Species at Risk Act
Management Plan Series

Report on the Progress of Management Plan Implementation for the Kiyi, Upper Great Lakes (*Coregonus kiyi kiyi*) in Canada for the Period 2016 to 2021

Kiyi, Upper Great Lakes

2023

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For copies of the progress report, or for additional information on species at risk, including Committee on the Status of Endangered Wildlife in Canada (COSEWIC) status reports, recovery strategies, residence descriptions, action plans, and other related recovery documents, please visit the Species at Risk Public Registry.

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Preface

The federal, provincial, and territorial government signatories under the Accord for the Protection of Species at Risk (1996) agreed to establish complementary legislation and programs that provide for protection of species at risk throughout Canada. Section 72 of the *Species at Risk Act* (S.C. 2002, c.29) (SARA) requires the competent minister to report on the implementation of the management plan for a species at risk, and on the progress towards meeting its objectives within 5 years of the date when the management plan was placed on the Species at Risk Public Registry and in every subsequent 5-year period, until its objectives have been achieved or the species becomes threatened or endangered under SARA.

Reporting on the progress of management plan implementation requires reporting on the collective efforts of the competent minister(s), provincial governments and all other parties involved in conducting activities that contribute towards the conservation of the species. Management plans identify broad strategies and conservation measures that will provide the best chance of conserving species at risk. Some of the identified strategies and measures are sequential to the progress or completion of others, and not all may be undertaken or show significant progress during the time frame of a report on the progress of management plan implementation (progress report).

The Minister of Fisheries and Oceans and the Minister responsible for the Parks Canada (PC), are the competent ministers under SARA for the Kiyi (Upper Great Lakes) and have prepared this progress report.

As stated in the preamble to SARA, success in the conservation of species at risk depends on the commitment and cooperation of many different groups that will be involved in implementing the directions set out in the management plan and will not be achieved by Fisheries and Oceans Canada (DFO) and PC, or any other jurisdiction alone. The cost of conserving species at risk is shared amongst different constituencies. All Canadians are invited to join in supporting and implementing the “Management Plan for Kiyi, Upper Great Lakes (*Coregonus kiyi kiyi*) in Canada” for the benefit of the species and Canadian society as a whole.

Acknowledgments

This progress report was prepared by Kurtis Smith, Peter Jarvis, and Joshua Stacey (DFO). To the extent possible, this progress report has been prepared with information provided by Mark Vinson, Daniel Yule and Darryl Hondorp (United States Geological Survey), Thomas Pratt (DFO) and Eric Berglund (Ministry of Natural Resources and Forestry). DFO would also like to express its appreciations to all individuals and organizations who have contributed to the conservation of the Kiyi and have reviewed this document.

Executive summary

The Kiyi Upper Great Lakes (*Coregonus kiyi kiyi*), hereafter referred to as Kiyi, was listed as special concern under the *Species at Risk Act* (SARA) in 2005. The "Management Plan for Kiyi, Upper Great Lakes (*Coregonus kiyi kiyi*) in Canada" was finalized and published on the Species at Risk Public Registry in 2016.

The main anthropogenic threat identified in the management plan for the Kiyi is invasive species introductions. Additional threats include contaminant inputs, nutrient loading, climate change, disease, and fishing pressure.

The goal of the management plan for the Kiyi is to ensure the long-term persistence of Kiyi throughout its current range in Lake Superior.

The "Report on the Progress of Management Plan Implementation for the Kiyi, Upper Great Lakes (*Coregonus kiyi kiyi*) in Canada for the Period 2016 to 2021" (progress report) documents the progress made in implementing the management plan for Kiyi between 2016 and 2021. It summarizes progress that DFO, PC, Ontario provincial agencies, conservation authorities, and other stakeholders have made towards implementing the management plan and achieving its objectives. During this period, progress has been made in:

- conducting population surveys and habitat monitoring to better understand the population dynamics of Kiyi in Lake Superior (as a result of the COVID-19 pandemic, sampling was greatly restricted in 2020 and 2021)
- collaborating through existing networks to coordinate implementation of management actions of benefit to Kiyi
- researching the quantity and quality of habitat required to ensure long-term conservation of Kiyi
- conducting threat assessments to evaluate threat factors that may be impacting Kiyi (for example, invasive species, eutrophication, disease)
- promoting aquatic species awareness, reporting and monitoring, and encouraging the use of best management practices (BMPs) that will help reduce impacts on Kiyi

Substantial progress has been made towards achieving the management objective for the Kiyi in Canada as a result of these ongoing and/or completed activities. Continued fish community sampling in Lake Superior has revealed temporal trends in Kiyi abundance and distribution. However, a number of research questions stemming from the management plan remain unanswered. For example, further research and surveys are required to ascertain the key drivers of Kiyi population dynamics. Additionally, the quantity and quality of habitat required to ensure long-term conservation of Kiyi to support management goals need to be determined. For this reason, it may be beneficial to focus future management activities on addressing these knowledge gaps.

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1. Introduction

The “Report on the Progress of Management Plan Implementation for the Kiyi, Upper Great Lakes (*Coregonus kiyi kiyi*) in Canada for the Period 2016 to 2021” outlines the progress made towards meeting the objectives listed in the “Management Plan for Kiyi, Upper Great Lakes (*Coregonus kiyi kiyi*) in Canada” during the indicated time period[1] and is part of a series of documents for this species that are linked and should be taken into consideration together; including the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) status report (COSEWIC 2005) and the management plan (Fisheries and Oceans [DFO] 2016).

Section 2 of the progress report reproduces and summarizes key information on the anthropogenic threats that this species is facing, management objectives for conserving this species, and conservation approaches to achieve the objectives (for more details, readers should refer to the management plan). Section 3 reports on the progress of activities identified in the management plan to support achieving management objectives. Section 4 provides a concluding statement about the progress of actions taken and outcomes of these conservation efforts.

2. Background

2.1 COSEWIC assessment summary

The listing of Kiyi (Upper Great Lakes) (hereafter referred to as Kiyi) under the *Species at Risk Act* (S.C. 2002, c.29) (SARA) in 2005 led to the development and publication of the management plan for Kiyi in 2016. The management plan is consistent with the information provided in the COSEWIC status report (COSEWIC 2005) and the COSEWIC summary information is included in section 1.1 of the management plan.

