasion and population numbers increase over time.

[87] 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.

Chapter 7: Socio-Economic Impact Assessment

For this study, the socio-economic impacts that are direct consequences of the ecological outcomes of an introduction of Asian carp have been considered. These socio-economic impacts are tied to the DFO (2012) ecological risk assessment and form the basis for the socio-economic analysis.

DFO (2012) provided the scenario for the socio-economic impact analysis, both for the estimate of the impact as well as for a comparison of the values with those of the baseline. In order to estimate the socio-economic impact of the presence of Asian carp in the Great Lakes, the study also heavily relied on the overall probability of introduction and the consequence scale developed in the ecological risk assessment.

In order to set the stage (scenario) for impact assessment, following DFO (2012), the study assumed that in the absence of added prevention and protection, Asian 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.

As stated in Chapter 3, in addition to the results extracted from DFO (2012), expert scientific opinion was sought from a group of scientists involved in the DFO (2012) assessment, in order to establish a defensible foundation for the socio-economic impact assessment. The discussion largely focused on: (i) the activities/sectors that might be impacted; (ii) the impact trend over 20 years and 50 years; and (iii) permissible ways to use the quantitative scales of the overall probabilities for the impact analyses.

Based on the results reported in DFO (2012), Cudmore, Mandrak, Dettmers, Chapman, and Kolar (2012), and subsequent discussion with scientists, the study identified that, of the list of activities covered in the calculation of baseline values generated by the Great Lakes basin, Asian carp will cause moderate to high damage to commercial fishing, recreational fishing, recreational boating and the beaches and lakefront use sectors/activities during the period covered. Asian carp will cause either negligible or low impact on water use, recreational hunting, commercial navigation and oil and natural gas extraction sectors/activities. Moreover, it was also found that the extent of damage is lake specific and is directly linked to the ecological damages as well as to the level of activities dependent on the lakes.

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

Commercial Fishing

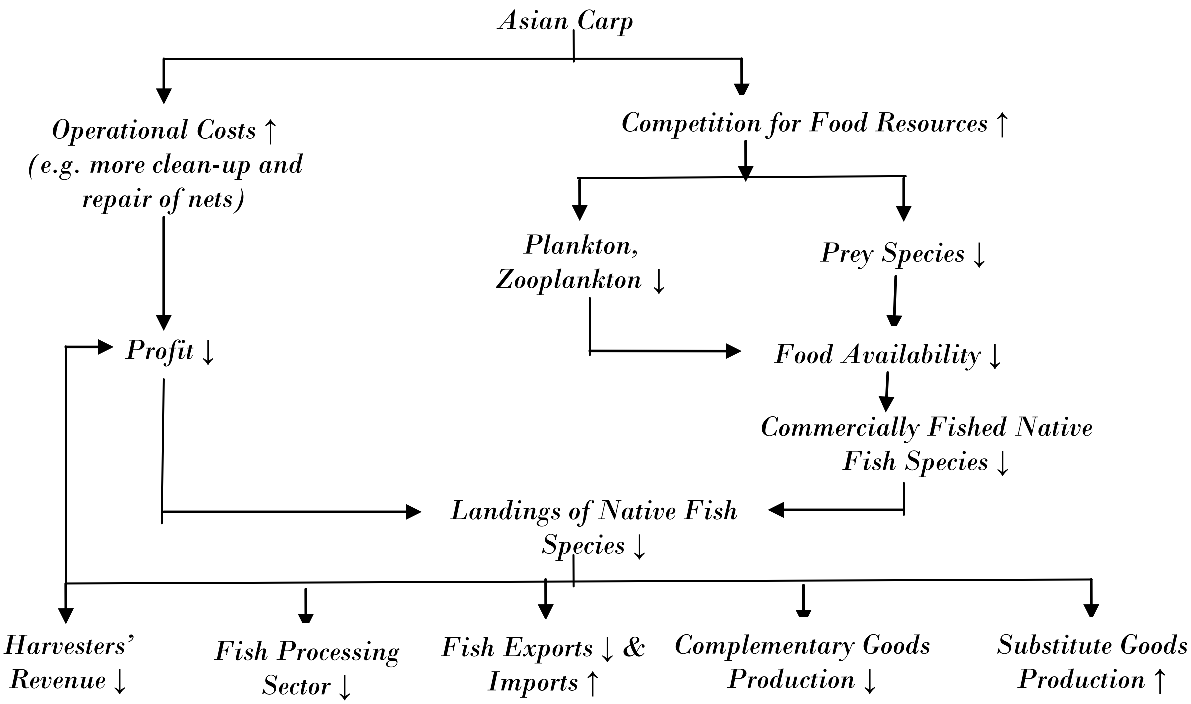
In order to assess the impact on commercial fishing and related activities, it was necessary to project the expected ecological consequences on native species commercially fished in the Great Lakes. Cudmore et al. (2012) found that Asian carp were capable of causing significant changes in plankton (the base of the Great Lakes food web) and in phytoplankton compositions, with substantial repercussions for the aquatic ecosystem. The harmful ecological effects due to the presence of Asian carp are also widely documented in pertinent literature. The most common effects include decline in: (i) planktivorous (feeding primarily on plankton) fish species; (ii) fish diversity; and (iii) populations of several species with pelagic early life stages. Cudmore et al. (2012) concluded that if Asian carp became established in the Great Lakes with ample populations, a similar impact to those documented worldwide would be realized.

Cudmore et al. (2012) found that the diet of Asian carp (5-20% of its average 30-40 lb. body weight each day[88]) overlaps with that of native fish species. The competition for food resources would result in: (i) reduced abundance of near-shore planktivorous forage/prey/bait fishes (e.g. cisco, bloater, rainbow smelt) and adult piscivores (fish-eating species, such as lake trout), reduced growth rates, and reduced recruitment in Lake Superior; (ii) reduced abundance of near-shore planktivorous forage/prey/bait fishes (e.g. alewife, cisco, bloater, rainbow smelt, yellow perch) and adult piscivores (e.g. chinook salmon, lake trout, walleye, Northern pike), reduced growth rates, and reduced recruitment in Lake Huron; (iii) reduced abundance of planktivorous forage/prey/bait fishes (e.g. emerald shiner, gizzard shad, rainbow smelt, white perch), fishes with pelagic early life stages and adult piscivores (e.g. lake trout, rainbow trout, walleye, yellow perch), reduced growth rates, and reduced recruitment in Lakes Erie and St. Clair; and (iv) depending on dreissenid (family of small freshwater mussels) biomass, reduced alewife biomass by up to 90%, which could damage salmonine populations in Lake Ontario. It was also found that Asian carp show high flexibility in terms of food habits. They are capable of changing food behaviour in accordance with food availability, without any impact on their high survival rate.

Based on the results reported in DFO (2012) and Cudmore et al. (2012), the presence of Asian carp in the Great Lakes could cause damage to commercial fishing and related activities as follows:

[88] http://www.asiancarp.org/background.asp.

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



The presence of an Asian carp population would likely cause damage to the commercial fishing industry through both the supply and demand sides of the market.

