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Socio-Economic Risk Assessment of the Presence of Zebra Mussel in Lake Winnipeg, Red River, Nelson River and Cedar Lake

FINAL REPORT

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Introduction

Lake Winnipeg is the the sixth-largest freshwater lake in Canada and 10th largest freshwater lake in the world. Its drainage basin is about 953,000 square km in size (second in size in Canada to the MacKenzie River Basin (Lake Winnipeg Stewardship Board, 2006)) and includes parts of four provinces in Canada (Manitoba, Saskatchewan, Alberta and Ontario) and four states of the United States (US) (Montana, North Dakota, South Dakota and Minnesota).[1] The shoreline of the lake is about 1,750 kilometers long (Lake Winnipeg Quick Facts, Sustainable Development).[2]

Lake Winnipeg's drainage basin is home to more than 7 million people – about 5.5 million in the Canadian portion (including 95% of the residents of the three Prairie Provinces (Clean Environment Commission, 2015) and over 1.5 million in the US portion.[3] More than 23,000 permanent residents live in 30 communities along the shores of Lake Winnipeg, including 11 First Nations communities (Lake Winnipeg Quick Facts, CWS).

Lake Winnipeg provides drinking water and supports wetlands, and a variety of landscapes, plants, fish and wildlife. The lake also provides water for agriculture, factories and industries, and hydroelectric generation. The lake supports world-class commercial and recreational fisheries and recreational activities in Canada, and provides both tangible and intangible benefits to Canadian residents. Lake Winnipeg is a major source of subsistence fishing for most families living in fisheries based communities and plays a central role in preserving the traditional lifestyle of the First Nations peoples (Lake Winnipeg Stewardship Board, 2006).

Lake Winnipeg is facing threats from the increasing number of aquatic invasive species[4] (AIS) that are weakening/threatening the health of the lake, and affecting both activities linked to the lake and the utilities it generates for the economy.[5] Zebra Mussel, AIS from the North American perspective, is well-known to be responsible for significant impacts on native species and associated human activities (e.g. commercial fishing, angling) through ecological damage, habitat alterations and direct competition for resources. While the degree to which lake ecosystems are impacted is highly variable, the impacts of Zebra Mussel have been well documented in lakes across Europe and North America (e.g. Robinson, Knowler, Kyobe & Bueno, 2013; Marbek, 2010a; Thomas, 2010; Ludyanskiy, McDonald & MacNeill, 1993).

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[1] See Annex 1 for the map of the study area.

[2] Several major rivers flow into Lake Winnipeg including the Red (including the Assiniboine) (16%), Winnipeg (50%), and Saskatchewan rivers (25%) (Environment Canada [EC] and Manitoba Water Stewardship [MWS], 2011). Only Nelson River flows out of Lake Winnipeg (Lake Winnipeg Quick Facts, CWS; Lake Winnipeg Stewardship Board, 2006). http://www.gov.mb.ca/waterstewardship/water_quality/lake_winnipeg/facts.html.

[3] About 80% of the population lives in major urban centres including Edmonton, Calgary, Saskatoon, Regina, Brandon, and Winnipeg in Canada, and Grand Forks and Fargo, North Dakota (EC and MWS, 2011; Lake Winnipeg Stewardship Board, 2006).

[4] AIS is defined as organisms not native to a region that when introduced, either intentionally or accidentially, out-compete native species for available resources.

[5] For a list of AIS in Lake Winnipeg, see Chapter 1.

Zebra Mussel are also well known to have negative impact on key infrastructure by colonizing objects immersed in the water such as clogging intake structures in power stations, cottages. They are a costly nuisance to boaters and beach-goers and thereby can reduce recreational potential.

Zebra Mussel was found in several Lake Winnipeg harbours in 2013, and in 2014, additional sources of adult Zebra Mussel was found to be present in Lake Winnipeg. As Lake Winnipeg empties into the Nelson River it is very likely that Zebra Mussel will be introduced and will become established in the Nelson River (Mackie and Claudi, 2010). The threat of Zebra Mussel to Lake Winnipeg has attracted the attention of Canada, the province of Manitoba, First Nations, the general public, tourism-reliant communities, industry associations and environmental non-governmental organizations.

The Government of Canada highly prioritized collaborative initiatives to protect the Lake Winnipeg basin. Fisheries and Oceans Canada (DFO) works collaboratively with key partners and stakeholders, including Sustainable Development department of provincial government, universities and research organizations, to prevent the presence of AIS in Lake Winnipeg. This is largely done through conducting AIS research and development policies in four core themes: early detection; rapid response; AIS as part of multiple stressors; and reducing uncertainty in prediction and management.[6]

As part of the Government of Canada's initiatives, Therriault, Weise, Higgins, Guo, and Duhaime (2013) conducted a risk assessment at the spatial scale of Canadian sub-drainages and found a very high probability of invasion of Zebra Mussel in the Lake Winnipeg, Western Lake Winnipeg and Nelson, Red and Saskatchewan rivers sub-drainages. The present study was conducted 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.

Objectives of the Study

The goal of this study is to provide a socio-economic risk assessment of the presence of Zebra Mussel in Lake Winnipeg, the Red River, Nelson River and Cedar Lake. The specific objectives of the study are to: (i) provide estimates of the economic value generated by Lake Winnipeg, the Red River, Nelson River and Cedar Lake; and (ii) examine the economic risk of the presence of Zebra Mussel in Lake Winnipeg, the Red River, Nelson River and Cedar Lake.

The outcomes of this study will support the AIS objectives under the Department of Fisheries and Oceans' Economically Prosperous Maritime Sectors and Sustainable Aquatic Ecosystems.[7]

[6] DFO has developed *Aquatic Invasive Species Regulations* to manage and control aquatic invasive species in Canada which were published in the *Canada Gazette*, Part II, on June 17th, 2015.
[7] For details, see http://www.dfo-mpo.gc.ca/about-notre-sujet/org/vision-eng.htm.

Organization of the Study

Having the objectives of the study outlined, the remaining part of the study is organized as follows: Chapter 1 presents an overview of the study areas; Chapter 2 presents the methodology adopted; Chapter 3 estimates the baseline values of activities in and around Lake Winnipeg, the Red River, Nelson River and Cedar Lake by sector; Chapter 4 discusses the social and cultural values associated with Lake Winnipeg, the Red River, Nelson River and Cedar Lake ; Chapter 5 discusses the relevant findings of the ecological risk assessment; Chapter 6 estimates the socio-economic impact assessment; and Chapter 7 draws conclusions.

Chapter 1: A Brief Overview of the Study Area

Socio-Demographic Profile

Manitoba has 94,241 square km (6.5%) of its surface area as freshwater.[8] The northern region of the province contains 61% of the province's waterbodies, the north-central region 33.5%, while the southern region accounts for only 5.7% of the waterbodies. About 33% of the entire water area in Manitoba (33,550 km^2) is accounted for by the three major lakes - Lake Winnipeg, Lake Winnipegosis and, Lake Manitoba.

Manitoba has a population of 1.3 million people, which is 3.6% of Canada's total population (see Annex 2). Of the total population in Manitoba, 15.1% (195,900) are of aboriginal identity, as compared to 3.9% for Canada.[9] The median income of persons 15 years and over in Manitoba is $30,371, which is slightly lower than the national average of $31,603.[10]

Business services, health care and social services and retail trade sectors employ most of the total experienced labour force age 15 years and over. In Manitoba, tourism accounted for 2.8% of GDP and employed around 13,500 people annually (Labour Market Bulletin, Manitoba, July 2014 (Quarterly Edition)).

A Brief Overview of Lake Winnipeg[11]

Lake Winnipeg's drainage basin is about 953,000 square km in size and the shoreline of the lake is about 1,750 kilometers long (Lake Winnipeg Quick Facts, CWS). The surface area of Lake Winnipeg is about 23,750 square km and covers about 3.7% of the surface area of the Province of Manitoba. Lake Winnipeg has two distinct basins – the north basin (100 km wide) and south basin (40 km wide) separated by the narrows, which is a 2.5 km wide channel.[12]

Lake Winnipeg's hydrology is dominated by the Winnipeg (contributes roughly 49% of the lake's Water), Saskatchewan (25%), Red (16%), and the Dauphin River (4%). All other rivers (Brokenhead, Berens, Pigeon, Manigotagan, Bloodvein, Poplar, Fisher, Icelandic, etc.) add up to 6% of the total input into the lake.[13] Waters of the Nelson River Drainage Basin pass through Lake Winnipeg and flow out as the Nelson River to Hudson Bay.

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[8] Statistics Canada, 2005, Data Table: Land and freshwater area, by province and territory.
[9] National Household Survey 2011, Data tables: National Household Survey.
[10] Supra note 9.
[11] For a detailed discussion on the importance of the Lake Winnipeg to activities/sectors, see the respective section in the study.
[12] There is another narrows, representing the narrowest point of the lake, which is a 500 metre wide channel between the eastern point of Black Island and the mainland.
[13] The relative contributions of the rivers have changed over time (The Red River's share is higher today than during the early and mid-20th century. The Saskatchewan River's share has declined over this same period).

Approximately 37% of the watershed is classified as cropland, 16% as cropland/woodland mosaic, and 3% as cropland/grassland mosaic. Evergreen, mixed and deciduous forest makes up over 17%, water and wetlands 9%, grassland and shrubland 6%, and built-up areas only about 0.2 percent of the total area (Clean Environment Commission, 2015).

Within the Lake Winnipeg drainage basin, there are nearly 55 million hectares of farmland in the three Prairie Provinces, of which 45 million hectares are in the Canadian portion of the watershed.[14] Although the numbers fluctuate, there are over 10 million cattle and more than 14 million pigs within the Lake Winnipeg watershed, producing approximately 97 million tonnes of manure per year (Clean Environment Commission, 2015).

Although Lake Winnipeg is a shallow lake[15] and therefore has a low volume of water, the lake provides drinking water, supports wetlands, and a variety of landscapes, plants, fish and wildlife. There are many native fish species (e.g. lake whitefish, sauger, walleye, burbot, yellow perch) in Lake Winnipeg that play an important part of the lake's food chain and ecosystem.

There are approximately 52 native fish species in Lake Winnipeg (Lake Winnipeg Implementation Committee, 2005). There are two species presently protected under the Species at Risk Act in Lake Winnipeg. The Mapleleaf Mussel (Saskatchewan-Nelson populations) is listed under the Species at Risk Act as Endangered and are located in Manitoba along the Red River and the lower reaches of its tributaries, the Assiniboine River and Lake Winnipeg and its tributaries (including the Bloodvein, Wanipigow, Brokenhead etc.), and the Bigmouth Buffalo is listed as Special Concern.

Lake Winnipeg is the most valuable fishery of the 300 fishing lakes listed in the commercial harvest schedule.[16] More than 10,000 cottages are located around the south basin of Lake Winnipeg (EC and MWS, 2011), which serves multiple recreational purposes.[17] Lake Winnipeg is the third largest hydro-electric reservoir in the world, and the largest in North America (EC and MWS 2011).

Moreover, the amount of water in the tributaries is not a reflection of the size of their watershed. For example, the Winnipeg River contributes substantially more than the Saskatchewan River but has a smaller watershed. For details, see Clean Environment Commission (2015).

[14] There is an additional 10 million hectares of farmland within the U.S. portion of the lake's watershed (Lake Winnipeg Stewardship Board, 2006).

[15] The lake averages about 12 metres deep. The deepest spot on the lake, at about 60 metres, occurs in a 500 metre-wide channel between the eastern point of Black Island and the mainland in the south basin (Lake Winnipeg Stewardship Board, 2006).

[16] The schedule lists lakes in Manitoba suitable for commercial fishing. The schedule also lists seasons, limits, and conditions applied to commercial harvesters.