Assessment summary: May 2005

Common name (population): Kiyi (Upper Great Lakes)
Scientific name: *Coregonus kiyi kiyi*
COSEWIC status: Special Concern
Reason for designation: Currently found only in Lake Superior, the subspecies has been extirpated from lakes Huron and Michigan, as the result of a complex of factors, which included exploitation and introduced exotic species. The extirpation in lakes Huron and Michigan occurred more than three generations in the past. The remaining population in Lake Superior appears to be stable, and supports a small, regulated fishery. Other threats, such as the introduction of exotic species, which impacted populations in the lower lakes do not appear to be important in Lake Superior.
Canadian occurrence: Ontario
COSEWIC status history: Designated special concern in April 1988. Split into two subspecies (Upper Great Lakes Kiyi and Lake Ontario Kiyi) in May 2005. The Upper Great Lakes Kiyi was designated special concern in May 2005. Last assessment based on an update status report.

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[1] This progress report primarily represents the 2016 to 2021 time period; however, any related progress that occurred from 2013 to 2015 (the time period leading up to the posting of the management plan) is also included in this report.

2.2 Distribution

Since 2013 (the latest year of data reported in the management plan), Kiyi has continued to be detected through trawling and acoustic surveys conducted in Lake Superior. Tables 1 and 2 list historical and recent records of the species within Canadian waters that resulted from surveys conducted by the United States Geological Survey (USGS) and the Ontario Ministry of Natural Resources and Forestry (MNRF). Figure 1 displays historical and recent records of the species throughout Lake Superior including both U.S. and Canadian waters. USGS reports describe the status and trends in the Lake Superior fish community, including Kiyi, from 2011 to 2019 (sampling was not undertaken by USGS in Canadian waters in 2020 and 2021); sampling details from these USGS reports are summarized in table 4. However, survey details are not available for all of the records. It is important to note that information provided in tables 1 and 2 provide an account of where and when Kiyi has been detected and is not meant to convey changes in abundance over time or infer population trends.

Table 1. Kiyi (Upper Great Lakes) captures from the United States Geological Survey's nearshore sampling of Canadian stations in Lake Superior and surveys conducted by the Ontario Ministry of Natural Resources and Forestry[2].

Location description	Station #	Time period	Years detected (# captured)
Little Trout Bay	400	Historical (pre 2000)	1993 (**3**), 1994 (**12**), 1997 (**3**)
		2000 to 2012	2000 (**2**), 2009 (**1**)
		2013 to 2021	2017 (**1**)
Pie Island	403	2000 to 2012	2005 (**1**)
Thunder Bay	401, 402	Historical (pre 2000)	1989 (**4**), 1992 (**12**), 1993 (**11**), 1994 (**2**), 1996 (**6**), 1997 (**2**)
		2000 to 2012	2000 (**75**), 2001 (**5**), 2002 (**10**), 2003 (**16**), 2004 (**16**), 2005 (**1**), 2006 (**1**)
Black Bay	405, 406, 407, 408	2000 to 2012	2000 (**1**), 2006 (**6**)
		2013 to 2021	2016 (**4**)
Nipigon Bay	412, 413, 414, 415	Historical (pre 2000)	1992 (**6**), 1994 (**2**), 1996 (**1**)
		2000 to 2012	2005 (**2**), 2006 (**1**)
		2013 to 2021	2017 (**4**), 2019 (**1**)
Simpson Island	416	Historical (pre 2000)	1992 (**3**), 1995 (**4**)
Ashburton Bay	420	Historical (pre 2000)	1994 (**1**)
Northeast Coast (Pukaskwa National Park to Michipicoten Bay)	451, 462, 463, 464, 465, 466	Historical (pre 2000)	1993 (**1**), 1994 (**13**), 1995 (**4**), 1996 (**35**), 1998 (**1**), 1999 (**18**)
		2000 to 2012	2000 (**40**), 2001 (**7**), 2002 (**2**), 2003 (**5**), 2005 (**5**), 2006 (**7**), 2007 (**8**), 2009 (**6**), 2012 (**1**)
		2013 to 2021	2019 (**1**), 2017 (**2**), 2016 (**2**), 2015 (**3**)
Eastern Coast (Lake Superior Provincial Park)	454, 455, 456, 457	2000 to 2012	2001 (**1**), 2008 (**1**)
Whitefish Bay	459, 460, 461	Historical (pre 2000)	1992 (**1**), 1994 (**19**)
		2000 to 2012	2000 (**1**), 2001 (**1**)

[2] Data provided by United States Geological Survey (USGS) from annual trawling surveys and surveys conducted by the Ontario Ministry of Natural Resources and Forestry (MNRF). Station # refers to sampling stations monitored by USGS.

Table 2. Kiyi (Upper Great Lakes) captures from the United States Geological Survey's offshore sampling of Canadian stations in Lake Superior and from the Ontario Ministry of Natural Resources and Forestry[3].

Location description	Station #	Time period	Years detected (# captured)
Central Basin	2127	2000 to 2012	2011 (**43**), 2012 (**6**)
		2013 to 2021	2013 (**15**), 2015 (**16**), 2016 (**33**), 2017 (**34**), 2018 (**54**), 2019 (**30**)
	2155	2000 to 2012	2012 (**116**)
		2013 to 2021	2013 (**118**), 2015 (**36**), 2017 (**134**), 2018 (**243**), 2019 (**144**)
	753	2000 to 2012	2012 (**103**)
		2013 to 2021	2013 (**99**), 2014 (**83**), 2015 (**111**), 2017 (**93**), 2018 (**12**), 2019 (**119**)
	2139	2000 to 2012	2011 (**102**), 2012 (**158**)
		2013 to 2021	2013 (**95**), 2014 (**272**), 2015 (**72**), 2016 (**9**), 2017 (**53**), 2018 (**48**), 2019 (**197**)
Eastern Basin	2135	2000 to 2012	2011 (**67**)
		2013 to 2021	2013 (**12**), 2015 (**10**), 2018 (**1**)
	2119	2000 to 2012	2011 (**2**), 2012 (**2**)
		2013 to 2021	2013 (**1**), 2016 (**4**), 2017 (**4**), 2018 (**2**), 2019 (**4**)
	2165	2013 to 2021	2017 (**1**)
	2145	2000 to 2012	2012 (**57**)
		2013 to 2021	2013 (**113**), 2014 (**14**), 2015 (**15**), 2017 (**74**), 2018 (**20**), 2019 (**82**)
	2129	2000 to 2012	2011 (**44**), 2012 (**16**)
		2013 to 2021	2013 (**18**), 2014 (**13**), 2015 (**10**), 2016 (**40**), 2017 (**15**), 2018 (**18**), 2019 (**28**)
	2153	2000 to 2012	2012 (**27**)
		2013 to 2021	2013 (**28**), 2014 (**26**), 2015 (**14**), 2017 (**33**), 2018 (**3**), 2019 (**167**)
	2121	2013 to 2021	2016 (**1**)
	2137	2000 to 2012	2011 (**91**), 2012 (**20**)
		2013 to 2021	2013 (**42**), 2014 (**12**), 2015 (**18**), 2016 (**31**), 2017 (**1**), 2018 (**2**), 2019 (**7**)

[3] Data provided by United States Geological Survey (USGS) from annual trawling surveys and surveys conducted by the Ontario Ministry of Natural Resources and Forestry (MNRF). Station # refers to sampling stations monitored by USGS.