As shown in the flow chart, the presence of Asian carp would increase costs and decrease revenues for commercial harvesters. It would increase the operational costs of commercial fishing industry (e.g. relocation of sites, frequent repair of nets), which would in turn reduce the fishing activities and profit earned by harvesters. The presence of Asian carp would also damage the commercial fishing industry through the expected impact on fishing revenue. The rationale is that the presence of Asian carp would increase competition for food resources with young and mature native species. Asian carp would reduce the plankton, zooplankton and prey species available for commercially harvested fish species. Prey species would be impacted through direct consumption by Asian carp as well as decreased food availability for themselves. Less food availability would adversely affect commercially targeted fish populations, 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.

An analysis of harvest data for the year 2011 shows that 12,141 tonnes were harvested from the Great Lakes that year, generating a total landed value of $33.6 million (see Annex 4). Of the total harvest, Lake Erie accounted for 81.5% (9,894 tonnes), followed by Lake Huron with 13.9% (1,691 tonnes), Lake Superior with 2.9% (354 tonnes) and Lake Ontario[89] with 1.7% (203

[89] 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/2ColumnSubPage/STEL02_173913.html#Aboriginal_Fishing).

tonnes). The major species harvested were perch (34.5%), rainbow smelt (22.1%), walleye (17.3%), lake whitefish (13.6%) and white bass (6.8%).

The current current study estimated that in 2018, the total present (market) value of the catches from Lakes Erie, Huron, Ontario, and Superior for the subsequent 20-year time period (2018 to 2038) would be $4.8 billion, based on inflation-adjusted market value. Of that total, Lake Erie accounted for 82.7% ($3.9 billion) followed by Lake Huron with 14.2% ($0.7 billion), Lake Superior with 1.7% ($82.4 million) and Lake Ontario with 1.4% ($65.0 million).

The current study also estimated that in 2018, the total present value of the catches from Lakes Erie, Huron, Ontario, and Superior for the subsequent 50-year time period (2018 to 2068) would be $10.3 billion, based on inflation-adjusted market value. Of that total, Lake Erie accounted for $8.6 billion, followed by Lake Huron with $1.5 billion, Lake Superior with $0.2 billion and Lake Ontario with $0.1 billion.

In terms of commercially harvested native fish species and based on observations of present Asian carp migration rates, it appears that Asian carp would be in direct competition with yellow perch and white bass, and that the same type of competitive interaction would occur to a lesser degree with whitefish, through benthic food (e.g. zooplankton) unavailability. Walleye, which has limited and variable reproduction, would be indirectly affected by the alterations in the food chain. Species of less commercial value, such as white sucker, rainbow smelt and northern pike, would likely be negatively affected by Asian carp through competition for food, and would decline. Degradation of water quality caused by Asian carp would also be a source of damage to populations of native fish species.

In order to estimate the impact of an arrival of Asian carp in the Great Lakes, the study applied the analyses for ecological consequences reported in DFO (2012) to the landings and market values for the time periods covered, and assumed that the ecological impact would similarly be transmuted to the species' populations and landings. In addition, the study assumed the absence of any additional measures to prevent the presence of Asian carp from the Great Lakes basin. Based on the foregoing, the study anticipated that the commercial fishing industry in Lakes Erie, Huron and Ontario, which accounted for $4.7 billion of the total net present value of $4.8 billion (98.6% of total), would be *moderately* affected with high to moderate uncertainty in 20 years starting 2018.[90] Only commercial fishing in Lake Superior, which accounted for $65 million of the total (1.4% of total), is anticipated to have *low* impact with high to moderate uncertainty.

Table 8: Estimated Present Values ($000) of Market Values in Commercial Fishing in 20 and 50 Years by Lake

Variables	Superior	Huron	Erie	Ontario	Total
20 Years	$64,998	$672,238	$3,929,996	$82,443	**$4,749,676**
50 Years	$141,544	$1,463,91 7	$8,558,253	$179,535	**$10,343,248**

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

90 Uncertainties are determined based on the certainties reported in DFO (2012) and the assumption made in Chapter 3 that the uncertainties associated with the socio-economic assessment must be greater than or equal to those of ecological risk assessment.

Table 8 shows that for the fifty year interval ending in 2068, the impact on the commercial fishing industry in Lakes Erie, Huron and Ontario, (which accounted for $10.2 billion of the total net present value of $10.3 billion (98.6%)), would be *high*, with moderate to high uncertainty. Only commercial fishing in Lake Superior, which accounted for $142 million of the total (1.4%), would be *moderately* affected, with moderate to high uncertainty.

The extent of the impact on commercial fishing by Great Lake is also related to the size and the depth of the lake. 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 Asian carp and native fish species.[91] 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 Asian carp could render commercial fishing operations unsustainable, abolishing the commercial fishing industry from Lake Erie (which accounted for 81.5% of the catches in 2011), and subsequently from the entire Great Lakes.

As the commercially harvested fish species are impacted by the presence of Asian carp in the 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 2011; together these species represented 75.7% of the total freshwater export.[92] In 2011, Ontario exported 14,682 tonnes of freshwater fish product that yielded a total export value of $89.0 million.[93] Exports of freshwater species from the Great Lakes, particularly whitefish, pickerel, mullet and pike, face competition from harvests elsewhere in Canada, international competitors and other related products.

The impact of Asian 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/complementary 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 products to favourably priced substitute products (e.g. 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.

An increased abundance of Asian carp could create income-generating opportunities, which

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

[92] http://www.dfo-mpo.gc.ca/stats/trade-commerce/can/export/export-eng.htm.

[93] Landings from Lake Huron are sold primarily in the US and Ontario markets. Landings from Lake Superior are shipped mainly to the US and Europe. Lake Ontario supports a locally important commercial fish industry (http://www.mnr.gov.on.ca/en/Business/GreatLakes/2ColumnSubPage/STEL02_173913.html#Aboriginal_Fishing).

might partially offset loss due to the reduced abundance of commercially harvested native fish species. So far, however, the commercial value of Asian carp has been quite low and much less than the native fish they would replace.[94]

The impacts discussed above are anticipated to be, by and large, proportional to the ecological consequences reported in DFO (2012) and Cudmore et al. (2012). It is also noteworthy that given the immense size of the Great Lakes and its complex ecosystems and food webs, a proper forecast on the magnitude of Asian carp impact, as well as the timeline for that impact to emerge on native fish abundance, is quite challenging.[95] For example, if the actual rate of arrival/migration differs from the predicted rate in DFO (2012) and Cudmore et al. (2012), both magnitude and realization of impact time will differ markedly.

Recreational Fishing

In order to estimate the impact of Asian carp presence on recreational fishing in the Great Lakes basin, it was necessary to determine how angler days would be reduced due to a deterioration of angler day quality. Based on the results reported in DFO (2012) and Cudmore et al. (2012), the presence of Asian carp in the Great Lakes Basin would damage recreational fishing activities as follows:

As shown in the flow chart, the rationale is that if catch rates were reduced by decrease in fish populations, demand for trips would likely decrease proportionally, 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.

The anglers in the Great Lakes are made up of (i) Canadian residents of Ontario; (ii) Canadians non-resident to Ontario; and (iii) foreign anglers visiting Canada. DFO (2008) found that in 2005, 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).[96]

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[94] Supra note 89.
[95] Supra note 89.
[96] 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).