[17] Grand Beach Provincial Park alone hosts an average of 20,000 visitors per weekend during the summer months (Labour Market Bulletin, Manitoba, July 2014).

Lake Winnipeg is a major source of subsistence fishing for families living in fisheries based communities and plays a central role in preserving the traditional lifestyle of the Indigenous peoples (Lake Winnipeg Stewardship Board, 2006).

Presence of AIS in Lake Winnipeg: Lake Winnipeg is facing significant threats from an increasing number of AIS.[18] The AIS that are known to occur in Lake Winnipeg are the Common Carp, Rainbow Smelt, White Bass, the cladoceran *Eusbomina coregoni*, Asian tapeworm, Spiny Water Flea and Zebra Mussel.[19]

Zebra Mussel was found in Lake Winnipeg in 2013 and the Red River and Cedar Lake in 2015.[20] Although the early stage of invasion appeared in 2013 to four harbours in the south basin (Arnes/Silver, Gimli, Boundary Creek/Winnipeg Beach, and Balsam Bay), with no evidence of Zebra Mussel at depth within the larger basins, Zebra Mussel was found elsewhere in the south basin in 2014.[21]

[18] Six aquatic invasive species are known to occur in Lake Winnipeg. These are the common carp, rainbow smelt, white bass, the cladoceran Eusbomina coregoni, Asian tapeworm, and spiny water flea (Lake Winnipeg Quick Facts, CWS).

[19] Lake Winnipeg Quick Facts, CWS, retrieved on June 22, 2016, from http://www.gov.mb.ca/waterstewardship/water_quality/lake_winnipeg/facts.html.

[20] See http://www.gov.mb.ca/waterstewardship/stopais/index.html. Zebra Mussel was first discovered in North America in Lake St. Clair in 1988 which quickly spread into all of the Great Lakes, the St. Lawrence River, connected waterways, and many inland lakes in southern Ontario (Invading Species Awareness Program, 2006). The vectors/sources of introduction were identified to be ship ballast water, recreational boating (overland transport of boat trailers and water-based equipment), natural dispersal (e.g., drift, attachment to wildlife) or other human-mediated activities (e.g. intra-basin ballast water discharge, canal creation, waterway operations, scientific expeditions). Zebra mussel is currently found in more than 750 lakes in North America (http://www.lakewinnipegfoundation.org/zebra-mussels-101).

[21] http://www.redriverbasincommission.org/Conference/Proceedings/32nd_Proceedings/Manitoba.pdf.

Chapter 2: Methodology Adopted

This study aims to evaluate the socio-economic impact of the presence of Zebra Mussel in Lake Winnipeg and in surrounding areas. This was conducted in two steps: Firstly, the baseline values of activities by sector in and around the lakes have been appraised, which provided the foundation for a quantitative and/or qualitative discussion of the magnitude of values that might be affected. It should be noted that while developing the baseline values, the study deferred from speculating whether a particular activity would be affected or not by the presence of Zebra Mussel. Secondly, a socio-economic risk assessment has been performed.

The analytical principles set down in Treasury Board of Canada Secretariat (2007) guided the analysis. The methodology adopted for the analysis was the Total Economic Valuation (TEV)[22] technique, which relates all benefits to human welfare measures. In the study, the TEV framework considered that the benefits provided by Lake Winnipeg and surrounding areas were linked to both use and non-use values:

TEV = Use Value + Non-use Value

While a continuous effort has been made to improve the understanding of the impacts of AIS in Canada, until recently, comparatively less attention has been paid to measuring the impacts for Lake Winnipeg, the Red River, Nelson River and Cedar Lake. 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. The present study will closely follow the recreational activities identified in EC (2000) for the purpose of both baseline scenarios and risk assessment.

In order to estimate the economic value of Lake Winnipeg, the Red River, Nelson River and Cedar Lake, and the impact should Zebra Mussel establish in these areas, the study will include estimates of: (a) the expenditures at market values, and (b) the consumer surplus generated by the activities (where available).

AIS can lead to significant ecosystem alterations and full effects and consequences sometimes may take decades to emerge (Wilson, 1992).[23] Adult colonization of Zebra Mussel has been found in Lake Winnipeg since 2013 and in the Red River in 2015. So far, Zebra Mussel has not been detected in Nelson River, with limited veliger detected in Cedar Lake. Therefore, based on opinions received from subject matter experts,[24] in the study, the time periods considered for impact assessments begin in 2022, and are for 20 years as the study used 2015 as the base

[22] A chart showing the total economic values, along with definitions for all categories and sub-categories of values, is provided in Matrix 1.

[23] A suitable example is the sea lamprey, an AIS that has severely affected the Great Lakes region since its population exploded in the upper Great Lakes in 1940s and 50s (though arrived in 1830s) 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.

[24] Sources are discussed in detail later in this chapter under “data sources”.

year.

The study extrapolated baseline values to the base year of 2015 using the inflation rate, given that the data pertains to different years. For the socio-economic risk assessment, adjustments were necessary because future losses are worth less than current losses. Therefore, the discounting of future impact has been performed according to the Treasury Board of Canada's recommendation of 3%. This rate represents the social opportunity cost.[25] 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 nominal discount rate.

Data Sources

The data used to develop the community profiles around Lake Winnipeg were primarily obtained from Statistics Canada and provincial websites. The scenarios for the study were based on Therriault et al. (2013). 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 discussions with subject matter experts in DFO and Sustainable Development and 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 ecological risk assessments expressed consequences that could not be unambiguously linked to socio-economic impact analysis. Therefore, the study assumed linearity between the ecological consequences proposed in Therriault et al. (2013) and the socio-economic factors proposed in the current document. In addition to the results extracted from risk assessments, further information was gathered from science experts.

Since there is no feasible way to separate out the impact from the presence of Zebra Mussel in Lake Winnipeg and from other influences in the economy (e.g. climate change, other AIS, nutrients, eutrophication, etc.), the analyses in the study were premised on scenarios both with, and without, the presence of Zebra Mussel, holding other variables unchanged. For example, other changes and/or developments in the economy that might alter the native fish biomass in Lake Winnipeg were assumed to be absent during the period of analysis.

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

[25] 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).

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 Therriault et al. (2013) delivered the foundation for the socio-economic risk assessment, the uncertainties associated with the socio-economic assessment must be greater than, or equal to, that of Therriault et al. (2013).

Scope of the Study

The scope of this socio-economic study aligns with the scenario provided by Therriault et al. (2013), particularly in terms of the impact of the presence of Zebra Mussel, and includes:

a) a brief overview of the study area including descriptions of local demographics and an overview of Lake Winnipeg and areas around Lake Winnipeg (including the Nelson River, Red River and Cedar Lake);

b) a discussion of the methodology to be used in the study;

c) estimates of the economic value generated by activity in and around Lake Winnipeg the Nelson River, Red River and Cedar Lake. The baseline scenario includes the current direct human use of the study area and the future trend, non-market value (e.g. ecosystem value);

d) identification of scenarios based on ecological risk assessment;

e) a description and quantification of the particular impacts (both positive and negative) that are expected to be experienced. A qualitative description of the impacts was provided, if not quantifiable and/or no feasible proxies are available; and

f) identification of major uncertainties and shortcomings of the analysis.

Chapter 3 - Baseline Values of Activities around Lake Winnipeg (including the Red and Nelson Rivers and Cedar Lake)

Lake Winnipeg provides drinking water and is used as input for agriculture, industries, and hydroelectricity generation. It also supports the largest commercial fishery in Manitoba as well as a variety of recreational activities for residents, non-residents and international tourists.

This chapter provides the situational overview, appraising the values generated by the major activities in and around Lake Winnipeg, the Red River, Nelson River and Cedar Lake, either quantitatively or qualitatively. As stated in Chapter 2, the values provide a baseline value of the major activities from which the impact of the presence of Zebra Mussel in Lake Winnipeg, the Red River, Nelson River and Cedar Lake will be 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; and (vi) wildlife viewing. 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 1).

The subsequent portion of the chapter provides a discussion of the estimated economic values of activities in and around Lake Winnipeg.

Water Use

Canadians rank water as this country's most important asset (Renzetti, Dupont and Wood, 2011). Water withdrawn from Lake Winnipeg is used in municipalities and supplied to homes, businesses and institutions like schools/hospitals for a diverse range of activities (e.g. drinking, washing, gardening, landscape). In industries and agricultural sectors, water is used as input into the production process, livestock watering and irrigation (e.g. metals, chemicals, paper and allied products, water applied for growing crops and pastures, the maintenance of parks and golf courses). Water is also used for electricity generation (electricity, heating/cooling).

Drinking Water: Drinking water systems in Manitoba are classified into three categories: Public water systems, semi-public water systems (e.g. school or hospitals with own water supply), and private systems supply water. There are approximately 430 public water systems (supplying drinking water to about 80% of the population of Manitoba), 1,500 semi-public water systems and 35,000 to 80,000 private water systems in Manitoba.[26]. Surface water is the source of drinking water for 85% of public water system customers. Statistics Canada (2009) estimated that in 2007, the drinking water plants in Manitoba processed 106.3 and 14.1 million cubic

[26] Sustainable Development (2016). *Public Information - Water System Data*. Retrieved October 3, 2016, from *http://www.gov.mb.ca/conservation/waterstewardship/odw/public-info/general-info/index.html*.

metres surface and groundwater, respectively, and served over 900,000 people in the province. In the same year, operation and maintenance costs of drinking water plants in Manitoba were in the amount of $30 million.

Based on data provided by Sustainable Development, there are 41 public water systems that have their intakes from Lake Winnipeg, Red River, and Nelson River.[27] More than 10,000 cottages, nine provincial parks, and several non-government camps are located around the south basin of Lake Winnipeg (EC and MWS, 2011).

Industries and Agricultural Sectors: Within the Lake Winnipeg drainage basin, there are nearly 55 million hectares of farmland in the three Prairie Provinces, of which 45 million hectares are in the Canadian portion of the watershed.[28] Although the numbers fluctuate, there are over 10 million cattle and more than 14 million pigs within the Lake Winnipeg watershed (Clean Environment Commission, 2015).

While information specific to Lake Winnipeg/Nelson/Cedar Lake is unavailable, Statistics Canada (2011) estimated that in 2010, 45 farms used on-farm underground water or well water, 60 farms used on-farm surface water (water from lakes, rivers, creeks, streams, ponds or dugouts) and 15 farms used off-farm water (transported via pipeline, canal system, vehicle (including municipal potable water) in Manitoba. The average volume of water used for irrigation per farm in Manitoba was estimated at 245,000 cubic metres. In the same year, no farms in Manitoba treated irrigation water.

Statistics Canada (2012) estimated that in 2009 water intake by manufacturing industries in Manitoba was 15.2 million cubic metres from freshwater sources supplied by public water system. In the same year, the total water costs by manufacturing industries in Manitoba was estimated at around $78 million, which includes water acquisition costs ($31 million), intake treatment ($8 million), and discharge treatment ($37 million). Manitoba's potato industry, the second largest potato industry in Canada, is heavily reliant on the Assiniboine River during the summer months.[29]

Power Generation[30]: Manitoba Hydro operates 17 stations that include 15 hydroelectric generating stations on the Nelson (5), Winnipeg (6), Saskatchewan (1), Burntwood (1) and Laurie (2) rivers to generate, on average, 30 billion kilowatt-hours of electricity in Manitoba, and two thermal generating stations (Brandon & Selkirk). Manitoba Hydro also operates four small remote diesel generating stations (Brochet, Lac Brochet, Shamattawa, and Tadoule Lake) and buys electricity from two wind farms (capable of delivering 99 MW and 138 MW).

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[27] Housseïni D. Coulibaly, Manitoba Conservation & Water Stewardship, personal communication, dated February 4, 2016.