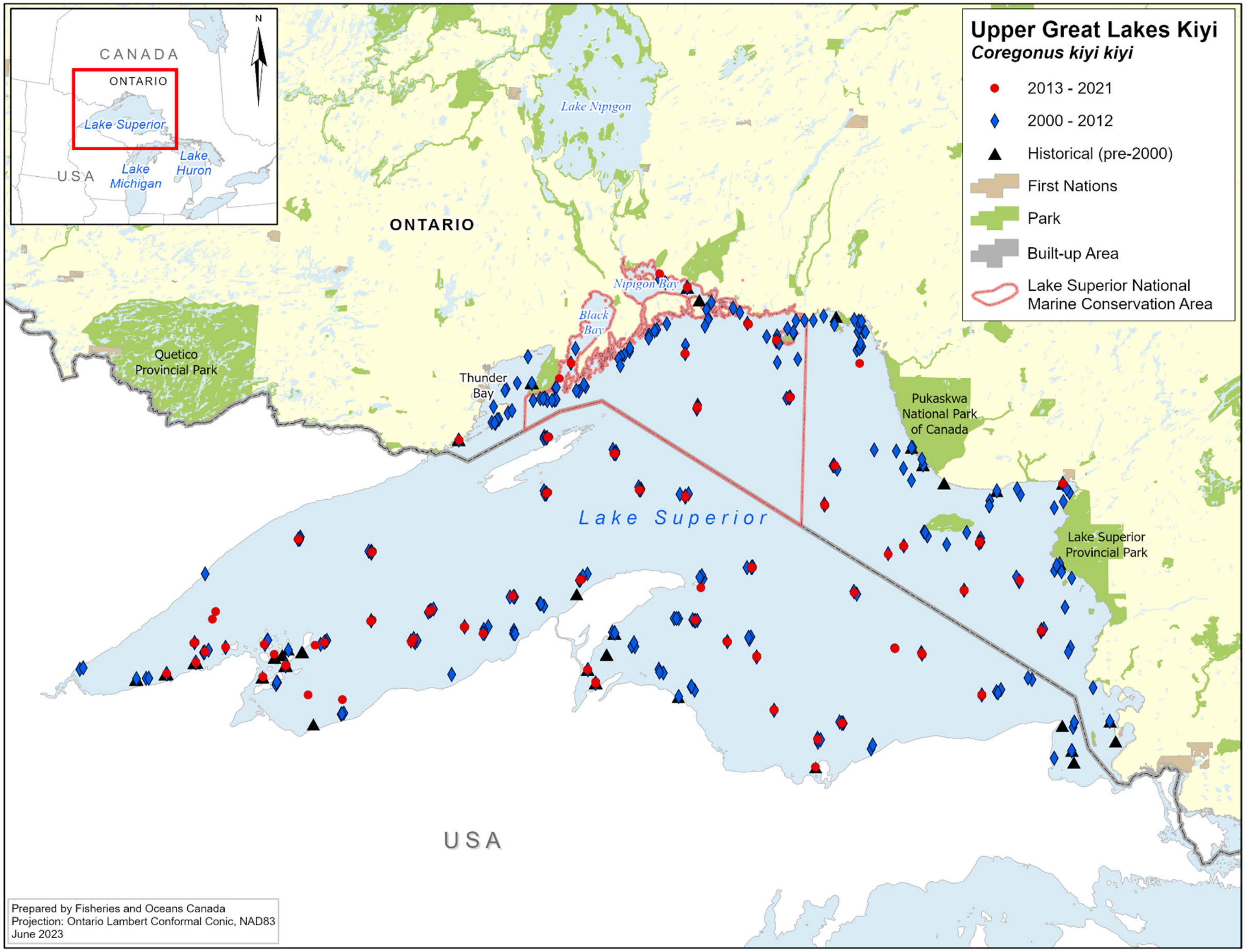

Figure 1. Historical distribution and recent detections of Kiyi (Upper Great Lakes).

2.3 Threats to the Kiyi

This section summarizes the information found in the management plan on threats to the conservation of Kiyi.

Table 3 summarizes the threats to Kiyi in Canada. Please refer to section 1.5 of the management plan for more information on these threats.

Table 3. Threat classification table for Kiyi (Upper Great Lakes) (Fisheries and Oceans [DFO] 2016).

Threat	Extent (widespread, localized)	Occurrence (current, imminent, anticipated)	Frequency (seasonal, continuous)	Causal certainty (high, medium, low)	Severity (high, medium, low)	Overall level of concern (high, medium, low)
Invasive species	Widespread	Current/ anticipated	Continuous	High	High	High
Water quality: contaminant inputs	Widespread	Current	Continuous	Low	Low	Low
Water quality: nutrient loading	Widespread	Current	Continuous	Low	Low	Low
Climate change	Widespread	Current/ anticipated	Continuous	Unknown	Unknown	Low
Disease	Unknown	Anticipated	Continuous	Unknown	Unknown	Low
Fishing pressure	Localized	Anticipated	Seasonal	Low	Unknown	Low

2.4 Management

This section summarizes the management objectives identified in the management plan (DFO 2016) for Kiyi conservation.

2.4.1 Goal

The goal of the management plan is to ensure the long-term persistence of Kiyi throughout its current range in Lake Superior. Management should be directed toward gaining a greater understanding of its life history and the causes of its range contraction, and addressing the threat of invasive species to Kiyi populations.

2.4.2 Objectives

The following short-term objectives (over the next 5 to 10 years) have been identified to assist in achieving the management goal:

i. to understand the health and extent of existing populations and to determine population and habitat trends
ii. to improve knowledge of the species' biology, ecology, and habitat requirements
iii. to evaluate and mitigate threats to the species and its habitat
iv. to maintain and expand existing populations, where applicable
v. to ensure the efficient use of resources in the management of this species
vi. to improve awareness of Kiyi and engage the public in the conservation of this species

3. Progress towards conservation

Section 72 of SARA requires the competent Minister(s) to report on the implementation of the management plan and the progress towards meeting its objectives, within 5 years after it is included in the Species at Risk Public Registry and in every subsequent 5-year period until its objectives have been achieved or unless the species becomes threatened or endangered under SARA. In the interest of capturing the most recent progress on the conservation of Kiyi, this document includes actions completed by the end of 2021. The management plan for Kiyi divides conservation efforts into five broad strategies:

1. monitoring and assessment
2. management
3. research and protection
4. stewardship and restoration
5. outreach and communication

Progress in carrying out these actions is reported in table 4.

