Species at Risk Act
Recovery Strategy Report Series

Report on the Progress of Recovery Strategy Implementation for the Northern Madtom (*Noturus stigmosus*) in Canada for the Period 2017 to 2021

Northern Madtom

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Canada

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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. Under Section 46 of the *Species at Risk Act* (S.C. 2002, c.29) (SARA), the competent ministers are responsible for reporting on the implementation of the recovery strategy for a species at risk, and on the progress towards meeting its objectives within five years of the date when the recovery strategy was placed on the Species at Risk Public Registry and in every subsequent five-year period, until its objectives have been achieved or the species' recovery is no longer feasible. The Minister of Fisheries and Oceans is the competent minister under SARA for Northern Madtom and has prepared this progress report.

Reporting on the progress of recovery strategy implementation requires reporting on the collective efforts of the competent minister, provincial and territorial governments, and all other parties involved in conducting activities that contribute towards the species' recovery. Recovery strategies identify broad strategies and approaches that will provide the best chance of recovering species at risk. Some of the identified strategies and approaches are sequential to the progress or completion of others; not all may be undertaken or show significant progress during the time frame of a report on the progress of recovery strategy implementation (progress report).

As stated in the preamble to SARA, success in the recovery 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 recovery strategy, and will not be achieved by Fisheries and Oceans (DFO) 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 "Recovery Strategy for the Northern Madtom (*Noturus stigmosus*) in Canada" for the benefit of the species and for Canadian society as a whole.

Acknowledgements

This progress report was prepared by Peter Jarvis and Joshua Stacey (DFO). To the extent possible, this progress report has been prepared with input from DFO, the Ontario Ministry of Natural Resources and Forestry, and Environment and Climate Change Canada.

Executive summary

The Northern Madtom (*Noturus stigmosus*) was listed as endangered under the *Species at Risk Act* (SARA) in 2003. The "Recovery Strategy for the Northern Madtom (*Noturus stigmosus*) in Canada" was finalized and published on the Species at Risk Public Registry.

The main threats identified in the recovery strategy for Northern Madtom include siltation, turbidity, nutrient loading, physical habitat loss, contaminants and toxic substances, invasive species (formerly referred to as exotic species), and climate change.

Population and distribution objectives for Northern Madtom are to maintain distributions of extant populations in Lake St. Clair, and the Detroit, St. Clair, and Thames rivers.

The "Report on the Progress of Recovery Strategy Implementation for the Northern Madtom (*Noturus stigmosus*) in Canada for the Period 2017 to 2021" (progress report) documents the progress made by DFO, the province of Ontario, Indigenous groups, conservation authorities, and other stakeholders towards achieving the recovery objectives set out in the recovery strategy. During this period, the following actions have been undertaken:

- targeted sampling in a river system where Northern Madtom was historically known to occur
- research pertaining to habitat and invasive species associations
- the implementation of stewardship activities and the encouragement of Best Management Practices within watersheds applicable to Northern Madtom, which were funded through the federal Habitat Stewardship Program

Substantial progress has been made towards the recovery of Northern Madtom populations in Canada; however, a number of areas still require further information. For example, a standardized index population and habitat monitoring program is desirable, and would enable estimates of population sizes and serve as an early warning system to any deterioration in habitat conditions. Ultimately, these initiatives would allow for more confident assessments, both of population status and trends over time, and of the effectiveness of recovery measures, and would support critical habitat identification.

Table of contents

1. Introduction

The “Report on the Progress of Recovery Strategy Implementation for the Northern Madtom (*Noturus stigmosus*) in Canada for the Period 2017 to 2021” outlines the progress made towards meeting the objectives listed in the Recovery Strategy (Edwards et al. 2012). This report should be considered as part of a series of documents that are linked and should be taken into consideration together, including the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) status reports (COSEWIC 2002; COSEWIC 2012), the recovery potential assessment (RPA) of Northern Madtom (DFO 2012), the recovery strategy, and the initial progress report (DFO 2018a).

Section 2 of the progress report reproduces and summarizes key information on the anthropogenic threats that this species is facing, population and distribution objectives for achieving its recovery, approaches to meeting the objectives, and performance indicators to measure the progress of recovery (for more details, readers should refer to the recovery strategy). Section 3 reports on the progress of activities identified in the recovery strategy to support achieving the population and distribution objectives. Section 4 provides a concluding statement about the progress of actions taken and outcomes of these recovery efforts.