[28] There is an additional 10 million hectares of farmland within the U.S. portion of the lake's watershed (Lake Winnipeg Stewardship Board, 2006).

[29] *http://mbwatercaucus.org/support-the-water-caucus/lake-winnipeg.*

[30] Information presented in this section was primarily based on information provided on Manitoba Hydro website.

In 2015, Manitoba Hydro's total generating capability was 5,701 MW. The capacity is supplied by three large generating stations on the Nelson River (Kettle, Long Spruce, and Limestone with a combined capacity of more than 3,500 megawatts) representing approximately 70% of Manitoba Hydro's generating capacity. Other generating stations on the Nelson River are Jenpeg (capable of producing 129 MW of electricity), Kelsey (capable of producing 250 MW of electricity). Keeyask generating station (capable of producing 695-megawatt) on Nelson River is currently under construction upstream of the Kettle station currently scheduled to be completed in 2020.[31]

In addition, Manitoba Hydro operates the Grand Rapids Generating Station (capacity of 480 MW) on the Saskatchewan River, the Wuskwatim Generating Station (capacity of 200 MW) on the Burntwood River, and six generating stations along the Winnipeg River (with a total capacity of approximately 580 MW). Manitoba Hydro also operates two thermal generating stations in Brandon and East Selkirk with a generation capacity of 458 MW of electricity, four remote diesel generating stations and purchases wind power from independent wind farms in Manitoba.

Manitoba Hydro's system of transmission lines includes connections to Saskatchewan, Ontario, North Dakota and Minnesota allowing surplus electricity sold to other jurisdictions and purchased from other jurisdictions in the event of a shortfall in Manitoba. In 2015-16, Manitoba Hydro's consolidated revenue of $2,258 million was comprised of $1,430 million in the electric segment, $356 million in the natural gas segment, and $415 million extra-provincial (Manitoba Hydro-Electric Board 65th Annual Report, 2016).

Commercial (Net) Fishing

The Sustainable Development department of Manitoba is responsible for regulating Manitoba's commercial fishery, including Lake Winnipeg, which has the largest commercial fishery in Manitoba.[32] There are 3,068 licensed fishers and hired helpers employed annually, on average, in commercial fishing in Manitoba (Manitoba Conservation and Water Stewardship, 2012). Over 850 licensed fishers (South Basin – 38%, Channel Area – 23%, and North Basin – 39%) were employed in the commercial fishery on Lake Winnipeg.[33] In some indigenous communities such as Misipawistik Cree Nation, Poplar River, and Berens River First Nation, commercial fishing is such an important industry that there may not be any employment in the absence of commercial fishing in the community (Clean Environment Commission, 2015).

During 2011-15, an estimated 5-year annual average of 7,343t of freshwater fish was harvested

[31] The Keeyask Project is a partnership among four First Nations (Tataskweyak Cree Nation, War Lake First Nation, Fox Lake Cree Nation, and York Factory First Nation) and Manitoba Hydro.
[32] During 2011-15, Lake Winnipeg contributed 62.3% of the province's total landings and 75.1% of landed value.
[33] Sustainable Development (2016). *Lake Winnipeg Fisheries*. Retrieved September 30, 2016, from *http://www.gov.mb.ca/conservation/waterstewardship/water_quality/lake_winnipeg/fisheries.html*.

from Lake Winnipeg, Cedar Lake and Nelson River[34] in Manitoba. On average, pickerel accounted for 51% of the total, followed by whitefish (32%), pike (5%) and mullet (4%). During the same period, 5-year annual average landed value[35] was estimated at $17.8 million (including fish sold directly to consumers and/or through Special Dealer Licences[36]).[37] Of the total landings sold to FFMC (7,222t), Lake Winnipeg accounted for 86.5%, followed by Nelson River at 7.0% and Cedar Lake at 6.5% (see Table 1 and also see Annex 3(a) and (b) for details).

Table 1: Commercial Fishing Sector – Five Year Average (2011-15) Landings, Landed Values and Market Values by Lake/River

Variables	Landings (Kg)	Landed Value ($000)	Market Value ($000)
Lake Winnipeg	6,244,503	$15,863,004	$31,726,007
Cedar Lake	472,118	$834,500	$1,669,001
Nelson River	505,462	$689,725	$1,379,451
Total	**7,222,083**	**$17,387,229**	**$34,774,458**
Peddled or private sale	121,331	$375,564	$751,128
Grand Total	**7,343,414**	**$17,762,793**	**$35,525,587**

Source: (i) Freshwater Fish Marketing Corporation (*FFMC);(ii) Staff Calculation, Policy and Economics, DFO.*

Once the fish has been processed and sent to food stores and restaurants in domestic markets, the US and around the world, the industry's total contribution in reflected by the market value of the landings. During 2011-15, the 5-year annual average of market value[38] of the landings was estimated at $35.5 million.

Neither the existing data nor the literature provides the total economic value (e.g. WTP) of commercial fishing generated from Lake Winnipeg (or from any other Canadian lakes). However, since the fishing industry is fairly competitive because of the availability of close substitute goods (e.g. fish from Great Lakes or meat), the associated consumer surplus could safely be assumed to be insignificant.

Therefore, the present study tallies only the market values of the landings of commercial fishing in Lake Winnipeg, Cedar Lake and Nelson River estimated at $35.5 million per year.

[34] Landings from Nelson River includes Playgreen Lake, Kiskitogissu Lake, Cross Lake, Duck Lake, Sipiwesk Lake, Bulger Bay, Nelson River, Split Lake, Kiskitto Lake, Bruneau Lake, and Cauchon Lake.

[35] Landed value is the price paid for the fish as it comes off the boat and before it is processed.

[36] Due to data gap, fish peddled for 2011-15 was estimated based on fish peddled data for the period 2005-10.

[37] According to FFMC, there were 1,888 harvesters who delivered freshwater landings to 36 delivery points in Manitoba in 2010/11. Seventy five percent (1,422) of harvesters were from predominantly Aboriginal communities; 610 Aboriginal harvesters (43% of 1,422) were concentrated at five delivery points (South Indian Lake, Grand Rapids, Islandview, St Martin Junction, and Winnipegosis) in 2010/11.

[38] The market value/ price of freshwater fisheries in Manitoba is not available for recent years. Hence, the present study applied the ratio of market value to landed value for 2007-08. Another feasible approach is to multiply the landings by market price for the year 2007-08. The limitation of this approach is that it fails to capture the changes in price over time. For example, landed price decreased from $2.69/kg in 2008 to $2.38/kg in 2015. The approach adopted in the study captures such price dynamism in the estimation.

Recreational Fishing

Recreational fishing is prominent in Lake Winnipeg, the Red River, Nelson River and Cedar Lake. The fishery is mainly concentrated in the lower Red River and associated marsh areas with fish stocks from Lake Winnipeg (Franzin, Stewart, Hanke and Heuring, 2003).

The recreational anglers are attracted by the population of Walleye, Sauger and Channel Catfish, Freshwater Drum, Goldeye and Common Carp throughout the open water season in the lower Red and Winnipeg rivers.[39] Also, winter ice fishery occurs in the lower Red River (Franzin, Stewart, Hanke and Heuring, 2003) and the south basin of Lake Winnipeg.

There are a number of sources (e.g. Travel Manitoba 2012, DFO, 2010, 2008; EC, 2000) that estimated the value of recreational fishing in Manitoba, employing different methodologies (e.g. Nested Logit models). For Manitoba, the most relevant and recent information on expenditures incurred for recreational fishing was estimated in DFO (2012) employing travel costs and expenditures for fishing trips to estimate the contributions of recreational fishing. Moreover, the consumer surplus value associated with recreational fishing that is not captured by expenditures is reported in EC (2000).

DFO (2012) estimated that, in 2010, 170,501 anglers spent around 2 million days in Manitoba for recreational fishing purposes. The majority of active anglers in 2010 were residents of Manitoba (140,873). The remaining angler population consisted of Canadian non-residents (11,844) and visitors to Canada (17,784). Anglers spent a total of $98 million in direct recreational fishing expenditures and invested $102 million in major purchases and investments wholly attributable to recreational fishing in Manitoba.

Based on data collected for the same survey, it was also estimated that, in 2010, 51,745 anglers spent 396,838 days in recreational fishing activities in Red River, Cedar Lake and Lake Winnipeg (see Table 2). The majority of active anglers in 2010 were residents of Manitoba (48,716 anglers spent 385,423 days). The remaining angler population consisted of Canadian non-residents (1,067 anglers spent 3,450 days) and visitors to Canada (1,962 anglers spent 7,965 days).

Table 2: Recreational Fishing Sector – Number of Anglers and Angling Days by Lake/River for the Year 2010

	Number of Anglers				Number of Angling Days			
Jurisdiction	**Resident**	**Non-resident**	**Foreigner**	**Total**	**Resident**	**Non-resident**	**Foreigner**	**Total**
Total	**48,716**	**1,067**	**1,962**	**51,745**	**385,423**	**3,450**	**7,965**	**396,838**
Red River	28,034	579	738	29,351	223,077	2,572	2,612	228,261
Cedar Lake	839	-	712	1,551	3,429	-	3,478	6,907
Lake Winnipeg	19,843	488	512	20,843	158,917	878	1,875	161,670

Source: 2010 Survey of Recreational Fishing in Manitoba (unpublished) provided by Conservation and Water Stewardship

[39] Channel catfish in North America and the large carp are drawing fishers from as far away as the United Kingdom and continental Europe (Franzin, Stewart, Hanke and Heuring, 2003).

In terms of species caught, DFO survey data found that in 2010, the major species caught by anglers were Walleye (45%), Channel Catfish (20%), Perch (13%), and Pike (5%) in Lake Winnipeg, Red River and Cedar Lake.

Pertaining to the estimation of consumer surplus, a number of studies presented some estimates for consumer surplus of fishing for some selected Canadian provinces (e.g. Rosenberger & Loomis, 2001; Apogee, 1990; Dupont, 2003). The most widely used consumer surplus value associated with recreational fishing in Canada is reported in EC (2000). Based on the results of a survey conducted in 1996, EC (2000) estimated that the average value of consumer surplus associated with recreational fishing in Manitoba was $14.6/daily per participant in 1996 dollars.

In the absence of lake specific data on direct expenditure and investment, the present study scaled down the values (after adjusting for inflation) reported at the provincial level in DFO (2012) using the proportion of days fished in Red River, Cedar Lake and Lake Winnipeg.[40] The resulting value was then added to the inflation-adjusted consumer surplus using consumer surplus reported in EC (2000) and number of days fished.

Following this approach, the economic contributions of the recreational fishing industry around Red River, Cedar Lake and Lake Winnipeg was estimated to be $50.9 million/year (expenditures - $42.7 million; consumer surplus - $8.2 million).

Recreational Hunting

The Lake Winnipeg watershed offers a wide range of hunting opportunities to residents, non-residents, and foreign residents. Netley Marsh, Whitewater Lake, Tom Lamb and Saskeram Wildlife Management Areas are world renown for waterfowl hunting. The Sleeve Lake, Broad Valley, and Mantagao Lake wildlife management areas in the Interlake are well known for white-tailed deer, elk, moose and black bear hunting. Upland bird hunters have access to ruffed and sharp tailed grouse as well as wild turkey in some areas (Manitoba Hunting Guide 2016).

A few studies (e.g. Rosenberger, 2001; EC, 2000) provided estimates of the number of hunters and the economic values of hunting activities for Canada. 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 Lake Winnipeg watershed.

EC (2000) found that residents of Manitoba spent $24.8 million on hunting in 1996. [41] The

[40] While Environment Canada & Manitoba Water Stewardship (2011) reported estimated value of recreational fishing on tributaries to Lake Winnipeg at $17 million, the present study scales down the recreational values reported in DFO (2012) for Manitoba to arrive at a corresponding number for Lake Winnipeg to maintain consistency in using data sources in estimating other components of recreational fishing in Lake Winnipeg, the Red River, Nelson River and Cedar Lake.