3.1 Actions supporting management objectives

Table 4 provides information on the implementation of activities undertaken to achieve the management objectives identified in the implementation schedule table of the Kiyi (Upper Great Lakes) management plan (DFO 2016). Table 4 is not necessarily an exhaustive list of all relevant activities, but is meant to broadly represent work undertaken between 2016 and 2021, as well as activities conducted in 2013, 2014, and 2015 that were not captured in the management plan.

Table 4. Details of activities supporting the conservation of the Kiyi (Upper Great Lakes) from 2016 to 2021 as well as activities conducted in 2013, 2014, and 2015 that were not captured in the management plan.

Conservation measure	Broad strategy	Descriptions and results	Management objectives	Participants[4]
Protocol development: Develop consistent protocols for surveying and monitoring Kiyi populations.	Monitoring and assessment	The United State Geological Survey (USGS) (Lake Superior Biological Station) conducts annual daytime bottom-trawl surveys in nearshore (approximately 15 to 80 m depths) and offshore (approximately 100 to 300 m depths) waters of Lake Superior (see Vinson et al. 2019a). Although these programs are not designed specifically for Kiyi (*Coregonus kiyi kiyi*), they have provided the best available information to estimate population trends. The nearshore survey has been conducted annually since 1978 in U.S. waters, and since 1989 in Canadian waters. The nearshore survey only captures Kiyi incidentally, as it occurs at depths that are too shallow to be prime Kiyi habitat. The offshore survey has been conducted annually since 2011 in both U.S. and Canadian waters. A total of 79 nearshore and 36 offshore sampling stations have been established. Additionally, as a part of the annual survey, surface water trawling is performed to monitor the abundance and spatial distribution of larval coregonids. Currently, larval coregonids are not identified to species but are assumed to be a mix of Cisco (*Coregonus artedi*), Bloater (*C. hoyi*), Shortjaw Cisco (*C. zenithicus*) and Kiyi. The USGS Great Lakes Science Center has a project underway to identify the	i, ii, iii, iv	**USGS**, Academic Institutions (AI), Red Cliff Band of Lake Superior Chippewa, USEPA, U.S. Fish and Wildlife Service (USFWS)

[4] Lead participant(s) is/are listed on top and in bold; other participants are listed alphabetically

Conservation measure	Broad strategy	Descriptions and results	Management objectives	Participants[4]
		larval species, which they hope to integrate into their annual surveys (Yule pers. comm. 2022). The binational Cooperative Science and Monitoring Initiative (CSMI) completes a summer whole-lake survey of Lake Superior on a 5-year cycle using cross- and along-contour daytime bottom-trawl surveys and nighttime mid-water trawling and acoustic surveys. The 2016 survey sampled 53 stations including both nearshore and offshore sites (5 to 315 m depths). The design of the study was informed by a collaboration between the US Environmental Protection Agency (USEPA) and the USGS. The fish community assessment component of the study was the responsibility of the USGS (Vinson et al. 2019b). Yule et al. (2013) described a new acoustic method for estimating the density of pelagic fish in Lake Superior, including Kiyi. This method is used in the CSMI surveys of Lake Superior. Grow et al. (2020) compared estimates of pelagic fish density, acquired by down-looking acoustic surveys such as those described in Yule et al. (2013), to estimates obtained by a new multi-directional-towed sled capable of sampling the entire water column. The down-looking acoustic survey method currently in use may miss fish in shallow water strata as well as those who may move out of the field of detection due to vessel avoidance behavior. The new method would employ transducers that are aimed downward, sideways, and upwards effectively compensating for such blind spots. The multi-directional-towed sled provided greater estimates of fish density in strata less than 14 m in depth; however, the two		

Conservation measure	Broad strategy	Descriptions and results	Management objectives	Participants[4]
		acoustic approaches provided similar results at water column depths greater than 14 m where Kiyi were predominant.		
Long-term monitoring: Integrate the long-term monitoring requirements of Kiyi with existing fish community survey efforts.	Monitoring and assessment	The most comprehensive fish community survey of Lake Superior is the USGS's annual nearshore and offshore daytime bottom-trawl (including sites in Canadian waters). Kiyi had been a minor component of the nearshore surveys but when the survey was expanded in 2011 to include the offshore portion, Kiyi became a well-represented species (see Vinson et al. 2019a). The CSMI surveys of Lake Superior that occur on a 5-year cycle also serve as a valuable source of Kiyi population metrics.	i	**USGS**
Prey monitoring: Monitor the status of *Mysis* populations.	Monitoring and assessment	The USEPA Great Lakes National Program Offices (GLNPO) biology monitoring program focuses on the Great Lakes lower food web, and includes biannual sampling of *Mysis*, a primary prey item of Kiyi, in Lake Superior (USEPA 2020). Additionally, the USGS collects *Mysis* during the CSMI surveys and the samples are analyzed by the USEPA. Based on the GLNPO monitoring, Jude et al. (2018) assessed *Mysis* density and biomass from 2006 to 2016; over this period they detected a significant increase in *Mysis* in Lake Superior. However, when compared to historical values (1960s to 1990s versus 2006 to 2016), the contemporary *Mysis* numbers were approximately 40% lower. Benthic macroinvertebrates are sampled as part of the CSMI surveys, and include secondary Kiyi prey items such as amphipods and chironomids (Mehler et al. 2018).	ii, iv	**USEPA**, AI, USGS
Invasive species monitoring: Monitor the existence and potential	Monitoring and assessment	Through the Aquatic Invasive Species (AIS) Annex of the 2012 Great Lakes Water Quality Agreement (GLWQA), the U.S. and Canada have developed and implemented an	iii	**DFO**, **USFWS**, **USGS**,