2. Background

2.1 COSEWIC assessment summary

The listing of Northern Madtom under the *Species at Risk Act* (S.C. 2002, c.29) (SARA) in 2003 led to the development and publication of the recovery strategy for Northern Madtom in 2012. The recovery strategy is consistent with the information provided in the COSEWIC status report (COSEWIC 2002). This information has also been included in section 1.1 of the recovery

Assessment summary: May 2012

Common name: Northern Madtom

Scientific name: *Noturus stigmosus*

Status: Endangered

Reason for designation: This species is one of the rarest freshwater fish in Ontario, being found at only four locations in river systems in southwestern Ontario. Substantial and ongoing threats in these rivers include siltation, turbidity, exotic species, and toxic compounds, which have all been assessed as high levels of concern. Although there may be some localized improvement in habitat, overall there is an inferred continuing decline in habitat quality and substantial ongoing threats throughout its range.

Canadian occurrence: Ontario

COSEWIC status history: Species considered in April 1993 and placed in the data deficient category. Re-examined in April 1998 and designated special concern. Status re-examined and designated endangered in November 2002 and May 2012.

strategy. In 2012, COSEWIC re-examined and confirmed the status of Northern Madtom as endangered (COSEWIC 2012).

2.2 Distribution

Since 2016, Northern Madtom continues to be detected in the Detroit and Thames rivers (figure 1). While no recent detections have occurred on the Canadian side of the St. Clair River, Northern Madtom has continued to be detected on the United States (U.S.) side of the river.

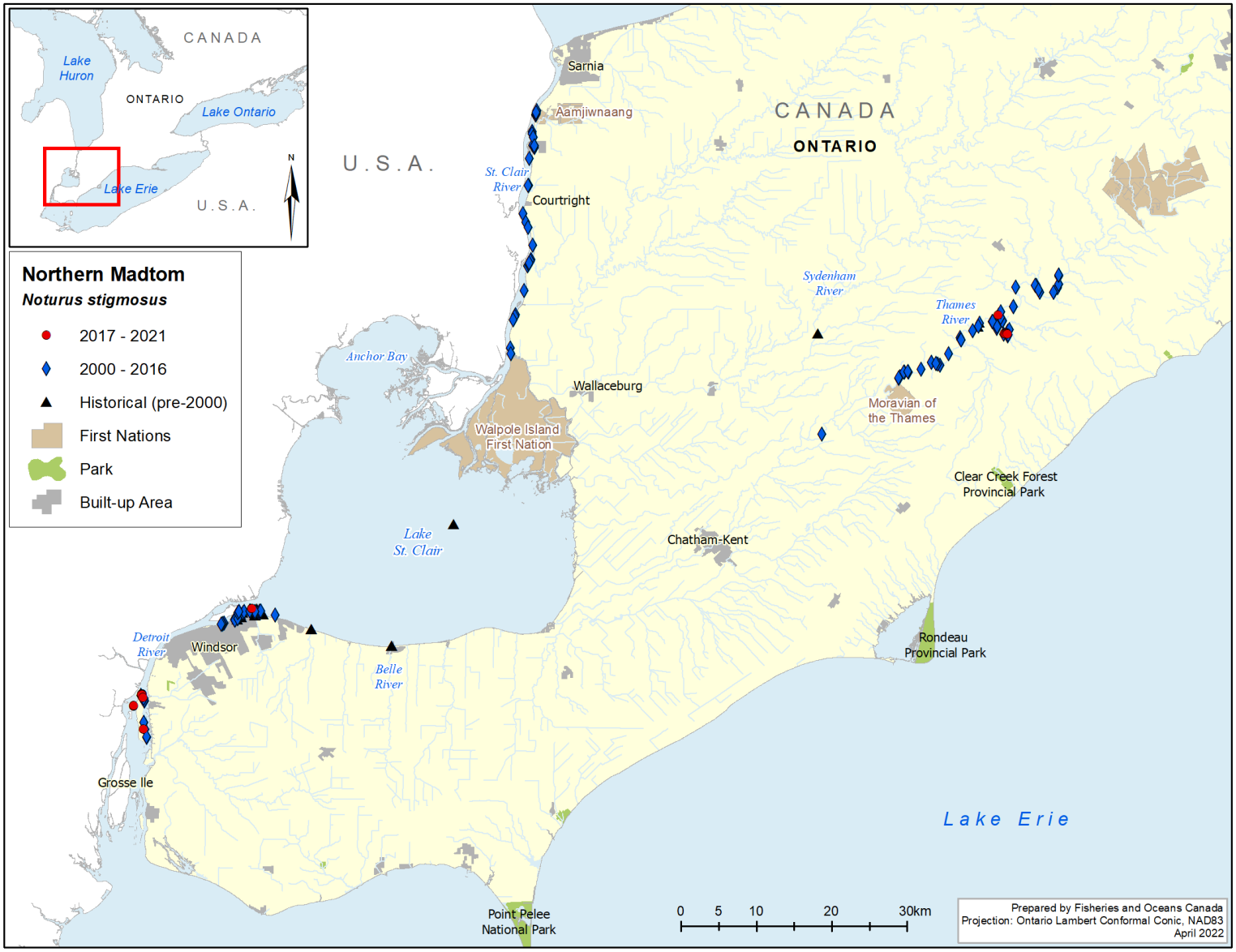

Figure 1. Historical and recent detections of Northern Madtom in Canada.