[41] Of the total $200.6 million, approximately $13.0 million (52.4%) was spent on equipment used, $4.9 million (19.8%) on transportation, $3.6 million (14.5%) on other items (e.g. entry fees), $2.6 million (10.5%) on food, and

average hunter spent $584 during the year, or $38/day of participation in hunting. Pertaining to the estimation of consumer surplus, the report estimated that the consumer surplus associated with hunting was $181.7/yearly or $18.8/daily per participant, in 1996 dollars.

As the above values were not lake-specific, to calculate the total economic contributions of hunting in the study area, the present study scaled down the hunting expenditures and the economic values reported in EC (2000), [42] and adjusted for inflation. Following this approach, the economic contributions of recreational hunting around the Lake Winnipeg was estimated to be $9.3 million/year (expenditures - $7.1 million; consumer surplus - $2.2 million).[43]

Recreational Boating

Several studies (e.g. Dutta, 1984; Hushak, 1999, Dupont, 2003) have assessed the economic values associated with recreational boating from regional or national perspectives.

Using data from online surveys and publicly available information from Industry Canada, Genesis Public Opinion Research Inc. (2007) estimated that Prairie boaters are serviced by 60 marinas and dry land dealers and 42 yacht clubs of which 16 yacht clubs are located in Manitoba. Moreover, there were 12 boat manufacturers and 5 suppliers of complementary products located within the Prairie provinces. Manitoba boaters spent a total of $485.2 million and boating related tourism expenditures was estimated at $218.5 million in 2006. There are several harbours on Lake Winnipeg that support recreational boating. These include Winnipeg Beach, Gimli, Silver Harbour and Hecla.

With respect to consumer surplus, while no specific value was provided for boating, EC (2000) estimated that the consumer surplus associated with outdoor activities in natural areas for Manitoba residents was $143.5/yearly, or $8.7/daily, in 1996 dollars. However, there was no information found pertaining to the number of boaters in Lake Winnipeg or Manitoba.

Therefore, the present study considered only the inflation-adjusted expenditures estimated by Genesis Public Opinion Research Inc. (2007), scaled down using the proportion of recreation fishing in Red River, Cedar Lake and Lake Winnipeg (20%). Following this approach, the economic contributions of recreational boating was estimated to be $163.3 million/year.

Wildlife Viewing

Watching the wildlife of the arboreal forest along the south-eastern shores of Lake Winnipeg attract day-trippers, campers, cottagers, and tourists from around the world every year. The

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the remaining $0.6 million (2.4%) on accommodation.

[42] The proportions of the total such expenditures (20%) are calculated based on the proportions of recreational fishing expenditures that are Red River, Cedar Lake and Lake Winnipeg specific discussed in recreational fishing section of this study.

[43] The estimation includes only the residents of Manitoba and excludes non-residents and foreign visitors due to insufficient information.

lake and its shores offer a wide variety of wildlife viewing.[44]

A number of studies (e.g. Hvenegaard , Butler, & Krystofiak, 1989; Kerlinger, (Unspecified)) highlighted and estimated the economic value of wildlife viewing for individual provinces and Canada as a whole. However, information on the economic values generated by wildlife watching specifically for Lake Winnipeg, the Red River, Nelson River and Cedar Lake is sparse.

From Canadian perspective, EC (2000) found that Manitoba residents spent $42.7 million on wildlife viewing in 1996. On average, the wildlife viewers spent $261/year or $15/day of participation. Pertaining to consumer surplus, the report estimated that the consumer surplus associated with wildlife viewing was $68.6/yearly or $7.2/daily, in 1996 dollars.

As the values were not Lake Winnipeg specific, to calculate the total economic contributions of wildlife viewing in Lake Winnipeg, the Red River, Nelson River and Cedar Lake, the present study scaled down (after adjusting for inflation) the wildlife viewing expenditures and economic values reported in EC (2000) by 20%.

Following this approach, the economic contributions of wildlife viewing was estimated to be $15.4 million/year (expenditures - $12.2 million; consumer surplus - $3.2 million).[45]

Ecosystem Services

Lake Winnipeg, Red River, Nelson River and Cedar Lake provide invaluable services to society through maintaining ecosystems and biodiversity. Some of these are captured with the corresponding direct benefits to the economy. For instance, a healthy ecosystem of Lake Winnipeg enables commercial harvesters and recreational anglers to fish. Indirect ecosystem services include but are not limited to natural local climate regulations, erosion control and sediment retention, soil formation, nutrient cycling, waste treatment, water regulation, stored carbon, carbon sequestration (Marbek, 2010b).

Lake Winnipeg maintains approximately 140,000 hectares of coastal wetlands (20,000 less than the area of wetland in the Laurentian Great Lakes) facilitated by Manitoba's flat topography, which provides a shallow relief profile where wetland plants can develop (Clean Environment Commission, 2015).[46] Wetlands filter and recharge freshwater, help prevent erosion and flooding, provide carbon storage, waste assimilation and metabolism, habitat for fish, wildlife, protected species and plants. They are also locations for recreation, education and research.

[44] The Eastern Beaches Area of Lake Winnipeg is ideal for birding or bird watching (Birdwatching).The numerous bird sanctuaries from Patricia Beach to Elk Island are home to a wide number of some of North America's rarer birds (http://www.eastern-beaches.mb.ca/recreation/birdwatching.html).

[45] Supra note 43.

[46] Manitoba's great lakes ((Winnipeg, Manitoba and Winnipegosis) is estimated to have approximately 271,000 hectares of coastal wetland (Clean Environment Commission, 2015) and, in Manitoba, wetlands cover 233,340 square kilometers or 43 per cent of the province (Lake Winnipeg Implementation Committee, 2005).

The Netley-Libau Marsh (26,000 hectares), one of the largest freshwater coastal wetlands in North America, is located on the Red River at Lake Winnipeg.[47] The marsh is internationally recognized for providing habitat for nesting, staging, and moulting waterfowl and muskrat, spawning, nursery, and feeding habitat for fish from Lake Winnipeg and the Red River, ecological goods and services such as filtering and sequestering nutrients from the Red River into Lake Winnipeg. The marsh is a candidate Heritage Marsh under the Manitoba Heritage Marsh Program and has been designated as an Important Bird Area by Bird Studies Canada and the Canadian Nature Federation (Environment Canada & Manitoba Water Stewardship 2011).

Unlike the direct benefits with established market values, the intrinsic values of the ecosystems and biodiversity are harder to define because they are much more intangible (Krantzberg and de Boer, 2008, 2006). As of now, literature providing the values of the (indirect) ecosystems services and biodiversity distinctively for Lake Winnipeg, the Red River, Nelson River and Cedar Lake, is very limited due to the lack of guidance, information and/or the uncertainty around predicting the future (e.g. knowledge of local weather and climate patterns). However, a few studies (Kreutzwiser, 1981; IJC Study Board, 2006) attempted to provide estimates of the intrinsic values of ecosystem services either for the Canadian economy or for some rivers and some (portion of) major lakes (e.g. the Great Lakes) in Canada.

Voora and Venema (2008) assessed environmental assets and respective ecosystem services of southern Manitoba's portion of the Red, Assiniboine and Souris River basin system (a sub-watershed covering approximately 5.7 million hectares or 6% of the Lake Winnipeg Watershed) by evaluating 17 ecosystem services grouped into six categories – water quantity and quality, climate change, biodiversity, material benefits, social wellbeing, and environmental integrity. The study found that the current landscape provides ecosystem service values ranging from CAD0.33 to CAD1.03 billion/year, with forests and wetlands accounting for 80% - 96% of the total ecosystem service values by land cover.

In terms of evaluating wetlands' value in providing habitat and/or habitat protection, Pattison, Boxall, Adamowicz (2011) examined the willingness to pay of Manitobans for wetland retention and restoration on a sample of 1,980 respondents and found that over a five-year period Manitobans would be willing to pay $296-$326/household per year depending on the level of the wetland program improvement. Using 5% (10%) discount rates, the present value aggregate payments were estimated at $504 ($550) million for retaining wetlands at current levels and $106($110) million for restoring wetlands to estimated 1968 levels. Voora and Barg (2008) assessed Pimachiowin Aki World Heritage Project Area located across Eastern Manitoba and Northwestern Ontario and found that the value of regulating and supporting ecosystem services provided by the Pimachiowin Aki could be conservatively estimated within the range of CDN$56.60-65.55 million per year.

Woodward and Wui (2001) estimated an average value of $1,363.79/hectare. Kazmierczak (2001) estimated the value of habitat and species protection to be $843.55/hectare. Costanza

[47] The marsh is bisected by the Red River, which branches into three main channels before reaching Lake Winnipeg.

et al. (1997) estimated a global average of the habitat ecosystem service of $690.71/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.

Wilson (2008) estimated that the value of Lake Simcoe watershed ecosystem services is at least $975 million annually or an average of $2,948 per hectare per year (every one of the 350,000 residents receives $2,780 annually in ecosystem services). By land cover type, the report estimated that the highest values per hectare are attributed to wetlands ($435 million per year) and forests ($319 million per year) followed by open water ($103 million per year), agricultural lands (cropland, hedgerows woodland, pasture) ($93 million per year), grasslands ($23 million per year) and urban parks ($3 million per year).

In order to assess ecosystems, functions and their respective (indirect) services provided by Lake Winnipeg, the Nelson River, Red River and Cedar Lake, it is important to take stock of the watershed's natural assets in terms of land and water cover, accurately identify/classify the land use and ecosystem types across the Lake, and then attribute estimated values to the respective services. Such estimations following primary data are very time consuming and hence beyond the scope of this study. However, the studies briefly discussed above sheds some light on the significance of the indirect ecosystem services provided by Lake Winnipeg, the Nelson River, Red River and Cedar Lake from the monetary perspective.

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. Lake Winnipeg, the Nelson River, Red River and Cedar Lake and associated unique biodiversity characteristics might be a case in point.

Research Value

Lake Winnipeg, the Red River, Nelson River and Cedar Lake also provide opportunities for research and educational activities that inform and benefit others and provide a better understanding of the ecology. Although, estimating the economic value of these uses is difficult, their contribution cannot be overlooked. 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.

Non-Use Value

Society, and in particular, people residing in and near Lake Winnipeg, the Red River, Nelson River and Cedar Lake, derives substantial non-use value from the services provided by these

areas.[48]

A few studies have estimated non-use values for different areas of Canada (e.g. Dupont, 2003; Rudd, Andres, & Kilfoil, 2016). Bishop (1987) estimated the taxpayers' WTP for the striped shiner 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.

Reviewing relevant literature, Apogee (1990) provided estimates of non-use values associated with water quality and concluded that the non-use component was 50% of TEV. Freeman (1979) stated that the total non-use values might fall in the range of 60% - 80% of TEV.

Although, it is a significant challenge to capture the non-use values, these values might be insignificant at the individual level, aggregated values for an entire economy are significant. While the total non-use value for Lake Winnipeg, the Red River, Nelson River and Cedar Lake has not been studied so far, the studies discussed above shed some light on the magnitude of non-use values associated with Lake Winnipeg resources.

Economic Contribution – At a Glance

Based on the calculations and discussions contained in this Chapter, Table 3 shows the details on the economic values generated by Lake Winnipeg, the Red River, Nelson River and Cedar Lake annually.[49]

Table 3: Economic Contributions ($Million) of Lake Winnipeg, the Red River, Nelson River and Cedar Lake by Activity in 2015

Sector	Baseline Values (2015)	
	Value/ Expenditure	Consumer Surplus
Water Use	NA	NA
Power Generation	NA	NA
Commercial (Net) Fishing	35,525,587	NA
Recreational Fishing	42,661,653	8,082,961
Recreational Hunting	7,061,411	2,197,018
Recreational Boating	163,315,160	NA
Wildlife Viewing	12,158,156	3,195,592
Ecosystem Services	Qualitative	Qualitative
Non-Use Values	Qualitative	Qualitative

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

[48] 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.