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

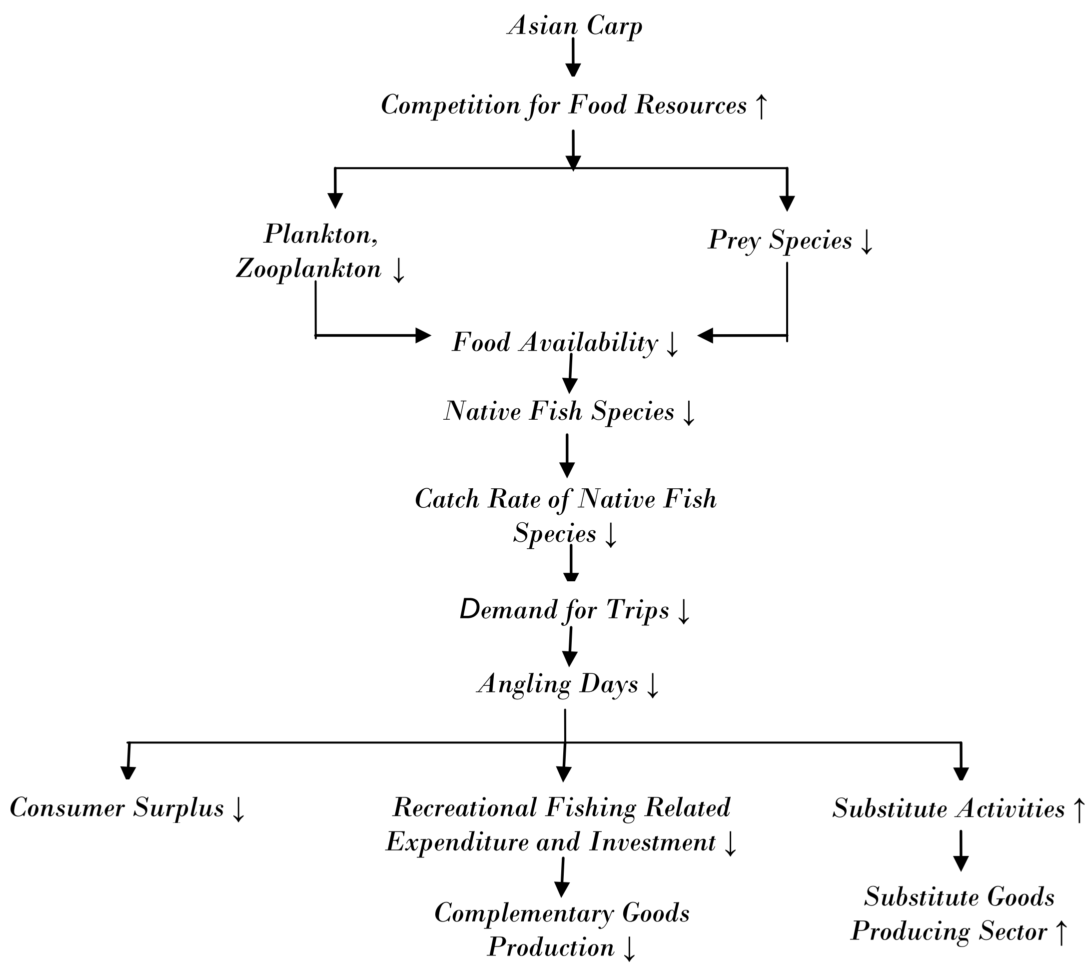

Table 9: Major Purchases/Investments and Direct Expenditures ($000) by Type of Anglers and Lake, 2005

Variables	Lake Ontario	Lake Erie	Lake St. Clair	Lake Huron	Lake Superior	St. Lawrence River	Great Lakes System
Major Purchases/Investments	**$47.97**	**$50.76**	**$14.17**	**$69.19**	**$10.29**	**$36.01**	**$228,394**
Resident Angler	$47,430	$45,924	$14,125	$62,093	$7,521	$35,752	$212,846
Non-Resident Angler	$123	-	$20	$2	-	$2	$147
Foreign Angler	$417	$4,840	$25	$7,095	$2,772	$252	$15,401
Direct Expenditures	**$44.93**	**$33.37**	**$13.91**	**$92.13**	**$17.06**	**$13.21**	**$214,607**
Resident Angler	$39,226	$29,368	$8,157	$69,685	$9,108	$7,707	$163,251
Non-Resident Angler	$1,396	$2	$1	$357	$42	$276	$2,075
Foreign Angler	$4,305	$4,001	$5,751	$22,087	$7,912	$5,225	$49,281
Grand Total	**$93**	**$84**	**$28**	**$161**	**$27**	**$49**	**$443,000**

Source: DFO (2008).

For Canadian economy, if recreational fishing on the Great Lakes is impacted, there is an impact on resident and non-resident Canadian anglers' expenditures and consumer surplus, and foreign expenditure that is associated with Great Lakes recreational fishing. As stated before, the argument here is that the non-resident, non-Canadian (foreign) consumer surplus is not a benefit to Canada, 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 in the Canadian Great Lakes region.[97]

The study estimated that in 2018, based on inflation-adjusted values for the subsequent 20-year time period, the total present value of the recreational expenditures and consumer surplus (excluding foreign consumer surplus) at Lakes Erie, Huron, Ontario, Superior, St. Clair and St. Lawrence would be approximately $11.8 billion (see Table 10). Of the total, Lake Huron accounted for $4.4 billion (37%), followed by Lake Erie (including St. Clair) with $3.0 billion (25%), Lake Ontario with $2.5 billion (21.0%), St. Lawrence with $1.3 billion (10.7%), and Lake Superior with $0.7 billion (6.0%).

Table 10: Estimated Present Values ($Mil.) of Recreational Fishing Expenditures and Consumer Surplus in 20 and 50 Years by Lake

Variables	Superior	Huron	Erie & St. Clair	Ontario	St. Lawrence	Total
20 Years	**$702**	**$4,345**	**$2,949**	**$2,493**	**$1,262**	**$11,751**
Domestic Con. Surplus	$57	$543	$305	$304	$102	$1,311
Domestic Expenditure	$393	$3,114	$2,300	$2,078	$1,031	$8,916
Foreign Expenditure	$252	$688	$344	$111	$129	$1,524
50 Years	**$1,528**	**$9,462**	**$6,422**	**$5,429**	**$2,749**	**$25,590**
Domestic Con. Surplus	$124	$1,183	$663	$661	$223	$2,854
Domestic Expenditure	$856	$6,781	$5,009	$4,525	$2,245	$19,416
Foreign Expenditure	$548	$1,498	$750	$242	$281	$3,320

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

As shown in Table 10, the study calculated that in 2018, based on inflation-adjusted market value for the subsequent 50-year time period, the total present value of the recreational expenditures and consumer surplus (excluding foreign consumer surplus) would be $25.6 billion. Of that total, Lake Huron accounted for $9.5 billion, followed by Lake Erie (including St. Clair) ($6.4 billion), Lake Ontario ($5.4 billion), St. Lawrence ($2.8 billion) and Lake Superior ($1.5 billion).

In terms of species caught in recreational fishing, 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%) [100] (see Annex 5).