2.3 Threats

This section summarizes the information found in the recovery strategy on threats to the survival and recovery of Northern Madtom, and threats to its critical habitat.

2.3.1 Threats to Northern Madtom

Potential threats were initially identified in the recovery strategy. However, since the publication of the strategy, a RPA (DFO 2012) has been published that identifies population-level threats to the Northern Madtom, ranked by priority (table 1). Threat status was ranked in terms of the threat likelihood and threat impact on a population-by-population basis (see McCulloch and Mandrak 2012 for further details).

Table 1. Threat classification table for Northern Madtom (adapted from McCulloch and Mandrak 2012).

Threats	Lake Erie Drainage: Detroit River	Lake St. Clair Drainage: Thames River	Lake St. Clair Drainage: St. Clair River	Lake St. Clair Drainage: Lake St. Clair	Lake St. Clair Drainage: Sydenham River
Invasive species	High	High	High	High	High
Climate change	Unknown	High	Unknown	High	High
Siltation	Low	High	Low	Medium	High
Turbidity	Low	Medium	Low	Low	Medium
Nutrient loading	Medium	Medium	Low	Medium	Medium
Physical habitat loss	Medium	Low	Medium	Medium	Low
Contaminants and toxic substances	Low	Low	High	Low	Low

2.3.2 Threats to critical habitat

Critical habitat for Northern Madtom has been identified, to the extent possible, in section 2.7 of the recovery strategy. Examples of activities that are likely to result in destruction to critical habitat (that is, threats to critical habitat) are listed below:

- Physical habitat loss:
  - Dredging
  - Grading
  - Excavation
  - Structure removals (for example, log salvage, moving of rocks in navigational channels)
  - Placement of material or structures in water (for example, groynes[1], piers, infilling, partial infills, jetties)
  - Shoreline hardening[2]
- Physical habitat loss or modification:
  - Construction of dams and/or barriers
  - Water-level management or water extraction activities

[1] Low breakwall/barrier built perpendicular to the shore to mitigate erosion.
[2] Alteration of the shoreline from a natural riparian zone to one comprised of artificial structures such as concrete or steel walls, or riprap borders with large stones or boulders.

- Toxic compounds:
  - Over-application or misuse of herbicides and pesticides
  - Release of urban and industrial pollution into habitat
- Nutrient loadings:
  - Over-application of fertilizer and improper nutrient management (for example, organic debris management, wastewater management, animal waste, septic systems and municipal sewage)
- Siltation and turbidity:
  - Work in, or around, water with improper sediment and erosion control (for example, overland run-off from ploughed fields, use of industrial equipment, cleaning or maintenance of bridges or other structures); removal of riparian zones
  - Unfettered livestock access to waterbodies

The list of activities provided above is neither exhaustive nor exclusive, and their inclusion has been guided by the relevant threats to habitat described in the recovery strategy. For further details on activities likely to result in the destruction of critical habitat, consult section 2.7.6 in the recovery strategy.

2.4 Recovery

This section summarizes the information found in the recovery strategy on the population and distribution objectives necessary for the recovery of Northern Madtom. This section also describes the performance indicators that provide a way to define and measure progress towards achieving the population and distribution objectives.

2.4.1 Population and distribution objectives

Section 2 of the recovery strategy identified the following goals and objectives necessary for the recovery of the species:

Recovery goal
The long-term recovery goal (greater than 20 years) is to sustain and enhance the viability of existing populations of Northern Madtom in the Huron-Erie corridor (St. Clair River, Lake St. Clair, and Detroit River), the Thames River from Littlejohn Road upstream to vicinity of Tate Corners (Northern Madtom has subsequently been detected downstream of Littlejohn Rd. in the vicinity of Scane Rd.), and the Sydenham River, if the species is still present in the system.

Population and distribution objectives
Population and distribution objectives for Northern Madtom over the next five years are to maintain distributions of extant populations in Lake St. Clair, the Detroit River, the St. Clair River, and the Thames River. Quantifiable objectives relating to individual populations are not currently possible; these objectives will be developed once necessary surveys and studies have been completed. Knowledge gaps will be addressed by recovery actions given ”urgent” priority included in the recovery planning approaches (refer to 2.5.1 of the recovery strategy).

Recovery objectives
Short-term objectives (five to 10 years) have been established to assist with meeting the long-term recovery goal and are listed in table 2.