[49] Due to the manner in which the secondary expenditures were calculated, it is not possible to add up the expenditures on activities shown in Table 3 without duplication.

There are some associated private values held by people who live near or who visit Lake Winnipeg, the Red River, Nelson River and Cedar Lake, usually captured in the literature as "aesthetic and amenity values" (Zhang, & Boyle, 2010). 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, 2010a). There is a growing economic literature (e.g. Johnston et al., 2001; Krantzberg et al., 2008, 2006; Pompe, 2008) pertaining to the implicit prices people are willing to pay to benefit from environmental amenities. This study refrains from estimating the aesthetic and amenities values in order to avoid double-counting problems, as these values overlap some of the benefits of recreational activities (e.g. recreational fishing, boating).

The estimations of the economic contributions of Lake Winnipeg, the Red River, Nelson River and Cedar Lake discussed in this chapter should be viewed as conservative estimates. The conservative estimates are provided by: (i) adjusting 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, 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 a 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 Lake Winnipeg, the Red River, Nelson River and Cedar Lake, the study found the following data gaps/limitations:

Water Use: Pertaining to water consumption from Lake Winnipeg, the Red River, Nelson River and Cedar Lake, there were shortcomings in the analysis due to incomplete information, and that resulted in a failure to capture the value of consumed water.

In the agricultural sector, water from Lake Winnipeg, the Red River, Nelson River and Cedar Lake is used as input into the production process (watering self-supply livestock and self-supply irrigation), for the maintenance of parks and golf courses etc. For example, there are 133 golf facilities in Manitoba (Golf Canada, 2015). While there are a few golf courses around the Eastern Beaches Area of Lake Winnipeg Canada, it is unknown how many of them use water from Lake Winnipeg or are located near Lake Winnipeg. Similarly, water use from Lake Winnipeg, the Red River, Nelson River and Cedar Lake for industrial and other agricultural activities are unavailable in the extant literature. Therefore, the study at hand refrained from estimating the contributions of Lake Winnipeg, the Red River, Nelson River and Cedar Lake to industrial and agricultural production in Manitoba.

Moreover, water used to maintain levels 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), field drainage were not available and, therefore, were excluded from the present study.

The study also excluded consumer surplus values of water use from the assessment due to missing information on subject areas.

Commercial (Net) Fishing: The economic contributions of commercial fishing may have differed from actual contributions because of market price proxies used to fill in the gap in market value/price data. Catches and values historically generated by bait fishery were excluded.

Recreational Hunting, Wildlife Viewing: The recreational hunting and wildlife viewing expenditures were not available for the study area. 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.

Recreational Boating: The recreational boating expenditures were not available for the study area. Therefore, the study scaled down expenditures estimated for Manitoba 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.

Other Recreational Benefits: The vast size of Lake Winnipeg offers many recreational opportunities from a variety of other recreational uses, such as sightseeing in natural areas, swimming/beach activity, skiing and snowmobiling in the winter, hiking in the beaches area of Lake Winnipeg, golfing day-trippers, campers, cottagers, and tourists from around the world every year. Water skiing and sunbathing have been a favorite past-time for revellers that frolic on the Beaches of Lake Winnipeg. Each year, thousands of bathers enjoy Lake Winnipeg's waters and sandy beaches located within easy commuting distances from major population centres along both the east and west shores of Lake Winnipeg. Many beaches are also located throughout other regions of Manitoba, and are associated with provincial campgrounds or privately owned facilities.

Several studies (e.g. Environment Canada, 2000) documented the benefits of such activities associated with tourism, with no attempts to separate the individual categories. For example, Environment Canada (2000) estimated that Manitoba residents spent $296 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 power boating, which have been included in the present study as individual category. 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.

Chapter 4: Social and Cultural Values of Lake Winnipeg, the Red River, Nelson River and Cedar Lake

In addition to economic contributions discussed in Chapter 3, Lake Winnipeg, the Red River, Nelson River and Cedar Lake have long supported the subsistence of fisheries-based communities and the traditional culture of First Nations.[50] Though at a very small scale, surface water is still considered to be a mode of transportation of goods and raw materials for many communities along the northeast shore of Lake Winnipeg. No comprehensive quantitative information/data was available on such benefits derived from Lake Winnipeg, the Red River, Nelson River and Cedar Lake. However, this chapter presents a qualitative discussion of the socio-cultural values of Lake Winnipeg, the Red River, Nelson River and Cedar Lake.

Subsistence fishing conducted on Lake Winnipeg is an activity that many Indigenous people use to feed their families. Subsistence harvest was most important in Lake Winnipeg from 1887 to 1909 when the mean annual harvest was 342,456 kilograms. Although decreased later, it is still considered to be an important source of food and plays a central role in the traditional cultural life of First Nations.

A study found that, in 1984, members of three communities located close to Lake Winnipeg consumed only 7.3-12.9 kg per capita per year for a total of about 13,000 kg/year (Franzin, Stewart, Hanke, and Heuring, 2003). Another survey on the community of Cross Lake in northern Manitoba indicated that over 103,000 kilograms of fish was caught in one year for subsistence purposes. Over half of this harvest was fish species popular for eating (i.e. 55,800 kg). Major species harvested for subsistence purposes are Lake Sturgeon, Longnose Sucker, Lake Whitefish, Yellow Perch, Lake Trout, Walleye, Northern Pike, and Arctic Char.[51]

In addition to providing a food source through subsistence harvesting, the harvest of fish from Lake Winnipeg, the Red River, Nelson River and Cedar Lake provides significant social benefits, particularly to Indigenous communities, through the distribution of food among communities, providing linkages to traditional lifestyles and ancestors, and therefore is important for social and cultural reasons.

Finally, Lake Winnipeg beaches provide a unique source of community pride (Blue Flag designation). The beaches and shorelines are the basis for the key public perception measure of environmental quality. These non-economic benefits are not only substantial, but also may even exceed the benefits of subsistence as a food source (GSGislason & Associates Ltd., 2003).

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[50] Treaties were signed in the 1800s and 1900s between Canada and First Nations representatives under The Constitution Act (1982) which protected the right of Status Indians to fish for food. In Manitoba, fish stock conservation is given the first priority followed by domestic fishing for food by First Nations peoples.
51 Sustainable Development (2016). *Lake Winnipeg Fisheries*. Retrieved September 30, 2016, from *https://www.gov.mb.ca/waterstewardship/fisheries_education_sustain_dev/sustain/econ.html*.

Chapter 5: A Brief on Ecological Risk of the Presence of Zebra Mussels

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.

Assuming only the current management measures in place and all else unchanged, Therriault et al. (2013) evaluated the probability of arrival, survival, and invasion, and determined the impacts of invasion and the ecological risk of Zebra Mussel. The assessment found that most sub-drainages in Manitoba, Saskatchewan, Alberta, (and eastern British Columbia and the Great Lakes basin) have calcium concentrations suitable to maintain Zebra Mussel populations at high to very high levels with highest probability of survival. The assessment also indicated a very high probability of invasion of Zebra Mussel in the Lake Winnipeg, Western Lake Winnipeg and Nelson, Red and Saskatchewan rivers sub-drainages.

The consequences of established Zebra Mussel populations are expected to include increases in water clarity, hard substrate fouling, changes in planktonic communities (reductions in phytoplankton (algae), zooplankton (animals)), reductions in zoobenthos (profundal)), increases in periphyton and macrophyte (plants) cover, reductions in planktivore fish (fish feeding primarly on plankton), deepwater benthivore fish (fish that feed on the deep bottom of lakes/rivers) and, piscivores fish (fish-eating species), reductions in native (including at risk) mussels, and increases in benthivore-littoral fish (fish that feed on the bottom near shore areas of lakes/rivers).

Therefore, the ecological risks immediately after the invasion of Zebra Mussel were assessed as high with a very low degree of uncertainty.

A time lag is expected with respect to seeing the consequences of an established population of Zebra Mussel in Lake Winnipeg, the Red River, Nelson River and Cedar Lake. Within 20 years, the magnitude of the ecological consequences was ranked very high. The ranking indicated the escalating consequences expected as the invasion and population numbers increase over time.

Chapter 6: Socio-Economic Impact Assessment

For this study, the socio-economic impacts that are direct consequences of the ecological outcomes of the presence of Zebra Mussel have been considered. This socio-economic risk assessment is primarily based on Therriault et al. (2013) ecological risk assessment as well as information provided by subject matter experts from DFO and Sustainable Development and formed the basis for the socio-economic analysis.

Therriault et al. (2013) 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 set the stage (scenario) for impact assessment, the study assumed that in the absence of added prevention and protection, Zebra Mussel will have an established population in Lake Winnipeg, the Red River, Nelson River and Cedar Lake.

The next section of this chapter provides a detailed discussion of the degree of damage caused by Zebra Mussel in Lake Winnipeg, the Red River, Nelson River and Cedar Lake by major activity impacted.

Water Use:

Drinking Water: The impact on residential water affects drinking water treatment plants as well as homeowners because service water piping system would be at risk of mussel settlement. Marbek (2010a) cited from a study that the average annual cost (retrofits, planning, monitoring, all control measures, training, research, and other related expenditures) for small water treatment plants amounts to $36,537/facility, and $126,821/facility for large facilities.

According to the data provided by the Office of Drinking Water, Sustainable Development, there are 41 public water systems that have their intakes from Lake Winnipeg, Red River, and Nelson River, of which seven of them serving population density ranging 2,000-24,000, which were classified as large facilities for the purpose of the study.[52] Therefore, the study multiplied inflationary adjusted cost values by the respective number of small and large drinking water treatment plants, and estimated that the costs to water treatment plants would be $2.3 million/year. After discounting, the present value of the costs to be incurred by the treatment plants for the subsequent 20-year time period was estimated at $35.5 million.

Moreover, to prevent the damage on water pipes of private homes, and cottages located along Zebra Mussel infected lakes, rivers, and streams, homeowners may invest in approved antifouling techniques. As a proxy for approved techniques, the study used example based on the use of water filters. The filter costs approximately $275 (Marbek, 2010a), which would be equivalent to $299 in 2015 and there are approximately 10,000 cottages located around the south basin of Lake Winnipeg (EC and MWS, 2011). There are some seasonal cottages that only

[52] Housseïni D. Coulibaly, Sustainable Development, personal communication, dated February 4, 2016.

cope with one season of fouling. Due to the absence of data on the number of seasonal cottages the study assumes that all of these residences are affected and will incur costs related to removing mussels that clog pipes and other techniques using mechanical or chemical treatments. After inflationary adjustment of the filter costs, the annualized total cost of mussel infestation to private homes amounts to around $804,000/year assuming 4-year filter life expectancy. After discounting, the present value of the filtering costs by cottage owners for the subsequent 20-year time period was estimated at $12.4 million.

Power Generation: Zebra Mussel is well known to cause severe damages to power generating stations. For example, all concrete structures may accumulate live mussels and cause problems once they are in a water passage where friction losses can affect the power output of the unit. These mussels eventually die and slough off the concrete surfaces and the dead shells enter raw water intakes. Zebra Mussel may also plug drain holes and vent of spill gates, increase wear and tears of rubber seals, infest trash racks at the water entrance (Mackie and Claudi, 2010). Unit cooling water and service water piping systems may be at risk of mussel settlement. Prevention measures include increased manual effort for cleaning of surfaces and strainers, increased monitoring and protection, annual flushing, installation of additional equipment.