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[97] It may be argued that there will still be some foreign expenditures associated with fishing at alternative sites and/or on alternative activities in Canada, as there are some close substitutes. However, for this analysis, the Canadian expenditure and consumer surplus, and foreigners' expenditure will be considered as benefits which would partially be impacted if angling is impacted.

[98] Smallmouth, largemouth and rock bass.

[99] Rainbow, brown, brook and lake trout.

In the absence of additional measures to prevent the presence of Asian carp to minimize the damages to the recreational fishing activities in the Great Lakes basin, the study anticipated that in 20 years starting in 2018, resident and non-resident Canadian anglers' expenditure and consumer surplus, and foreign expenditure associated with recreational fishing in Lakes Erie, Huron and Ontario would be *moderately* affected, with moderate to high uncertainty.[101] For Lake Superior the impact would be *low*, with moderate to high uncertainty.

Employing a 50 year horizon starting in 2018, the impact on resident and non-resident Canadian angler consumer surplus and foreign expenditure associated with recreational fishing in Lakes Erie, Huron and Ontario would be *high*, with moderate to high uncertainty. Lake Superior would be *moderately* affected, with moderate to high uncertainty.

As stated earlier, it is expected that damage to recreationally harvested fish species caused by the presence of Asian carp in the Great Lakes basin would be followed by some relocation of expenditures of resident and non-resident Canadians to other sectors in the economy.[102] With moderate to high uncertainty, the study estimated that over 20 years and 50 years starting 2018, the present value of the relocation of expenses by Canadians from Lakes Erie, Huron, Ontario and Superior would be in the amount of $7.9 billion and $17.2 billion, respectively.[103]

In addition to damage from ecological consequences found in DFO (2012) and Cudmore et al. (2012), the presence of Asian carp might discourage recreational fishing through direct harm to people. Silver carp is reported to startle easily at the sound of a boat motor, leading them to leap out of the water and land in boats, and thereby damage property and injure boaters. They are reported to break fishing rods, windshields and other equipment in a boat. Furthermore, once they land in the boat, they leave slime, blood and excrement.

The jumping behavior of Asian carp might not only discourage people from fishing, but also result in a transfer of wealth from boat owners to service providers operating in the Great Lakes region. While Asian carp might raise the operational and maintenance costs of boat owners (e.g. installing protective equipment), the study recognizes that the additional costs borne on boat owners would be a mere transfer of resources from boat owners to those service providers.[104]

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 also 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 economic impact to those whose livelihood

[100] For a discussion on the impact of the presence of Asian carp on native species, as reported in DFO (2012) and Cudmore et al. (2012), see commercial fisheries sub-section which is suitably applies here because of the similarity in the species caught.

[101] Supra note 88.

[102] For example, if recreational fishing is unavailable, people's recreational activities may shift to other areas such as hiking.

[103] Excluding St. Lawrence.

[104] Though there is no information on the estimated increase in operational and maintenance costs that is specific to Asian carp invasion, Vilaplana and Hushak (1994) estimated that zebra mussels caused boat owners in Ohio's Lake Erie region additional expenses for protective paints (average cost of $154 per year) and maintenance costs (approximately $280 per year) totaling $434/boat/year.

depends on the development of this sector. The impacts on such subsidiary activities are anticipated to be notable, but are not quantified due to insufficient information.

Recreational Boating

Great Lakes boaters, water-skiers, and others who go out on the water for pleasure will be adversely affected by the presence of Asian carp through the hazards the fish present to boaters (e.g. injury to boaters), as described earlier in this study in the recreational fishing section, and by reduced opportunities for water sports, pleasure boating and sailing. Moreover, like recreational fishing, recreational boating in the Great Lakes will be impacted through higher operational and maintenance costs associated with boating in waters where Asian carp have become established.

Table 11: Projected Present Values ($000) of Recreational Boating Expenditures and Consumer Surplus in 20 and 50 Years

Variables	Boating Expenses	Tourism	Consumer Surplus	Total
20 Years	$108,982,348	$37,696,090	$6,234,075	$152,912,513
50 Years	$237,328,071	$82,089,811	$13,575,786	$332,993,668

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

The study estimated that the present value of boaters' consumer surplus and foreign expenditure associated with recreational boating in the Great Lakes basin was in the amounts of $43.9 billion and $95.7 billion, in 20 years and 50 years, respectively, starting in 2018 (see Table 11). In the absence of additional measures to prevent the presence of Asian carp to minimize the damages to the recreational boating activities in the Great Lakes basin, boaters' consumer surplus and foreign expenditure associated with recreational boating in the Great Lakes would be jeopardized to an extent relative to the scope of the jumping behavior of silver carp.[105]

Similar to recreational fishing, it is anticipated that there would be some relocation of expenses by resident/non-resident Canadians to other sectors due to the expected damage to recreationally boating and related activities.[106] The study estimated that the present value of the expenses for boating by Canadians in the Great Lakes was $109.0 billion and $237.3 billion, in 20 years and 50 years respectively, starting in 2018, and that this value would be relocated to some extent relative to the scope of the jumping behavior of silver carp.

[105] Unlike commercial and recreational fishing, since recreational boating is not linked to ecological consequences found in DFO (2012) and Cudmore et al. (2012), the impact and (un)certainty analyses could not be derived more precisely without additional information on impact related to recreational boating.
[106] For example, if recreational boating is unavailable, people's recreational activities may shift to other areas such as hiking.

Wildlife Viewing

Since Asian carp consume cladophora,[107] they may cause Cladophora mats in the Great Lakes basin to expand, particularly around the near-shore areas.[108] Decomposing Cladophora provides a breeding ground for enteric bacteria, including some pathogens which can produce dangerous toxins. Using traditional microbiological and DNA-based techniques, studies found that cladophora provided suitable habitat for indicator bacteria, and potentially for pathogens, to persist and grow. This may in turn impact beach water quality (GLSC Fact Sheet 2009).

Despite the Great Lakes clean-ups in the 1970s, there has been a resurgence of cladophora in the Great Lakes in recent years for a variety of reasons (e.g. zebra and quagga mussels, agricultural operations, sewage). Mass cladophora accumulations along shorelines have been documented to affect recreational activities (e.g. wildlife viewing), potentially influencing water quality, and causing significant health and economic concerns (GLSC Fact Sheet 2009). The presence of Asian carp will enhance cladophora build-up capacity in the Great Lakes, increase cladophora-related problems, pose increased health risk to Great Lakes users, and contribute to a decreased level of wildlife viewing activities around the Great Lakes basin.

The study estimated that the present values of resident wildlife viewers' consumer surplus associated with wildlife viewing in the Great Lakes basin are in the amounts of $1.1 billion and $2.4 billion in 20 years and 50 years, respectively, starting in 2018 (see Table 12).