Conservation measure	Broad strategy	Descriptions and results	Management objectives	Participants[4]
arrival of invasive species in Kiyi habitat. Where possible, this should be coordinated with relevant ecosystem-based programs.		early detection and rapid response initiative committed to preventing the introduction of AIS, to control or reduce the spread of existing AIS, and to eradicate, where feasible, existing AIS within the Great Lakes Basin ecosystem. DFO is developing environmental DNA (eDNA) assays to test for aquatic invasive species. The eDNA tools are being incorporated into monitoring and surveillance activities of various management programs. The aforementioned USGS's annual Lake Superior fish community trawl surveys detect the presence of invasive species, including Alewife (*Alosa pseudoharengus*) and Rainbow Smelt (*Osmerus mordax*) (see Vinson et al. 2019a). Few Alewife are detected in Lake Superior but Rainbow Smelt have become a predominant component of the nearshore fish community, while few are detected offshore. The USEPA GLNPO's biology monitoring program focuses on the Great Lakes lower food web; the program includes a component that searches for new aquatic invasive species within the zooplankton, phytoplankton and benthic communities. Regular surveys are performed in Lake Superior as a part of the program (USEPA 2020).		**USEPA**, Ontario Ministry of Natural Resources and Forestry (MNRF)
Collaboration: Collaborate through existing networks and relevant groups (for example, the Great Lakes Fishery Commission - Lake Superior Technical Committee), initiatives and recovery/management teams (for example, MNRF)	Management	DFO participates in a variety of partnerships that benefit the Lake Superior ecosystem; these are described below. DFO has participated in the creation of the Lake Superior National Marine Conservation Area (NMCA), which is led by the Parks Canada (PC). Considerations for species at risk are contained within the Lake Superior NMCA of Canada Interim Management Plan.	v	**DFO**, ECCC, GLEC, GLFC, IJC, MNRF, PC, USEPA, USGS

Conservation measure	Broad strategy	Descriptions and results	Management objectives	Participants[4]
to coordinate implementation of management actions of benefit to Kiyi.		The GLWQA is a commitment between the United States (U.S.) and Canada to restore and protect the waters of the Great Lakes, and is led by the USEPA and Environment and Climate Change Canada (ECCC). The Great Lakes Executive Committee (GLEC) serves as a forum to advise and assist the parties in coordinating, implementing, reviewing and reporting on programs, practices and measures that support the implementation of the GLWQA. Pursuant to the GLWQA, the Lake Superior Lakewide Action and Management Plan (LSLAMP) is a binational ecosystem-based strategy for protecting and restoring Lake Superior water quality. The plan focuses on chemical contamination, invasive species, nutrients and algae, as well as measures to conserve habitats and species. Kiyi is considered within the latest plan (LSLAMP 2016); a new 2020 to 2024 LSLAMP is currently in development. DFO has participated in and funded activities prescribed by the International Joint Commission (IJC) to achieve objectives laid out in the GLWQA, which are aimed at improving habitat conditions within the Great Lakes. Improvement of habitat within Lake Superior is expected to be of benefit to a wide array of aquatic species including the Kiyi. DFO has collaborated with the CSMI. The CSMI is a binational effort by the U.S. and Canada, pursuant to the GLWQA, to coordinate Great Lakes research and monitoring activities designed to guide management actions. CSMI focuses research on one Great Lake annually, the most recent lake-wide surveys of Lake Superior occurred in 2016 (Vinson et al. 2019b), and 2021.		

Conservation measure	Broad strategy	Descriptions and results	Management objectives	Participants[4]
		The Great Lakes Fishery Commission (GLFC) coordinates fisheries research, coordinates binational efforts for the control of the invasive Sea Lamprey (*Petromyzon marinus*), and facilitates cooperative fishery management among the state, provincial, U.S. tribal, and federal agencies. DFO's involvement in the GLFC has aided in the coordination of interjurisdictional management of the Great Lakes, and the dissemination of information useful for the management of Kiyi (Eshenroder et al. 2016; Ebener and Pratt 2021). Currently DFO is participating with the GLFC through coregonine task teams, which are focused on addressing knowledge gaps including, but not limited to, taxonomy, threats, population viability analysis for coregonine species including Kiyi. These task teams are developing reports that will be sent to Lake Committees for endorsement, and will guide future science input (and management activities) around all coregonine species in the Great Lakes (Drake pers. comm. 2022).		
Coordinate management actions: Collaborate with U.S. researchers involved in management actions benefiting Lake Superior and those involved in regular surveys capturing Kiyi (for example, USGS).	Management	DFO is collaborating with the USGS on an ongoing basis. Relationships are also maintained through DFO's participation in the CSMI, IJC, GLEC, and GLFC.	v	**DFO**, **USGS**, IJC, GLEC, GLFC, USEPA
Data management: Integrate knowledge in a central database, including habitat parameters, to	Management	USGS is a contributor to the open science data movement, hence, much of their data are available publicly online (for example, bottom-trawl data).	i	**USGS**, **DFO**, MNRF

Conservation measure	Broad strategy	Descriptions and results	Management objectives	Participants[4]
facilitate Kiyi data synthesis and transfer.				
Species biology: Ensure expansion of general Kiyi knowledge, including biology and ecology, to inform conservation planning efforts, particularly in areas where data gaps exist.	Research and protection	Lepak et al. (2017) compared Lake Superior Kiyi ages estimated from scales and otoliths[5], and determined that Kiyi age may be reliably estimated to within one year by examination of thin-sectioned otoliths. In contrast, age estimates derived from the interpretation of scales were consistently lower than estimates interpreted from otoliths and were more prone to variation in age interpretation dependent on the reader's level of experience; therefore, the authors suggest that scales should no longer be used to estimate Kiyi age when otoliths are available. Furthermore, their results indicate that Kiyi are long-lived and exhibit high interannual variability in year-class strength that may be synchronous with recruitment patterns exhibited by other *Coregonus* species and that the critical period for survival may be prior to age one. Lucke et al. (2020) investigated early life history of larval coregonines (a mix of predominantly Cisco, Kiyi and Bloater). Copepod nauplii constituted a majority of their diets, while a generally positive selection for adult copepods and *Holopedium* was detected. Hence, Kiyi must undergo a diet shift between the larval and older life stages, which largely consume macroinvertebrates (for example, *Mysis* and *Diporeia*). In a parallel study, Lachance et al. (2021) investigated identity, phenology and population demographics of larval ciscoes, including Kiyi. They demonstrated that an assemblage of shallow and multiple deepwater larval coregonine species can be identified to species using genomic data, and they detected a progression	ii	**DFO**, **AI**, **MNRF**, **USGS**

[5] Calcium carbonate structure in the inner ear of fish that forms annual growth rings and is used to estimate the age of fish.