While water environment in which Manitoba Hydro stations are located are distinct, in the absence of complete cost information (e.g. research costs to control Zebra Mussel) incurred by Manitoba Hydro, the present study assumed that generating stations were similarly infested and required a similar level of monitoring/control activities. In the absence of sufficient information associated with different sized hydro plants and independent power plants in Manitoba, the present study adopted a cost relating to monitoring and control of Zebra Mussel in the amount of $810/MW based on information provided in Marbek (2010a). Following this approach, the study calculates that the annualized capital costs of infrastructure retrofits as well as operating costs such as maintenance, planning, monitoring, materials, operators and technician labour is $4.6 million. The current study also estimated that in 2022, the total present value of the costs to be incurred for Zebra Mussel monitoring and control to maintain power generation for the subsequent 20-year time period would be $70.6 million.[53]

Commercial (Net) Fishing

In order to assess the impact on commercial fishing and related activities, it is necessary to project the expected ecological consequences of Zebra Mussels on native species commercially fished in the Lake Winnipeg.

The ecological risk assessments identified some pathways of effects (algae, water clarity) of the presence of Zebra Mussels on native commercial fish species. Zebra Mussel invasions are

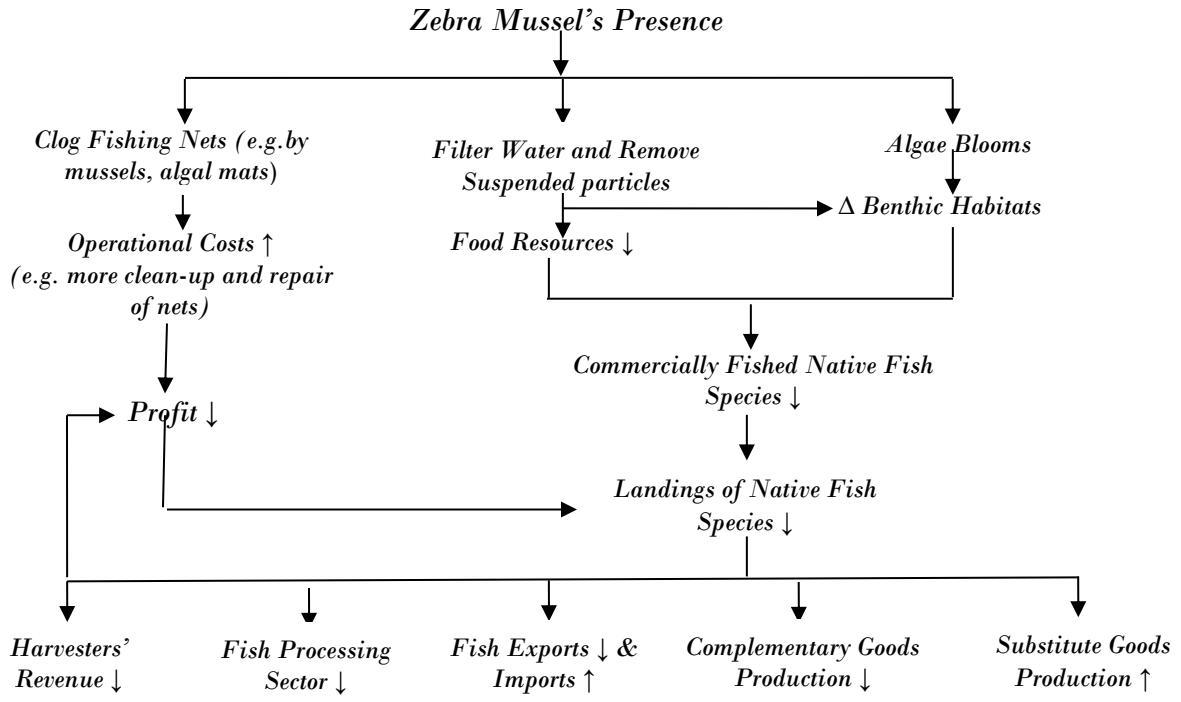
[53] $810/MW is an estimated annualized median cost per MW of installed capacity of hydropower facilities, a number being used by some provinces as a proxy in the absence of information. The study recognized that while there are cost differences between small (<150 MW) and large (>150MW), in the absence of information, a median value per MW was used and applied to both hydropower and other facilities. The estimation also excludes loss of power generation revenues due to increased shutdowns for maintenance.

known to contribute to algae blooms. The Zebra Mussels release phosphorus as a waste product, which the algae take up and grow. The algae blooms are considered to be a serious threat to commercial fisheries as toxicity from algal blooms modify benthic habitats and travels up the food chain (Therriault et al., 2013). Zebra Mussel may cause Cladophora[54] mats to expand. Decomposing Cladophora provides a breeding ground for enteric bacteria, including some pathogens, which can produce dangerous toxins. This may create suitable habitat for indicator bacteria, and potentially for pathogens, to persist and grow.

Zebra Mussel removes suspended particles by filtering water from the water column and deposit them into sediment. This action makes nutrients available to the benthic species on the freshwater floor leaving less food material for the planktonic species (e.g. Lake Whitefish). Moreover, the increased clarity of water may increase the euphotic zone (water that the sunlight can reach) and, as a result, stimulate the growth of rooted aquatic weeds plants (Mackie and Claudi, 2010). These changes in habitat may have severe impacts on many freshwater species (e.g. walleye/sauger, may be replaced with small mouth bass (centrarchids)), and on the commercial fishing industry.

Based on the results reported in Therriault et al. (2013) and discussions with subject matter experts in DFO and Manitoba Sustainable Development, the presence of Zebra Mussel in Lake Winnipeg, the Red River, Nelson River and Cedar Lake is predicted to cause damage to commercial fishing and related activities as follows:

Flowchart 1: Impact on Commercial Fishing Resulting from the Presence of Zebra Mussel



[54] A green alga that grows attached to hard substrates (rocks and boulders) and the lake bottom.

As shown in the flow chart, the presence of Zebra Mussel would increase the operational costs of commercial fishing industry (e.g. frequent repair of nets fouled by algae and/or dead mussel shells, maintaining motors, increased gas consumption from attached mussels) and reduce commercial fishing revenue through reduced landings of native species of fish and would in turn reduce the fishing activities. This in turn would reduce the level of gross profit and thereby create a circular flow of impact.

Taking a conservative assumption of the 20% reduction of the catches[55] by the presence of Zebra Mussel population, the study estimated that the current market value of reduction of the catches would be at $7.1 million. Of the total value, Lake Winnipeg accounted for $6.3 million, Cedar Lake $334,000 and Nelson River $276,000.

The study also estimated that in 2022, the total present (market) value of the impact for Lake Winnipeg, the Red River, Nelson River and Cedar Lake for the subsequent 20-year time period (2022 to 2041) would be $108.9 million (Table 4). Of that total, Lake Winnipeg accounted for $97.2 million (89.3%), Cedar Lake $5.1 million (4.7%) and Nelson River $4.2 million (3.9%).

Table 4: Estimated Present Values (in Million) of the Impact on Market Values in Commercial Fishing in 20 Years by Lake

Variables	Winnipeg	Cedar	Nelson	Peddled	Total
Com. Fishing Impact	$97.2	$5.1	$4.2	$2.3	$108.9

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

As the commercially harvested fish species are impacted by the presence of Zebra Mussel in Lake Winnipeg, Cedar and Nelson Rivers, 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.

In addition to the licenced fishers and their helpers on the lake, the industry also employs people for packing, shipping, and processing the product. Commercial fishing is the sole source of income for some communities and a major source of income for many communities around Lake Winnipeg, Cedar and Nelson Rivers, including Indigenous communities. Income of some harvesters solely comes from fishing in one lake (e.g. Cross Lake on the Nelson River).

[55] The percentage used here is determined by consultations with subject matter experts in DFO and Manitoba Sustainable Development. The percentage used excludes the probable decrease in commercial fishing due to higher operational costs shown in Flowchart 1.

Therefore, any negative impact on commercial fishery would be a significant loss to the provincial economy and cause economic disruption within fisheries-based communities around the lake.

The impact of Zebra Mussel in commercial fishing would possibly also trigger some (re)distributional effects in terms of production and employment. This is due to the presence of substitute/complementary products to freshwater species from the Lakes/rivers, 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 the 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 both commercial fishing sector and the sectors producing complementary products.

The impacts discussed above are anticipated to be, by and large, proportional to the ecological consequences reported in Therriault et al. (2013). It is also noteworthy that given the immense size of the study area and its complex ecosystems and food webs, a proper forecast on the magnitude of Zebra Mussel impact, as well as the timeline for that impact to emerge on native fish abundance, is quite challenging.

Recreational Fishing

In order to estimate the impact of Zebra Mussel's presence on recreational fishing in the Lake Winnipeg, Red, Cedar and Nelson Rivers, 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 Therriault et al. (2013), the presence of Zebra Mussel in the Lake Winnipeg, Red, Cedar and Nelson Rivers would damage recreational fishing activities. The rationale is that if catch rates were reduced by decrease in fish populations (as explained in the commercial fishing section), 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 study area, measured by a decrease in expenditures related to recreational fishing and consumer surplus.

Moreover, the accumulation of live Zebra Mussels as well as dead Zebra Mussel shells may increase operational costs (e.g. repair of nets fouled by algae and/or dead mussel shells, maintaining motors, regulatory costs to comply with legislation, particularly to move from control zone water bodies to another water body, anglers relocated due to decontamination requirements). Also, the dead Zebra Mussel shells and decaying mats of cladophora resulting from nutrient enrichment may create foul odour and unpleasant sight surrounding the beach areas when they decay, which may also lead to the decline in recreational fishing.

If recreational fishing in the study area is impacted, there is an impact on resident and non-

resident Canadian anglers' expenditures and consumer surplus, and foreign expenditure that is associated with recreational fishing. The argument here is that the non-resident, non-Canadian (foreign) consumer surplus is not a benefit to the economy, 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 Manitoba.[56]

Taking a conservative assumption of the 20% reduction of the catches by the presence of Zebra Mussel, the study estimated that the total inflation-adjusted values of the recreational expenditures and investment, and consumer surplus (excluding foreign consumer surplus) for Lake Winnipeg, the Red River, Nelson River and Cedar Lake would be approximately $10.2 million. Of the total value, recreational expenditures and investment accounted for $8.5 million and consumer surplus accounted for $1.6 million.[57]

In 2022, based on inflation-adjusted values for the subsequent 20-year time period, the total present value of the impact of recreational expenditures and investment, and consumer surplus (excluding foreign consumer surplus) would be approximately $155.5 million. Of the total value, recreational expenditures and investment accounted for $130.8 million and consumer surplus accounted for $24.8 million.

As stated earlier, it is expected that damage to recreational fishing caused by the presence of Zebra Mussel would be followed by some relocation of expenditures of resident and non-resident Canadians to other sectors in the economy. For example, if recreational fishing is unavailable, people's recreational activities may shift to other areas such as hiking or some other indoor activities. Similarly, while Zebra Mussel might raise the operational and maintenance costs of boat owners (e.g. repair, installing protective equipment)[58], 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.

Apart from recreational fishing, anglers also seek opportunities to enjoy other supplementary outdoor activities while on trips. The Canadian Tourism Commission (2006) found that relative to the average Canadian pleasure traveler, anglers were more likely to have attended sporting events (e.g., professional sporting events, amateur tournaments) and attractions with an agricultural or western theme (e.g., agro-tourism). Reduced recreational fishing and related activities will have economic impact to those whose livelihood depends on the development of this sector. The impacts on such subsidiary activities are anticipated to be notable, but are not

[56] It may be argued that there will still be some foreign expenditure 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.

[57] The estimation excludes decrease in activities caused by increased operational costs or by foul odour and unpleasant sight as Zebra Mussel decay.