Table 12: Estimated Present Values ($000) of Wildlife Viewing Expenditures and Consumer Surplus in 20 and 50 Years

Variables	Viewing Expenses	Tourism	Consumer Surplus	Total
20 Years	$3,453,391	NA	$1,108,425	$4,561,816
50 Years	$7,520,362	NA	$2,413,789	$9,934,151

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

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

Similar to recreational fishing/boating, 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.[109] The study estimated that the present values of the expenses for viewing by resident Canadians in the Great Lakes were $3.5 billion and $7.5 billion

[107] A green alga that grows attached to hard substrates (rocks and boulders) and the lake bottom.
[108] Centre of Expertise for Aquatic Risk Assessment Team, Great Lakes Laboratory for Fisheries and Aquatic Sciences, DFO, personal communication, June 4, 2012.
[109] For example, if recreational boating is unavailable, people's recreational activities may shift to other areas such as hiking.

in 20 years and 50 years, respectively, starting in 2018, and that these values would be relocated relative to the extent of the problems caused by the presence of Asian carp.[110]

Beaches and Lakefront Use

The impact the presence of Asian carp would present to beach and lakefront use can be linked to the increased accumulation of cladophora mats.[111]

Similar to recreational fishing, boating and wildlife viewing, 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 Asian carp would cause.[112] The study estimated that the present values of the expenses for beach use in the Great Lakes were $5.2 billion and $11.3 billion in 20 years and 50 years, respectively, starting in 2018, and that these values would be relocated relative to the extent of the problems caused by the presence of Asian carp.[113]

Other Sectors

As stated above, based on DFO (2012), Cudmore et al. (2012) and subsequent discussions with scientists, the study found that Asian carp would likely have either negligible or no impact on recreational hunting,[114] water use, commercial navigation, and oil and natural gas extraction activities.

Ecosystem Services

The variability in ecosystem services might increase upon the presence of Asian carp. As firms/households generally prefer to avoid risk or to be compensated for the changes which might be seen as an additional impact of the presence of Asian carp.[115]

Social and Cultural Impact

Over time, the presence of Asian carp to the Great Lakes basin could change lake ecosystems

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[110] Expenditures related to non-residents of the studied regions and tourism is not available. Therefore, the impact and (re)distribution effects may be considered conservative estimates.
[111] The mechanism has been discussed in details in wildlife viewing sub-section.
[112] Supra note 106.
[113] Expenditures related to tourism and consumer surplus generated by these activities were not available. Therefore, the potential net impact could not be discussed further.
[114] Although DFO (2012) and Cudmore et al. (2012) found that the presence of Asian carp would have no impact on recreational hunting (waterfowl), the presence of grass carp (which was not covered in DFO (2012) and Cudmore et al. (2012)) has been documented to be detrimental to waterfowl habitat because of their destructive nature on wetland plants (Dibble and Kovalenko, 2009) and to have put waterfowl production areas at risk. Reductions of waterfowl populations in turn decrease hunting opportunities and associated economic impacts from hunting expenditures.
[115] Wittmann et al., University of Notre Dame, personal communication, December 15, 2012.

from ones dominated by native fish species to ecosystems dominated by carp, and has the potential to damage the public image of these lakes regionally, nationally and internationally. It would also harm the well-being of residents living close to such a unique natural resource.

Despite that Asian carp may present an opportunity for subsistence harvests and harvesters are adaptive to changing environment, Asian 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. 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; and (ii) gaining access to subsistence fishing 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. Finally, the presence of Asian carp may also encourage the increased level of (i) competition among subsistence harvesters/communities for fewer native fish species; and (ii) conflict and competition with recreational and commercial harvesters if changes causes fewer species availability. Quantitative assessments of these impacts are not feasible due to a lack of pertinent information.

Chapter 8: Conclusion

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

While additional secondary source information was used, the report heavily relied on the bi-national (Canada -US) ecological risk assessment to describe the Asian carp threat to the Great Lakes led by CEARA, DFO. The ecological risk assessment report, including the supplementary reports, provided a solid and defensible foundation for assessing the socio-economic impacts that would result from the presence of Asian carp in the Great Lakes basin.

The study estimated that the value of economic contributions of activities in and around the Great Lakes basin that are closely linked to the lakes themselves to the Canadian economy is in the amount of $13.8 billion dollars. Of that total, expenditures made as well as imputed values/prices for the activities in and around the Great Lakes comprised $13.4 billion (96.9%), while consumer surplus constituted the remaining $0.4 billion (3.1%).

The study recognized that the Great Lakes basin provides invaluable services to society through maintaining ecosystem health and biodiversity. The intrinsic values of ecosystem health and biodiversity are, however, hard to define, because they are much more intangible than other benefits, such as commercial fish harvesting (Krantzberg et al., 2008, 2006). The study found a similar challenge in quantitatively capturing the benefits of option and non-use values based on the existing set of information. 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 the economy 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.

The study estimated that, starting in 2018, the total present (economic) values of the activities (commercial fishing, recreational fishing, recreational boating, wildlife viewing, and the beaches and lakefront use) in 20 years and 50 years were $179 billion and $390 billion, respectively, which may be affected due to the presence of Asian carp in the Great Lakes basin (see Table 13 and Annex 6 for Heat-Maps on risk and uncertainties[116]).

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

Table 13: Estimated Present Values (billion) of Affected Activities in the Great Lakes in 20 and 50 Years by Activity

List of Activities	Base Year (Mil.)	20 Years (Bil.)	50 Years (Bil.)
Commercial Fishing	$227	$5	$10
Recreational Fishing	$560	$12	$26
Recreational Boating	$7,291	$153	$333
Wildlife Viewing	$218	$5	$10
Beaches and Lakefront Use	$248	$5	$11
Total	**$8,544**	**$179**	**$390**

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

Moreover, the study found that Asian carp would likely have either negligible or no impact on recreational hunting, water use, commercial navigation, and oil and natural gas extraction activities.

Finally, 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 Asian 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.

As discussed in Chapter 4, the estimations of the economic contributions of the Great Lakes discussed in this report 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' opinions.

It was also noted that the baseline values generated by activities in and around the Great Lakes basin should not be directly compared with those provided in the extant literature, because of differences in methodology followed by different studies. Methodologies varied in terms of scope, estimation procedures, time periods considered, and industries covered. Variances in estimations have also arisen due to considerations of whether to include both Canada and the US, and secondary multiplier effects (indirect and induced) in appraising the baseline values as well as the impacts.

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:

i. Lack of Great Lakes specific information by activity;

ii. The values by activity predicted in 20 and 50 years are based on the values by activity for the most recent year assuming that the values will prevail for the time period covered if everything else is remaining the same. In reality economic conditions or values (e.g. commercial fishing, recreational fishing) may change rapidly over time. Moreover, the presence of overlaps in some activities (e.g. recreational fishing and recreational boating) and/or complementarity and substitutability of goods/activities, predictions based on such specific (equilibrium) conditions may inflict upward and/or downward biases.

iii. Lack of a more explicit linkage between the ecological consequences proposed in DFO (2012) and the socio-economic factors proposed in the current document. The study assumed linearity between ecological and socio-economic impact and uncertainty and drew conclusions based on the present values of the activities and cited the verbal ranking of the results from DFO (2012). A revision of the study based on a quantitative scale of ecological consequence that could be linked to socio-economic consequences would provide a more accurate socio-economic impact assessment in a quantitative 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 impact of the presence of Asian carp.

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), 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 Computable 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.