Conservation measure	Broad strategy	Descriptions and results	Management objectives	Participants[4]
		of hatch times, starting with Cisco, followed by Kiyi and then Bloater. Harrington et al. (2015) investigated visual sensitivity of Kiyi (along with Deepwater Sculpin [*Myoxocephalus thompsonii*] and Siscowet [*Salvelinus namaycush siscowet*]), to help better understand predator-prey interactions. The visual sensitivity of the 3 species appears sufficient to utilize visual cues for predator avoidance and prey capture at the depths and times when they overlap in the water column. Eaton et al. (2021) analyzed vision genes in ciscoes. Their results suggest that Kiyi is adapted to the blue-shifted depths[6] of Lake Superior after evolving from shallow-water ancestors. Genetic and morphological investigations into Lake Superior deepwater coregonines are underway (Pratt pers. comm. 2022), and may improve species identification and increase life history knowledge of the coregonines, including Kiyi. Currently, a COSEWIC special report on cisco taxonomy and designatable unit structure is in development that may provide further insight on biological and ecological aspects of Kiyi in Lake Superior and their interactions with other cisco species with regard to potential for introgression and niche overlap (Drake pers. comm. 2022).		
Habitat quantity and quality: Determine the quantity and quality of habitat required to ensure	Research and protection	Determination of the quality and quantity of habitat required to ensure the long-term conservation of Kiyi remains to be defined. However, recent research activities are helping to improve knowledge of Kiyi biology (Harrington et al. [2015];	i	**USGS**, **DFO**, AI, MNRF

[6] There is a shift in wavelengths of light toward the blue end of the spectrum at deeper depths.

Conservation measure	Broad strategy	Descriptions and results	Management objectives	Participants[4]
long-term conservation of Kiyi and to support the long-term management goal.		Lepak et al. [2017]; Lucke et al. [2020]; Eaton et al. [2021]), and of their position in the Lake Superior fish community, particularly in relation to other coregonines (Sierszen et al. 2014). Rosinski et al. (2020) mapped potential preferred habitat area available for Kiyi, which was based on Kiyi presence in relation to average bathymetric depth and distance from shore. Modelling exercises have been conducted that estimated the quantity of habitat occupied by Kiyi (van der Lee and Koops In press). These models estimate that there is 55,825 km^2 of habitat suitable for Kiyi in Lake Superior, of which 19,836 km^2 are found on the Canadian side of the lake. Further understanding of the species' life history and their surrounding environment is required before a more precise quantification of their habitat requirements can be accomplished.		
Population dynamics: Gather information on population dynamics of Kiyi and the associated fish community, including clarifying the role of Kiyi in the Lake Superior fish community and offshore food web.	Research and protection	Data generated from the aforementioned USGS's annual Lake Superior fish community trawl surveys serve as the basis of understanding Kiyi population trends. As a result of the COVID-19 pandemic, USGS sampling on Lake Superior was greatly restricted in 2020 and 2021, and no Canadian stations were sampled. In 2013, 79 nearshore and 35 offshore locations were sampled using daytime bottom-trawls (Vinson et al. 2014). A total of 4 Kiyi were captured at nearshore sites and 2,118 were captured at offshore sites. The lakewide mean offshore biomass of Kiyi was 2.6 kg/ha, which was a slight increase from what was observed in 2011 and 2012. In 2014, 73 nearshore and 30 offshore locations were sampled using daytime bottom-trawls (Vinson et al. 2015). A total of 50 Kiyi were captured at nearshore sites and 928 were captured at offshore sites. The lakewide mean offshore	i	**USGS**, **DFO**, AI, MNRF, USEPA

Conservation measure	Broad strategy	Descriptions and results	Management objectives	Participants[4]
		biomass of Kiyi was 1.5 kg/ha, which was less than what was observed in the previous three years. In 2015, 76 nearshore and 33 offshore locations were sampled (Vinson et al. 2016). A total of 12 and 1,116 Kiyi were captured in the nearshore and offshore surveys, respectively. Lakewide mean offshore biomass of Kiyi was calculated at 1.4 kg/ha, which was less than observed in the previous four years. In 2016, 76 nearshore and 35 offshore locations were sampled (Vinson et al. 2017). A total of 43 Kiyi were captured in the nearshore survey and 1,011 in the offshore survey. Lakewide mean offshore biomass of Kiyi was calculated at 0.7 kg/ha, which was 50% of that observed in 2015. With the exception of 2013, a steady decline in Kiyi biomass was noted (since 2011). In 2017, 76 nearshore and 36 offshore locations were sampled (Vinson et al. 2018a). Lakewide mean offshore biomass of Kiyi was calculated at 1.0 kg/ha, which was less than the long-term average (1.6 kg/ha 2011 to 2016), but slightly greater than that observed in 2016 (0.7 kg/ha). A total of 59 Kiyi were captured in the nearshore survey and 1,250 in the offshore survey. In 2018, 77 nearshore and 35 offshore locations were sampled (Vinson et al. 2018b). Lakewide mean offshore biomass of Kiyi was calculated at 0.7 kg/ha, which was less than the long-term mean of 1.5 kg/ha. Overall, Kiyi biomass had demonstrated a decreasing trend since 2011. A total of 8 Kiyi were captured in the nearshore survey and 846 in the offshore survey.		

Conservation measure	Broad strategy	Descriptions and results	Management objectives	Participants[4]
		In 2019, 76 nearshore and 35 offshore locations were sampled (Vinson et al. 2019a). Lakewide mean offshore biomass of Kiyi was calculated at 1.6 kg/ha, which was similar to the period-of-record (2011 to 2018) mean of 1.5 kg/ha. As measured from the offshore survey, Kiyi biomass was highest in the 140 to 200 m zone. Age-1 Kiyi density at offshore sites was 0.9 fish/ha in 2019, which was less than the 2011 to 2018 average of 5.8 fish/ha. A total of 24 Kiyi were captured in the nearshore survey and 1,706 from the offshore survey. In 2020, the COVID-19 pandemic limited the sampling effort in Lake Superior. A total of 9 nearshore locations where sampled, all of which were within U.S. waters. These surveys led to the capture of 97 Kiyi. No offshore locations were sampled in this year (Vinson pers. comm. 2022). In 2021, the COVID-19 pandemic limited the sampling effort in Lake Superior. A total of 45 nearshore locations were sampled, all of which were within U.S. waters. These surveys led to the capture of 17 Kiyi. No offshore locations were sampled in this year (Vinson pers. comm. 2022). Additionally, the CSMI summer whole-lake surveys, which employ a combination of midwater trawls, bottom-trawls and hydroacoustic sampling, add to the understanding of Kiyi population dynamics. For example, the results of surveys conducted in 2016 indicated that the estimated total lakewide Kiyi biomass was 5,511 metric tons, down from the 2011 estimate of 12,229 metric tons. The highest mean biomass was recorded in the 100 to 200 m depth zone (1.01 kg/ha), followed by 0.84 kg/ha at depths greater than 200 m.		