[58] Vilaplana and Hushak (1994) estimated that Zebra Mussel 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.

quantified due to insufficient information.

Recreational Boating

Recreational boating in the study area will be impacted largely through higher operational and maintenance costs (e.g. routine maintenance/de-fouling, cost to comply with AIS regulations)[59] associated with boating and foul odour in waters and around beaches where Zebra Mussel have become established.

Boaters may also find increases in the accumulation of dead Zebra Mussel shells on beaches creating an unpleasant sight when they decay. Algae blooms and associated increased abundance of pollution indicator bacteria (e.g., *E. coli*) and pathogenic bacteria creating foul odour (Zebra Mussels Invade Ontario Waters).

While the annual costs for protective paint and maintenance for a boat in mussel infested waters is available in extant literature, the numbers of boats registered in Manitoba is not available. Hence, the resulting impact on operational and maintenance costs could not be estimated. Moreover, unlike commercial and recreational fishing, since recreational boating is not linked to ecological consequences found in Therriault et al. (2013) the impact analyses could not be derived precisely without additional information on impact related to recreational boating. However, it is anticipated that recreational boating activities along with consumer surplus would be reduced proportionally to the scale of the intensity of the odour.

Finally, similar to recreational fishing, it is also 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.

Other Recreational Activities

Zebra Mussel invasions are known to have contributed to dramatic increases in algae blooms. These blooms are anticipated to modify benthic habitats, recreational beaches and areas and create unpleasant sights and foul odour.

Zebra Mussel may cause Cladophora mats to expand, particularly around the near-shore areas posing health risk to Lake/river users. These are, in turn, expected to cause to a reduced level of wildlife viewing, hunting and other recreational activities along and associated economic impacts around Lake Winnipeg, Red, Cedar and Nelson Rivers.

Moreover, because mussels grow on hard, rocky lake bottoms colonies of Zebra Mussel on the lake bottom may cut viewers, hunters and beach users' feet by their sharp shell. (Zebra Mussels Invade Ontario Waters).

[59] Supra note 57.

Unlike commercial and recreational fishing, since recreational activities (e.g. wildlife viewing, hunting, Beach use) are not linked to ecological consequences, the impact analyses could not be derived more precisely without additional information on impact related to such activities.

In the absence of additional measures to prevent the presence of Zebra Mussel in the study area, it is also anticipated that the recreational users' consumer surplus associated with these activities would be to some degree jeopardized, relative to the extent of cladophora-related problems and habitat degradation for waterfowl and bird populations.[60]

Ecosystem Services

The variability or alteration of ecosystem services might increase upon the presence of Zebra Mussel, which may be economically inefficient in the long term. The loss or alteration of (indirect) ecosystem services provided by the study area may result in poorer water quality. For example, Zebra Mussel has led to dramatic losses to native mussel populations. The general rule is to expect a 90% loss of native mussel populations within 10 years of Zebra Mussel arrival (Therriault et al., 2013). These native mussels maintain water quality and are also considered to be food for certain native fish species. As a result, habitat for native fish species and ecosystem overall may significantly be altered.

The variability or alteration of ecosystem services might force us to find substitutes for the services they once provided, which might be much more expensive to duplicate and operate. Besides, there might be no suitable substitutes that might be found. As firms/households generally prefer to avoid risk or to be compensated for the changes, this might be deemed as impact of the presence of Zebra Mussel from ecosystem services context. Such calculations are highly expensive and time consuming process to follow and, as a result, were beyond the scope of this study.

Social and Cultural Impact

Over time, the presence of Zebra Mussel to Lake Winnipeg, Red, Cedar and Nelson Rivers could change lake ecosystems suitable for native fish species and has the potential to damage the public image of these lakes regionally, nationally and internationally.

The presence of Zebra Mussels may impact subsistence harvests 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 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 Zebra Mussels may also encourage the increased level of conflict and competition among

[60] 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.

subsistence harvesters/communities, and between recreational and commercial harvesters if changes cause fewer species availability.

In terms of social impact, changes in the structure of commercial and recreational activities (e.g. loss of beaches) may change the culture and way of life of many communities (e.g. Aborginal communities and in Gimli, Selkirk and Grand Marais). Quantitative assessments of these impacts are not feasible due to a lack of pertinent information.

Chapter 7: Conclusion

The goal of this study was to provide a detailed socio-economic impact assessment of the presence of Zebra Mussel in Lake Winnipeg, Red, Cedar and Nelson Rivers. The study heavily relied on Therriault et al. (2013) as well as additional sources of information which provided a solid and defensible foundation for assessing the socio-economic impacts that would result from the presence of Zebra Mussel in Lake Winnipeg, Red, Cedar and Nelson Rivers.

The study found that the Lake Winnipeg, Red, Cedar and Nelson Rivers make significant contribution to Manitoba's economy in terms of providing drinking water, water for agriculture, power generation, factories and industries and supporting commercial and recreational fisheries and other numerous recreational activities.

The study recognized that Lake Winnipeg, Red, Cedar and Nelson Rivers provide invaluable services to society, particularly those who reside close to the resources, through maintaining ecosystem health and biodiversity. The ecosystem value is presumed to be high, yet difficult to assess. The study found a similar challenge in quantitatively capturing the benefits of option and non-use values based on the existing set of information.

The Lake Winnipeg, Red, Cedar and Nelson Rivers provide considerable subsistence, social, cultural, and spiritual benefits to the people residing in the region and to the economy as a whole. The area also provides opportunities for research and educational activities that result in a better understanding of the ecology.

Table 5 below summarizes the findings of the study by sector:

Table 5: Baseline Values and Impact of Zebra Mussel in Lake Winnipeg, the Red River, Nelson River and Cedar Lake by Sector*

Sector	Baseline Values		Impact			
	2015		2022		Present Values for 20 Years	
	Expenditure	Consumer Surplus	Costs	Consumer Surplus	Costs	Consumer Surplus
Drinking Water	NA	Not Applicable	3,119,057	Not Applicable	47,795,807	Not Applicable
Power Generation	NA	Not Applicable	4,608,900	Not Applicable	70,625,858	Not Applicable
Agriculture/industry	NA	NA	NA	NA	NA	NA
Commercial Fishing	35,525,587	NA	7,105,117	NA	108,877,391	NA
Recreational Fishing	42,661,653	8,082,961	8,532,331	1,616,592	130,747,719	24,772,334
Recreational Hunting	7,061,411	2,197,018	1,412,282	439,404	21,641,530	6,733,332
Recreational Boating	163,315,160	NA	Qualitative	Qualitative	Qualitative	Qualitative
Wildlife Viewing	12,158,156	3,195,592	Qualitative	Qualitative	Qualitative	Qualitative
Other Recreational Act.	Qualitative	NA	Qualitative	Qualitative	Qualitative	Qualitative
Ecosystem Services	Qualitative	Qualitative	Qualitative	Qualitative	Qualitative	Qualitative
Non-Use Values	Qualitative	Qualitative	Qualitative	Qualitative	Qualitative	Qualitative

Source: Fisheries and Oceans Canada staff calculation, Policy and Economics, Central and Arctic Region.
*Note: NA – Not available; * For details, please see the respective section in Chapter 3 and 4.*

The study estimated that the presence of Zebra Mussel can negatively impact key infrastructure by colonizing anything immersed in the water and impose additional costs to power generation, commercial fishers, anglers, boaters, and beach-goers and thereby reduce recreational potential of the Lake Winnipeg, Red, Cedar and Nelson Rivers (see Table 5 and the respective section in Chapter 4).

The study found that the variability or alteration of ecosystem services might increase upon the presence of Zebra Mussel which may be economically inefficient in the long term. This may, in turn, affect trapping and hunting opportunities particularly for Aboriginal communities, weaken/obsolete inter-generational transfer of knowledge/culture, change traditional ways of life, and damage the public image of these lakes regionally, nationally and internationally.

The study also recognizes that the impact of Zebra Mussel would possibly trigger some (re)distributional effects in terms of production and employment due to the presence of substitute/complementary products or activities. Furthermore, 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 Zebra Mussel 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 discussed in Chapter 3, the estimations of the baseline values as well as impacts discussed in this study should be viewed as mostly speculative, providing the best estimates from available research. 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. Furthermore, since Therriault et al. (2013) 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 Therriault et al. (2013).

It was also noted that the baseline values as well as impact 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, industries covered, inclusion of 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. The most notable obstacles/limitations identified are: (i) lack of Lake specific information by activity; (ii) assumptions about the future baseline values of activities; (iii) lack of a more explicit linkage between the ecological risk assessments and the socio-economic factors proposed in the current document.

These limitations have been mitigated to some extent through the adoption of assumptions and application of proxies, with appropriate adjustments, 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). 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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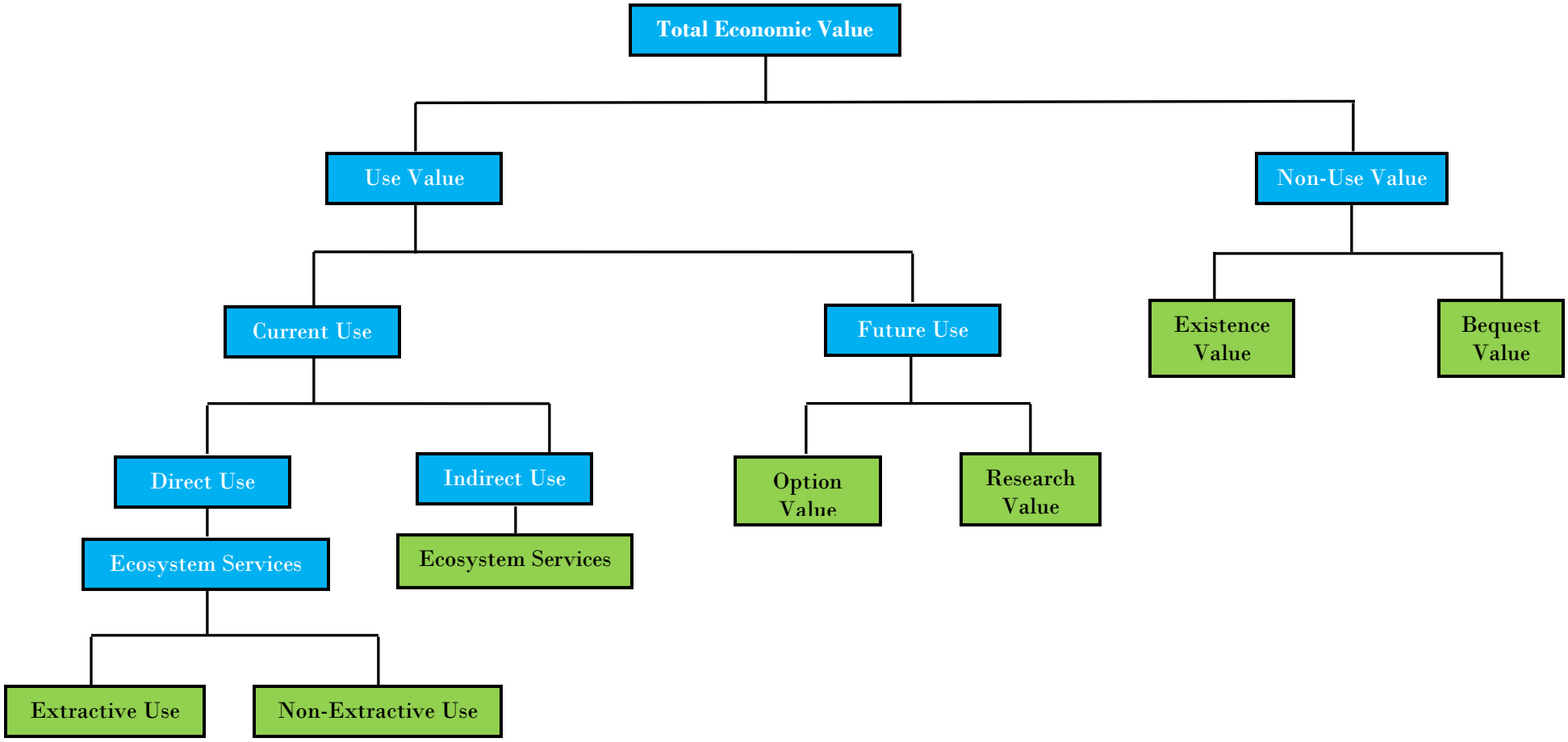
Matrix 1: Total Economic Valuation Flowchart



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 Lake Winnipeg, the Red River, Nelson River and Cedar Lake (e.g. commercial fishing).