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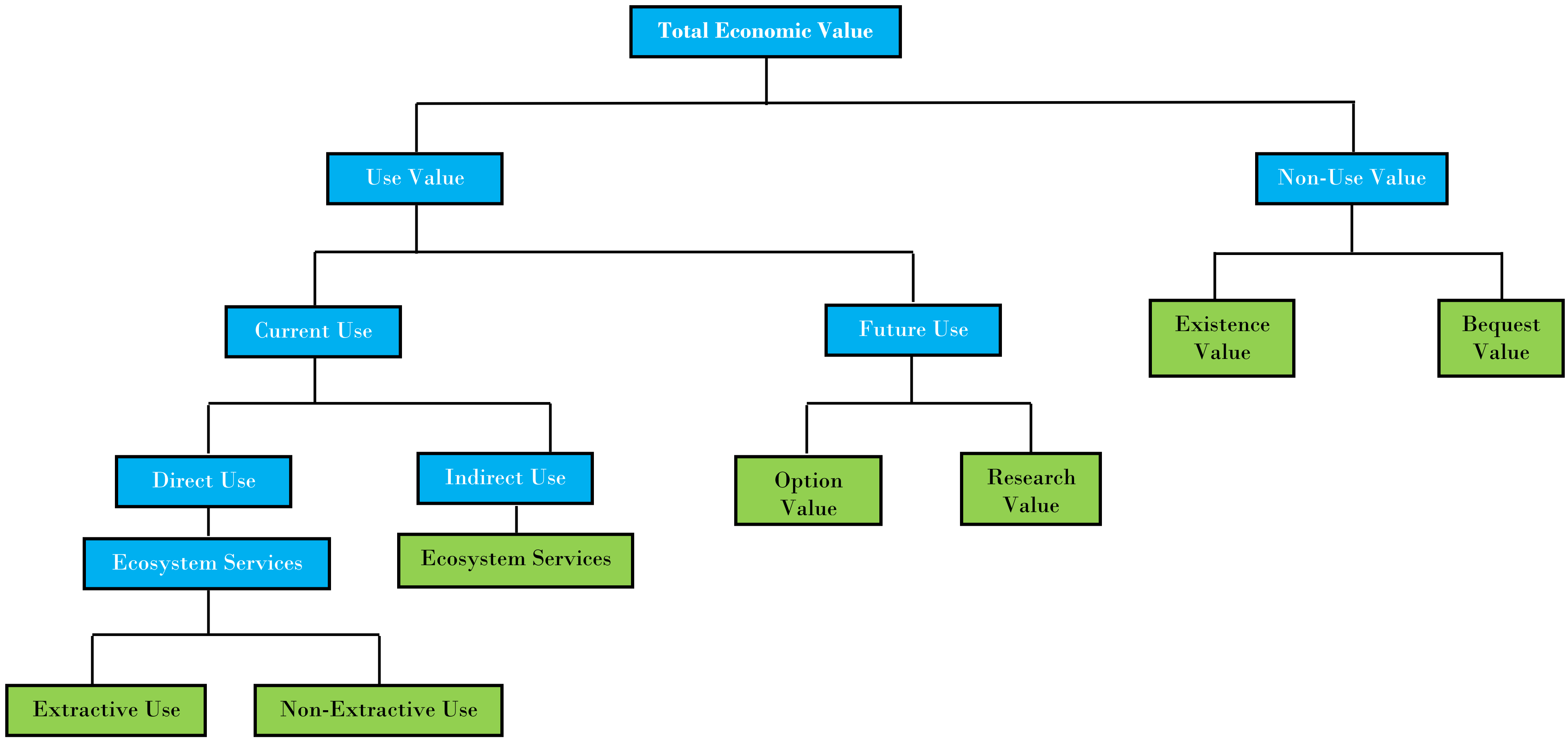
Matrix 1: Total Economic Valuation Flowchart



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). [117]

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.

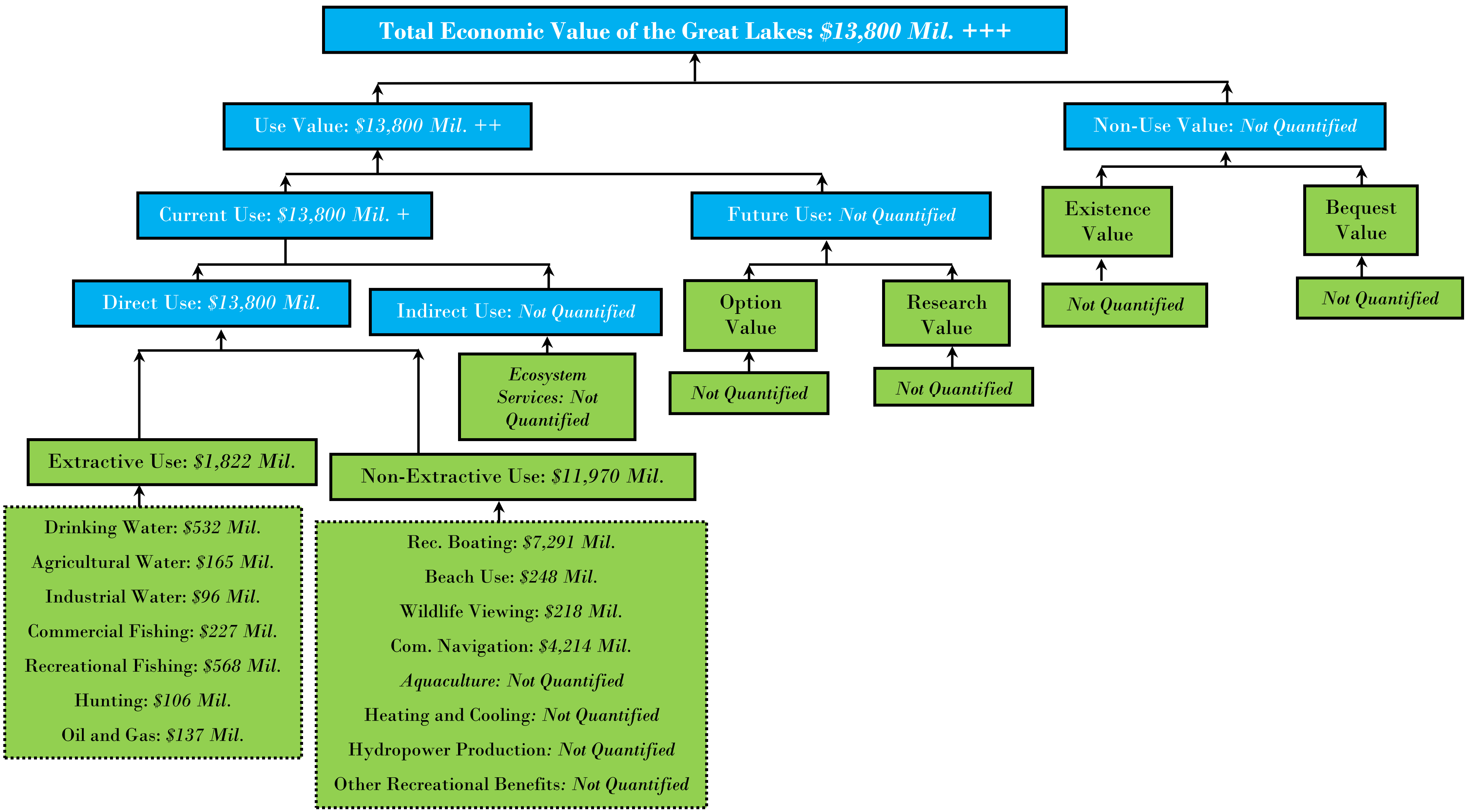
Bequest value: Conservation for future generations (e.g. future biodiversity). Bequest value takes into account people's WTP for future total use by their children and future generations.