Conservation measure	Broad strategy	Descriptions and results	Management objectives	Participants[4]
		Concern was raised about the lack of recruitment in Kiyi populations (Vinson et al. 2019b). Gorman et al. (2021) compared annual Kiyi biomass estimates from the CSMI surveys (2003 to 2006, 2011, and 2016). They determined that Kiyi abundance in 2016 was reduced (57 to 65%) compared to 2003 to 2006 and 2011. Furthermore, based on summer bottom-trawl surveys of offshore waters, Kiyi biomass declined 42% from an average of 2.1 kg/ha during 2011 to 2013 to 1.2 kg/ha during 2014 to 2016. A lack of regular recruitment combined with strong predation pressure were postulated to underlie the reduction in Kiyi biomass. van der Lee and Koops (In press) modelled Kiyi population trends based on USGS bottom-trawl data (2011 to 2019). A decline in density between the first half (2011 to 2014) and second half (2015 to 2019) of the time series was detected; however, density increased between 2018 and 2019. The model was used to project population size (as measured through biomass) to the entire lake and the median population size was estimated to be to greater than 8,000 metric tons in 2019 (with greater than 2,500 metric tons in Canadian waters), a decline from 2011 where median abundance was greater than 13,000 metric tons. Since 2009, MNRF (Upper Great Lakes Management Unit) have conducted an annual fish community index netting (multi-mesh gill net) survey in Canadian waters of Lake Superior. While this annual survey does not specifically target Kiyi, it has led to the detection of 768 individuals since 2009 with annual catches ranging from 6 to 184 individuals (Berglund pers. comm. 2022).		

Conservation measure	Broad strategy	Descriptions and results	Management objectives	Participants[4]
		Sierszen et al. (2014) investigated food-web pathways in Lake Superior by analyzing patterns in carbon and nitrogen isotope ratios. Kiyi demonstrated a low relative use of benthic resources as they obtained nutrition largely from planktonic pathways. Ackiss et al. (2020) used genomic methods to examine genetic diversity and differentiation among sympatric forms in the *Coregonus artedi* complex in Lake Superior, and observed that Bloater hybridizes with Cisco and Kiyi, but Cisco and Kiyi do not hybridize. Blanke et al. (2018) investigated historical trophic position and niche partitioning among deepwater coregonines (Bloater and Kiyi) in the Great Lakes through comparison of tissue samples taken from museum specimens and conspecifics that were recently captured. Trophic niche partitioning appears to have been maintained in Lake Superior but trophic position, a measure of a species' position within a food web in relation to energy transferred from the bottom to the top that is determined through amino acid-specific nitrogen isotope analysis, has shifted downward by approximately 0.5 trophic level. This change in trophic level may be attributable to a wide variety of ecosystem changes that have occurred over the last 100 years including non-native fish introductions, native fish species declines, eutrophication, changes in the zooplankton community, and changes in the macroinvertebrate community (Blanke et al. 2018). Rosinski et al. (2020) investigated niche partitioning among similar planktivorous species, Bloater, Cisco, Kiyi, and		

Conservation measure	Broad strategy	Descriptions and results	Management objectives	Participants[4]
		Rainbow Smelt for both small and large sizes, which represent the juvenile and adult stages, respectively. These two size-groups were based on total length and differentiated using a compromise of several approaches including: observing natural breaks in the length frequency distributions of individuals captured in this study; considering the estimated length at transition from immaturity to sexual maturity documented in published literature; and using unpublished length-at-age data from other USGS surveys (Rosinski et al. 2020). Juvenile and adult cisco species and Rainbow Smelt were found to have a high degree of niche partitioning in spring and summer, suggesting that direct competition among these species is minimal during these seasons. Kiyi had the least niche overlap with other cisco species and Rainbow Smelt. Annual pelagic prey fish surveys are conducted in Lake Huron in U.S. and Canadian waters by the USGS. The integrated acoustic and mid-water trawl surveys have failed to capture Kiyi (Riley et al. 2020). No other surveys of Lake Huron have detected Kiyi.		
Threat evaluation: Conduct a threat assessment to evaluate threat factors that may be impacting Kiyi (for example, invasive species, eutrophication, disease) and develop mitigation plans to address these factors, updating as new information becomes available.	Research and protection	Potential impacts of climate change on the Lake Superior ecosystem have been assessed (Huff and Thomas 2014). The report provides a structure to track and share climate science and outlines potential adaptation strategies relevant to Lake Superior. Matthias et al. (2021) developed an updated Lake Superior EcoPath model to assess the impacts of invasive species on trophic transfer efficiency in the Lake Superior food web. Kiyi was included in the model; the results represent a baseline estimate of invasive species impacts on Lake Superior.	iii	**DFO**, AI, MNRF, USEPA, USGS

Conservation measure	Broad strategy	Descriptions and results	Management objectives	Participants[4]
		Mitigation plans specific to Kiyi have not been developed; however, plans that pertain to invasive species have been developed. DFO's AIS program has developed a management action plan to address the potential arrival/establishment of high priority AIS. The focus of this program is to prevent the introduction of AIS, respond rapidly to the detection of new species, and manage the spread of already established AIS. Furthermore, the Lake Superior AIS complete prevention plan (LSAIS 2014) is a binational initiative intended to prevent new AIS from becoming established in the Lake Superior ecosystem.		
Compliance monitoring: Develop and implement a compliance monitoring plan for activities potentially affecting Kiyi to improve awareness of Kiyi and engage people in conservation efforts for this species.	Research and protection	No progress has been made on this conservation measure.	iii, v	**N/A**
Mechanisms of decline: Determine the mechanisms that have led to the loss of Kiyi from lakes Huron, Michigan, and Ontario to inform conservation efforts for remaining Kiyi populations.	Research and protection	A factor related to the loss of Kiyi from its former range (that is, lakes Huron, Michigan, and Ontario) may be related to introgression into a generic deepwater cisco swarm by interbreeding with other deepwater cisco species (Eshenroder et al. 2016). The introgression of the cisco swarm is likely the result of combinations of multiple events or stressors that can vary from lake to lake that include: overfishing of large cisco forms leading to the proliferation of smaller forms; overfishing of top predators (for example, Lake Trout) leading to reduced predation pressure on smaller cisco forms; and the introduction and proliferation of invading species such as Rainbow Smelt, Alewife, and Sea Lamprey	i, ii, vi	**USGS**, AI, DFO, GLFC, MNRF