Non-extractives use: Non-extractives uses do not cause water level and/or commodities provided by Lake Winnipeg, the Red River, Nelson River and Cedar Lake (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). [61]

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.

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

Existence value: Existence value arises because people intrinsically value the existence of Lake Winnipeg, the Red River, Nelson River and Cedar Lake regardless of its use. Existence value includes the benefits from knowing that Lake Winnipeg, the Red River, Nelson River and Cedar Lake is being used by others as well as cultural values for an economy.[62]

[62] 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).

Annex 1: Map of Lake Winnipeg, the Red River, Nelson River and Cedar Lake

Source: Manitoba Sustainable Development, April 2017

Annex 2: Selected Socio-Economic Indicators for Manitoba

Characteristics	Manitoba	Canada
Total population	1,296,000	35,848,600
Male	*644,411*	*17,776,946*
Female	*651,570*	*18,071,664*
Population density per square kilometre	2.35	4.00
Land area (square km)	552,329	8,965,121
Median age of the population	37.7	40.5
% of the population aged 15 and over	81	79
Aboriginal identity population	195,900	1,400,700
Total population 15 years and over	1,053,232	28,183,312
In the labour force	674,100	19,278,000
Employed	*636,200*	*17,946,600*
Unemployed	*37,900*	*1,331,400*
Employment rate	*64.4%*	*61.3%*
Unemployment rate	*6.9%*	*5.6%*
Total experienced labour force 15 years and over	6,473,730	16,861,180
Agriculture and other resource-based industries	*28,700*	*646,200*
Construction	*46,300*	*1,360,000*
Manufacturing	*63,800*	*1,709,000*
Retail trade	*90,300*	*2,739,000*
Finance and real estate	*31,500*	*1,108,600*
Business services	*18,500*	*759,700*
Other services	*29,900*	*756,300*
Median income - Persons 15 years and over ($)	*30,371*	*31,603*

Source: Statistics Canada, 2015. 2011 Statistics Canada National Household Survey.

Annex 3(a): Landings/Landed Values of Commercial fisheries in Lake Winnipeg/the Red River/Nelson River/Cedar Lake during 2011-15

Species	2011	2012	2013	2014	2015	2011	2012	2013	2014	2015
	Landings (Round Eq. Weight in Kg)					Landed Value				
	Lake Winnipeg									
Pickerel	4,435,340	4,379,928	4,169,411	3,149,346	2,791,203	$14,032,553	$12,323,640	$12,149,526	$10,688,489	$8,814,392
Whitefish	1,473,884	1,282,472	1,634,053	2,102,390	2,675,411	$2,143,972	$2,005,293	$2,750,513	$3,830,126	$4,833,165
Sauger	260,505	192,567	271,647	337,928	256,312	$692,902	$533,265	$692,017	$875,026	$714,320
Pike	44,959	108,393	162,275	203,208	156,671	$32,398	$82,612	$112,537	$159,380	$117,800
Mullet	49,368	59,660	129,567	142,434	151,562	$21,675	$29,055	$62,591	$71,712	$78,565
Perch	8,206	19,531	23,877	27,061	31,015	$18,779	$49,254	$56,210	$63,404	$78,965
Others*	33,969	37,084	58,628	157,796	204,850	$73,805	$101,726	$177,231	$359,960	$488,156
Total	**6,306,231**	**6,079,635**	**6,449,458**	**6,120,164**	**6,267,025**	**$17,016,085**	**$15,124,847**	**$16,000,626**	**$16,048,097**	**$15,125,364**
	Cedar Lake									
Pickerel	207,662	182,863	205,886	156,310	227,583	$656,638	$517,757	$601,017	$553,464	$775,875
Pike	206,618	206,603	138,892	119,076	126,942	$148,149	$158,900	$99,519	$96,500	$90,962
Whitefish	29,378	20,464	21,941	22,165	37,982	$40,444	$31,521	$34,059	$40,406	$73,725
Mullet	64,814	53,253	105,983	104,084	116,292	$28,033	$26,442	$52,417	$52,495	$60,640
Others**	966	889	592	769	2,582	$4,500	$3,796	$2,726	$5,046	$17,468
Total	**509,437**	**464,072**	**473,294**	**402,405**	**511,380**	**$877,765**	**$738,416**	**$789,738**	**$747,912**	**$1,018,670**
	Nelson River									
Pickerel	113,339	137,940	113,017	101,181	90,328	$349,787	$356,861	$309,382	$342,544	$307,505
Pike	212,971	337,060	271,090	242,307	162,082	$161,684	$256,606	$199,871	$197,931	$117,567
Whitefish	57,316	80,901	88,385	75,549	74,746	$67,014	$117,963	$130,669	$133,008	$123,999
Others***	42,047	73,331	95,556	69,424	88,740	$36,410	$53,275	$62,219	$52,090	$72,241
Total	**425,673**	**629,232**	**568,049**	**488,462**	**415,895**	**$614,896**	**$784,706**	**$702,140**	**$725,573**	**$621,312**
Grand Total	**7,241,342**	**7,172,939**	**7,490,801**	**7,011,031**	**7,194,300**	**$18,508,746**	**$16,647,968**	**$17,492,504**	**$17,521,582**	**$16,765,345**

Source: Freshwater Fish Marketing Corporation

*Notes: * Includes whitefish roe, goldeye, tullibee, whitebass, carp, drum, inconnu and trout; ** Includes whitefish roe, sauger, carp, perch and goldeye; *** Includes whitefish roe, goldeye, tullibee, sauger and perch.*

Annex 3(b): Landings, Landed Values and Market Values of Commercial fisheries in Lake Winnipeg, the Red River, Nelson River and Cedar Lake during 2006-15

Lake	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
	Landings (Kg)*									
Cedar	399,774	389,306	510,611	566,216	645,508	509,437	464,072	473,294	402,405	511,380
Nelson River	781,599	753,039	520,341	529,416	625,288	425,673	629,232	568,049	488,462	415,895
Lake Winnipeg	6,239,469	6,376,937	6,453,625	6,507,197	6,582,631	6,306,231	6,079,635	6,449,458	6,120,164	6,267,025
Total	**7,420,842**	**7,519,283**	**7,484,576**	**7,602,829**	**7,853,427**	**7,241,342**	**7,172,939**	**7,490,801**	**7,011,031**	**7,194,300**
Peddled**	124,670	126,324	125,741	127,728	131,938	121,655	120,505	125,845	117,785	120,864
Grand Total	**7,545,512**	**7,645,607**	**7,610,317**	**7,730,557**	**7,985,365**	**7,362,996**	**7,293,444**	**7,616,646**	**7,128,817**	**7,315,164**
Manitoba Total	**11,631,991**	**11,031,872**	**11,427,710**	**11,182,198**	**10,934,101**	**10,080,144**	**10,637,553**	**10,688,251**	**11,135,535**	**11,538,539**
	Landed Values*									
Cedar	$751,788	$566,759	$685,546	$809,919	$984,308	$877,765	$738,416	$789,738	$747,912	$1,018,670
Nelson River	$1,284,869	$1,291,551	$799,145	$643,977	$833,345	$614,896	$784,706	$702,140	$725,573	$621,312
Lake Winnipeg	$17,176,008	$18,902,439	$18,049,681	$16,718,196	$15,943,235	$17,016,085	$15,124,847	$16,000,626	$16,048,097	$15,125,364
Total	**$19,212,665**	**$20,760,749**	**$19,534,372**	**$18,172,091**	**$17,760,888**	**$18,508,746**	**$16,647,968**	**$17,492,504**	**$17,521,582**	**$16,765,345**
Peddled**	$414,994	$448,432	$421,942	$392,517	$383,635	$399,789	$359,596	$377,838	$378,466	$362,131
Grand Total	**$19,627,658**	**$21,209,181**	**$19,956,315**	**$18,564,608**	**$18,144,523**	**$18,908,535**	**$17,007,564**	**$17,870,342**	**$17,900,048**	**$17,127,477**
Manitoba Total	**$24,404,136**	**$25,446,593**	**$24,745,679**	**$22,473,576**	**$21,732,917**	**$22,272,547**	**$21,840,770**	**$21,731,647**	**$22,880,704**	**$22,694,477**
	Market Values**									
Cedar	$1,503,575.66	$1,133,518	$1,371,093	$1,619,837	$1,968,616	$1,755,531	$1,476,832	$1,579,475	$1,495,825	$2,037,340
Nelson River	$2,569,738	$2,583,101	$1,598,290	$1,287,953	$1,666,690	$1,229,792	$1,569,411	$1,404,280	$1,451,145	$1,242,623.68
Lake Winnipeg	$34,352,017	$37,804,879	$36,099,362	$33,436,392	$31,886,469	$34,032,169	$30,249,694	$32,001,252	$32,096,194	$30,250,727
Total	**$38,425,330**	**$41,521,499**	**$39,068,745**	**$36,344,182**	**$35,521,775**	**$37,017,493**	**$33,295,937**	**$34,985,007**	**$35,043,164**	**$33,530,691**
Peddled**	$829,987.12	$896,864	$843,885	$785,034	$767,270	$799,578	$719,192	$755,676	$756,932	$724,263
Grand Total	**$39,255,317**	**$42,418,363**	**$39,912,630**	**$37,129,216**	**$36,289,046**	**$37,817,071**	**$34,015,129**	**$35,740,683**	**$35,800,097**	**$34,254,954**

*Source: * Freshwater Fish Marketing Corporation; ** Staff Calculation, Policy and Economics, DFO.*

Annex 4: Fish caught by Recreational Anglers by Species in Lake Winnipeg, the Red River, Nelson River and Cedar Lake in 2010

Origin of Anglers	Walleye	Pike	Channel catfish	Smallmouth bass	Perch	Other species	Total fish
Lake Winnipeg							
Resident	408,400	18,521	10,453	11,361	132,769	80,227	661,730
Canadian Non-Resident	1,269	195	-	98	-	-	1,561
Foreign Visitor	9,183	184	31	154	768	256	10,577
Total	**418,852**	**18,900**	**10,484**	**11,612**	**133,538**	**80,483**	**673,868**
Cedar Lake							
Resident	5,514	5,254	-	-	-	-	10,768
Canadian Non-Resident	-	-	-	-	-	-	-
Foreign Visitor	15,882	21,469	-	-	51	61	37,464
Total	**21,397**	**26,723**	**-**	**-**	**51**	**61**	**48,232**
Red River							
Resident	123,882	17,186	215,210	13,431	25,640	105,535	500,885
Canadian Non-Resident	474	-	11,111	195	-	195	11,976
Foreign Visitor	3,012	184	9,313	-	1,076	1,383	14,968
Total	**127,368**	**17,371**	**235,634**	**13,626**	**26,715**	**107,114**	**527,828**
Grand Total	**567,617**	**62,994**	**246,118**	**25,238**	**160,304**	**187,658**	**1,249,928**

Source: 2010 Survey of Recreational Fishing in Manitoba (unpublished) provided by Manitoba Sustainable Development.