[117] 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.[118]

[118] 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: The Great Lakes - Total Economic Valuation Flowchart



Matrix 3: 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
Raw water use				
The Great Lakes Commission (2010)	2008 the US by State and Canada by Province and Lake	Water use database	Ontario's annual water consumption was 180 million m^3. In Quebec, total consumptive use was 161.7 million m^3.	2000 data was used for Ontario and 1993 data was used for Quebec due to data unavailability and assumed that water use estimates for 2006 are not anticipated to be greatly different than those reported assuming a similar data collection and assessment approach.
Statistics Canada (2009) cited in Marbek (2010)	2007 - Great Lakes basin	Survey	Ontario - The operating and maintenance costs of treating 180.5 million cubic metres of raw intake water from the Great Lakes basin was approximately $260 million.	Underestimation of economic valuation as it excludes consumer surplus. Adjustment has been made for inflation.
Industrial Water				
The Great Lakes Commission (2010)	2008 the US by State and Canada by Province	Water use database	Ontario's industrial users consumed 80.4 million m^3 of water from the Great Lakes each year. In Quebec, total consumptive use was 17.3 million m^3.	See notes for The Great Lakes Commission (2010)
Dachraoui and Harchaoui (2004)	1981-1996 – Canadian business sector industries	Seemingly unrelated regression techniques on data from EKLEMS database maintained by Statistics Canada	The shadow price of water intake - $0.73/$m^3$. The introduction of water recirculation reduces the shadow price estimate to $0.55 cubic metre.	Adjustment has been made for inflation.

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
Agricultural water use				
The Great Lakes Commission (2010)	2008 the US by State and Canada by jurisdiction	Water use database	Ontario's annual water consumption was 120 million m^3. In Quebec, total consumptive use was 33 million m^3.	See notes for The Great Lakes Commission (2010)
To (2006) cited in Marbek (2010)	2000-2004	Average market crop price	The loss in profitability in the short-term due to a decrease in water, assuming fixed costs, ranged from $3.79/$m^3$ for ginseng, to 0.22/m^3 for sweet corn.	Stated many challenges with this simple method of calculating the value of water and various data gaps and therefore, should be seen as a first approximation.
Commercial Fishing				
Ontario Ministry of Natural Resources website (2010)	2008 - Great Lakes Basin		Value of commercial fishing after processing was in 2008 was in the range of $180 - $215 million.	Underestimation of economic valuation as it excludes consumer surplus.
Recreational Fishing				
DFO (2008)	2005 – Great Lakes Basin	Recreational Fishing Survey on 16,000 households within Canada and in other countries	The total direct expenditures and major purchases/investment of $443.0 million in recreational fishing in the Great Lakes based on travel costs and expenditures for fishing trips.	Adjustment has been made by scaling down as well as adjusting for inflation.
Recreational Hunting				
EC (2000)	1996 – Canada by jurisdiction	Survey among a sample of approximately 87,000 Canadians	Residents of Ontario spent $200.6 million and residents of Quebec spent $285.6 million	As no specific estimate was provided for the Great Lakes basin, adjustment has been made by scaling down as well as adjusting for inflation.

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
Recreational Boating				
Genesis Public Opinion Research Inc. (2007)	2006 – Canada by jurisdiction	Online surveys and publicly available data from Industry Canada	The total expenditures (direct and indirect) in Ontario was $7.3 billion.	As no specific estimate was provided for the Great Lakes basin, adjustment has been made by scaling down as well as adjusting for inflation.
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 for Canadian Great Lakes beachgoers was in the range of $200 - $250 million	Adjustment has been made for inflation.
Wildlife Viewing				
EC (2000)	1996 – Canada by jurisdiction	Survey among a sample of approximately 87,000 Canadians	Ontario residents spent $410.9 million and Quebec residents spent $281.0 million	As no specific estimate was provided for the Great Lakes basin, adjustment has been made by scaling down as well as adjusting for inflation.
Commercial Navigation				
The Canadian Shipowners Association website (2011)	The Great Lakes, St. Lawrence Waterway		The estimated annual economic contribution of $4 billion (direct and indirect impact) from cargo handling, vessel services, and inland transportation services on this integrated waterway system in Canada.	
Oil and Gas				
Ontario Ministry of Natural Resources website (2012)	2009 – the Great Lakes		88,000 cubic meters of crude oil with a wellhead value of $50 million and 240 million cubic meters of natural gas with retail value of $80 million was produced.	Adjustment has been made by scaling down as well as adjusting for inflation.

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
General – Consumer Surplus				
EC (2000)	1996 – Canada by jurisdiction	Survey among a sample of approximately 87,000 Canadians		As no specific estimate was provided for the Great Lakes basin, adjustment has been made by scaling down as well as adjusting for inflation.

Annex 1: Selected Socio-Economic Indicators for Ontario

Characteristics	Ontario	Canada
Total population	12,160,285	31,612,895
Male	*5,877,875*	*15,326,265*
Female	*6,151,020*	*15,914,765*
Population density per square kilometre	13.40	3.51
Land area (square km)	907,574	9,017,699
Median age of the population	39	40
% of the population aged 15 and over	82	82
Aboriginal identity population	242,490	1,172,785
Male	*117,585*	*572,095*
Female	*124,900*	*600,695*
Total population 15 years and over	9,819,420	25,664,220
No certificate; diploma or degree	*2,183,625*	*6,098,325*
High school certificate or equivalent	*2,628,575*	*6,553,425*
University certificate or diploma below the bachelor level	*405,270*	*1,136,145*
University certificate; diploma or degree	*2,012,060*	*4,655,770*
In the labour force	6,587,580	17,146,135
Employed	*6,164,245*	*16,021,180*
Unemployed	*423,335*	*1,124,955*
Employment rate	*94%*	*93%*
Unemployment rate	*6%*	*7%*
Total experienced labour force 15 years and over	6,473,730	16,861,180
Agriculture and other resource-based industries	*190,000*	*895,415*
Construction	*384,775*	*1,069,095*
Manufacturing	*899,670*	*2,005,980*
Retail trade	*720,235*	*1,917,170*
Finance and real estate	*442,610*	*992,720*
Business services	*1,274,345*	*3,103,195*
Other services	*1,209,390*	*3,271,505*
Persons 15 years and over with earnings (counts)	6,991,670	18,201,265
Median earnings - Persons 15 years and over ($)	*29,335*	*26,850*
Median earnings - Persons 15 years and over who worked full year; full time ($)	*$44,748*	*$41,401*

Source: Statistics Canada. 2007. 2006 Community Profiles. 2006 Census.