Conservation measure	Broad strategy	Descriptions and results	Management objectives	Participants[4]
		through competition and/or predation (Eshenroder et al. 2016).		
Coordination: Coordinate stewardship activities with existing programs and initiatives that promote aquatic invasive species awareness, reporting, and monitoring (for example, Ontario's Invading Species Awareness Program).	Stewardship and restoration	Ontario's ongoing Invading Species Awareness Program helps to address threats posed by invasive species in Ontario by generating awareness and educational outreach information, addressing key pathways contributing to introductions and/or spread, and facilitating monitoring and early detection initiatives. Furthermore, this program includes several reporting tools including the Invading Species Hotline and the Early Detection and Distribution Mapping System (EDDMapS). The government of Ontario has legislated the *Invasive Species Act* (2015), which seeks to prevent new invasions, slow and/or reverse the spread of existing invasive species, and reduce the harmful impacts of existing invasive species. *Aquatic Invasive Species Regulations* were enacted under the *Fisheries Act* in 2015. The regulations provide a national regulatory framework to help prevent intentional and unintentional introductions of aquatic invasive species in Canada from other countries, across provincial and territorial borders, and between ecosystems within a region. They also provide measures to facilitate response and control activities related to invasive species.	v, vi	**DFO**, **MNRF**, Ontario Federation of Anglers and Hunters (OFAH)
Stewardship promotion: Promote stewardship initiatives (for example, federal/provincial funding programs) related to Kiyi conservation, and ensure that information related to	Stewardship and restoration	DFO is continuing to fund the Habitat Stewardship Program, which provides support for local stewardship initiatives led by conservation authorities (CAs) and environmental non-governmental organizations (ENGOs). Additionally, funding is available through the Aboriginal Fund for Species at Risk (AFSAR), which supports the development of Indigenous capacity to participate actively in the implementation of	iv, vi	**N/A**

Conservation measure	Broad strategy	Descriptions and results	Management objectives	Participants[4]
funding opportunities for stewardship and restoration actions is available to interested groups.		SARA. The supported activities facilitate the implementation of conservation measures such as best management practices (BMPs) associated with water quality improvements. At this time, no projects have been funded that would apply to Kiyi in Lake Superior.		
Existing/ future communication and outreach programs: Include Kiyi in ecosystem-based recovery plans and promote aquatic invasive species awareness, prevention, and control programs through existing and future communication and outreach efforts.	Outreach and communication	As an ongoing effort, DFO distributes aquatic invasive species educational information through public postings and direct engagement, including the dissemination of information through the Watercraft Inspection Program. Additionally, various U.S. entities are involved in the control of AIS and public outreach in the Lake Superior watershed. For example, the Minnesota Department of Natural Resources (MNDNR) has an Invasive Species Program that has increased public awareness and understanding about invasive species.	vi	**DFO**, MNDNR, OFAH, MNRF, USEPA
Indigenous engagement: Engage Indigenous groups to include traditional knowledge to current understanding of Kiyi biology, ecology, and distribution.	Outreach and communication	Federal funding that is made available annually through AFSAR has the capacity to engage Indigenous peoples and expand the current understanding of Kiyi biology, ecology, and distribution through the inclusion of tradition knowledge. At this time, no projects have been funded that would apply to Kiyi in Lake Superior.	vi	**N/A**
Promote awareness and BMPs: Promote awareness with industry (for example, shipping, commercial fishers) user groups (recreational boaters), and landowners to adopt BMPs for land and water activities	Outreach and communication	To increase awareness, DFO's Species at Risk Program staff have constructed and disseminated infographics of aquatic species at risk, including one for Kiyi.	iii	**DFO**, CA, ENGOs,

Conservation measure	Broad strategy	Descriptions and results	Management objectives	Participants[4]
that will help reduce impacts on Kiyi.				
Develop educational materials for cisco species: Develop educational materials that provide the key characteristics to distinguish the cisco species and distribute to key groups, stakeholders (for example, shipping companies, recreational boaters, commercial fishers) that visit or reside within the Lake Superior watershed.	Outreach and communication	No progress has been made on this conservation measure.	vi	**N/A**

4. Concluding statement

Overall, management activities conducted from 2016 to 2021 have helped to provide a clearer understanding of the abundance of Kiyi in Lake Superior. The annual fish community surveys conducted in Lake Superior are beginning to shed light on Kiyi population dynamics. However, further surveys will be required to determine their population trajectory because the offshore survey (where Kiyi are predominantly found) only began in 2011. The 2020 and 2021 surveys were significantly restricted as a result of the COVID-19 pandemic. Predation pressure has been identified as one cause of observed declines in Kiyi abundance (USGS 2017). With the recovery of Lake Trout populations, prey populations (including Kiyi) are under high predation pressure, while invasive Alewife (*Alosa pseudoharengus)* and Rainbow Smelt (*Osmerus mordax*) prey on the larvae of Kiyi. Further research is required to ascertain a fuller picture of the factors driving Kiyi population dynamics.

Acoustic methods of detection for Kiyi continue to be investigated and are beginning to be a valuable complement to traditional trawl surveys used to ascertain Kiyi abundances and distribution. Genetic research has indicated that Kiyi hybridizes with Cisco (*Coregonus artedi*), but not Bloater (*Coregonus hoyi*), and that the apparent loss of Kiyi from Lake Huron may be related to interbreeding with other deepwater coregonines. Progress has been made in larval identification of coregonine species using genomic data and the accuracy of aging techniques has been improved. Investigation of niche partitioning of Kiyi with other similar planktivorous species (Bloater, Cisco, and Rainbow Smelt) has demonstrated that Kiyi has the least niche overlap of the four species.

The monitoring and control of invasive species are ongoing actions that are supported by provincial and federal legislation including the Province of Ontario's *Invasive Species Act* (2015), and the *Aquatic Invasive Species Regulations* (2015) under the *Fisheries Act*. Furthermore, specific to Lake Superior, the binational Lake Superior Aquatic Invasive Species Complete Prevention Plan (2014) outlines new actions to manage existing invasive species and to prevent new invaders from entering and becoming established in the lake.

Collaboration with partners in the U.S. is continuing in management and research activities relevant to the conservation of deepwater coregonines, including Kiyi. For example, partnerships are leading to the development of a new 2020 to 2024 Lake Superior Lakewide Action and Management Plan (LSLAMP), a binational ecosystem-based strategy designed to protect and restore the Lake Superior ecosystem. The ongoing USGS surveys and research activities continue to play a vital role in our understanding of Kiyi biology, distribution, and abundance within Lake Superior.

These ongoing and/or completed activities illustrate the progress that has been made towards the goal of conserving Kiyi populations in Canada; however, further information is required in several areas that can only be obtained through:

- continued annual monitoring of Kiyi abundance in Lake Superior to gain a better understanding of the population dynamics of the species
- researching Kiyi life history, for example, the reproductive biology of Kiyi, to improve the reliability of population models
- determining habitat requirements (quantity and quality) to ensure long-term conservation of the species (for example, understanding spawning habitat requirements/locations as these are largely unknown)
- determining the main factors affecting Kiyi recruitment variability

Future research and monitoring efforts focusing on filling these knowledge gaps will support and inform ongoing conservation efforts for Kiyi. The feasibility of the management goal and objectives may be reassessed in the future using updated distribution and abundance information, as well as threat information gathered since the publication of the management plan.

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