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

Provinces/Territories	Total population	Aboriginal Population*	North American Indian	Métis	Inuit	Non-aboriginal identity population
Population by Ethnicity						
Ontario	12,028,895	242,495	158,395	73,605	2,035	11,786,405
Canada	31,241,030	1,172,785	698,025	389,780	50,480	30,068,240
Male by Ethnicity						
Ontario	5,877,875	117,585	75,955	37,025	940	5,760,285
Canada	15,326,270	572,095	338,050	193,500	25,025	14,754,175
Female Age by Ethnicity						
Ontario	6,151,020	124,900	82,440	36,580	1,095	6,026,115
Canada	15,914,760	600,695	359,975	196,285	25,460	15,314,065
Median Age by Ethnicity						
Ontario	38.7	29.7	27.9	32.8	21.2	38.9
Canada	39.2	26.5	24.9	29.5	21.5	39.7
Total population 15 years and over						
Ontario	9,819,420	178,170	111,925	58,180	1,345	9,641,255
Canada	25,664,225	823,885	473,235	291,330	32,775	24,840,335

Sources: Statistics Canada; Censuses of Population; 2006.

*Note: * The total Aboriginal identity population includes the Aboriginal groups (North American Indian, Métis and Inuit).*

Annex 3: Estimated Water Consumption and Values by Sector, Lake and Province for the Year 2008

Name of the Lake	Raw Water Use			Agricultural Sector			Industry	Total
	Public Sector	Self-Supply Domestic	Total	Livestock	Irrigation	Total		
Quantity (Mil. M^3/Year)								
Ontario	**158.1**	**22.4**	**180.5**	**40.7**	**78.9**	**119.6**	**80.36**	**380.45**
St. Lawrence	15.1	2.4	17.5	6.5	2.5	9.1	14.00	40.58
Lake Ontario	96.6	13.3	109.9	6.0	19.1	25.1	19.99	154.94
Lake Erie	19.5	4.1	23.6	14.6	34.3	48.9	15.71	88.23
Lake Huron	17.5	2.2	19.7	13.4	22.5	36.0	16.55	72.18
Lake Superior	9.5	0.4	9.9	0.2	0.4	0.6	14.11	24.51
Quebec	**151.8**	**9.9**	**161.7**	**21.1**	**11.5**	**32.6**	**17.34**	**211.62**
St. Lawrence	151.8	9.9	161.7	21.1	11.5	32.6	17.34	211.62
Grand Total	**310.0**	**32.2**	**342.2**	**61.8**	**90.4**	**152.2**	**97.70**	**592.06**
Value (Mil.)								
Ontario	**$245.7**	**$34.8**	**$280.4**	**$44.9**	**$87.0**	**$131.9**	**$79.3**	**$491.6**
St. Lawrence	$23.5	$3.7	$27.2	$7.2	$2.8	$10.0	$13.8	$51.0
Lake Ontario	$150.0	$20.7	$170.7	$6.6	$21.1	$27.7	$19.7	$218.1
Lake Erie	$30.2	$6.4	$36.6	$16.1	$37.9	$54.0	$15.5	$106.1
Lake Huron	$27.2	$3.4	$30.6	$14.8	$24.9	$39.7	$16.3	$86.6
Lake Superior	$14.7	$0.6	$15.3	$0.2	$0.4	$0.6	$13.9	$29.8
Quebec	**$235.9**	**$15.3**	**$251.2**	**$21.3**	**$11.5**	**$32.8**	**$17.1**	**$301.1**
St. Lawrence	$235.9	$15.3	$251.2	$21.3	$11.5	$32.8	$17.1	$301.1
Grand Total	**$481.6**	**$50.1**	**$531.7**	**$66.1**	**$98.6**	**$164.7**	**$96.4**	**$792.8**

Source: Great Lakes Commission (2011)

Annex 4: Landings and Landed Values of Commercial fisheries in the Great Lakes by Species and Lake in 2011

Species	Erie	Huron	Ontario	Superior	Grand Total
Landings (lbs.)					
Yellow and White Perch	8,639,438	400,888	153,276	1,600	9,195,202
Rainbow Smelt	5,909,710	261	-	1	5,909,972
Walleye	4,417,966	176,516	24,230	811	4,619,523
Lake Whitefish	530,013	2,774,792	78,208	255,714	3,638,727
White Bass	1,823,374	1,243	155	-	1,824,772
Others*	445,358	365,797	189,944	519,934	1,521,033
Total	**21,765,859**	**3,719,497**	**445,812**	**778,061**	**26,709,229**
Landed Values					
Yellow and White Perch	$15,188,370	$887,012	$285,436	$2,416	$16,363,235
Rainbow Smelt	$1,359,120	$73	$0	$0	$1,359,193
Walleye	$9,039,586	$444,159	$57,113	$1,217	$9,542,074
Lake Whitefish	$717,572	$3,223,094	$72,497	$246,538	$4,259,701
White Bass	$1,432,657	$909	$89	$0	$1,433,655
Others*	$36,961	$195,631	$167,512	$209,183	$609,287
Total	**$27,774,266**	**$4,750,877**	**$582,648**	**$459,354**	**$33,567,145**

Source: Ontario Ministry of Natural Resources
*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.*

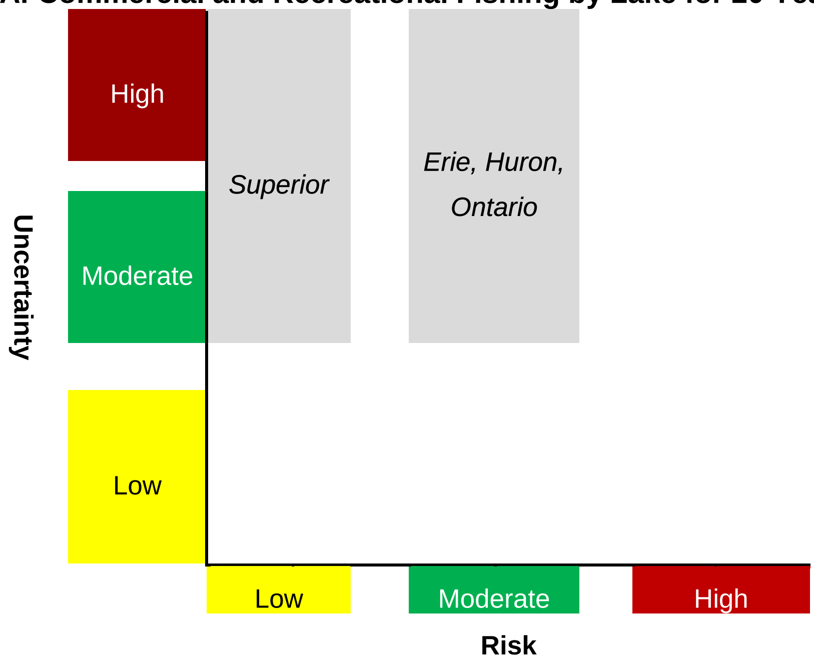
Annex 5: Number of Fish Harvested All Anglers Who Fished on the Great Lakes, by Species and Lake, 2005

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 6: Heat-Map - Commercial and Recreational Fishing for 20 and 50 Years

A: Commercial and Recreational Fishing by Lake for 20 Years



B: Commercial and Recreational Fishing by Lake for 50 Years