2.4.2 Performance measures

Section 2.6 of the recovery strategy includes performance indicators to define and measure progress towards achieving the population and distribution objectives. These indicators are outlined in table 2.

Table 2. Performance indicators for evaluating the achievement of recovery objectives for the Northern Madtom (adapted from Edwards et al. 2012).

Short-term recovery objective	Performance indicator
i. Refine population and distribution objectives.	Completion of background surveys required to fully describe all extant populations by 2015.
ii. Ensure the protection of critical habitat.	Completion of activities outlined in the schedule of studies (refer to table 11 of the recovery strategy) for the complete determination of critical habitat within the proposed timelines.
iii. Determine long-term population and habitat trends.	Population and habitat monitoring program established by 2014 (within regions currently identified as critical habitat).
iv. Evaluate and mitigate threats to the species and its habitat.	Report results of research on the impacts/effects of competition by Round Goby (*Neogobius melanostomus*) by 2014. Report results of additional research that assists with the evaluation of impacts/effects of threats to Northern Madtom by 2016. Quantification of Best Management Practices (BMPs) (for example, number of Nutrient Management Plans [NMPs] or Environmental Farm Plans [EFPs] established) implemented to address threats by 2014.
v. Examine the feasibility of relocations and captive rearing.	Report on the feasibility (and need) for relocations and captive rearing of Northern Madtom.
vi. Ensure efficient use of resources (human and fiscal) during recovery planning efforts.	Collaboration with all ecosystem recovery teams and other stakeholders.
vii. Improve awareness of Northern Madtom and engage the public in the conservation of the species.	Document any changes in public perceptions and support for identified recovery actions through guidance identified in the communications strategy by 2015.

3. Progress towards recovery

Northern Madtom recovery effort is divided into four broad strategies: 1) inventory and monitoring; 2) research; 3) management and coordination; and 4) stewardship and outreach. Progress in carrying out these broad strategies is reported in section 3.1 of this progress report. Section 3.2 reports on the activities identified in the schedule of studies to identify critical habitat. Section 3.3 reports on the progress on meeting the performance indicators and other

commitments (for example, completion of the Critical Habitat Order) identified in the recovery strategy and information obtained through its implementation.

3.1 Activities supporting recovery

Table 3 provides information on the implementation of activities undertaken to address the broad strategies and recovery actions identified in the recovery strategy. Table 3 is not necessarily an exhaustive list of all relevant activities, but is meant to broadly represent work undertaken since 2017.

Table 3. Details of activities supporting the recovery of the Northern Madtom from 2017-2021.

Activity	Broad strategy	Descriptions and results	Recovery objectives	Participants[3]
Population assessment: Conduct targeted sampling in areas of occupied habitat, as well as historically occupied habitat (for example, Sydenham River). Use sampling techniques proven to detect Northern Madtom (for example, night/day seining and trawling).	Inventory and monitoring	Between 2017 and 2021 no conventional targeted sampling was conducted for Northern Madtom within its current or known historical range. Balasingham et al. (2018) used an environmental DNA (eDNA[4]) approach for analysing the fish community composition in the Sydenham and Grand rivers. Northern Madtom presence was detected in the north and east branches of the Sydenham River. Corroboration of the presence of Northern Madtom in the Sydenham River with traditional sampling methods is ongoing (see Barnucz and Drake [2021] below). Given the limitations of this sampling technique (false positive detections may result from the presence of closely related cooccurring species such as Brindle Madtom [*Noturus miurus*] and/or Stonecat [*Noturus flavus*]), the presence of Northern Madtom in new or historical locations cannot be validated until specimens have been captured through conventional sampling. Furthermore, future eDNA sampling may be improved by using fin clips from taxonomically identified Northern Madtom. Northern Madtom has been detected in non-targeted surveys by both Fisheries and Oceans Canada (DFO) and external partners. DFO captured Northern Madtom in the Thames River in 2020	i	**DFO**, academic institutions (AI), Ontario Ministry of Natural Resources and Forestry (OMNRF), United States Fish and Wildlife Service (USFWS), United States Geological Survey (USGS)

[3] Lead participant(s) is/are listed on top and in bold; other participants are listed alphabetically.
[4] DNA (genetic material) originating from organisms that has accumulated and can be detected in various environmental samples, including water from lakes and streams.

Activity	Broad strategy	Descriptions and results	Recovery objectives	Participants[3]
		during the course of a physiological tolerance study on the Eastern Sand Darter (*Ammocrypta pellucida*). Nine Northern Madtom were captured at 6 out of the 8 sites surveyed. In 2017 and 2018, the United States Fish and Wildlife Service (USFWS) captured 18 Northern Madtom at 8 Canadian sites in the Detroit River during an investigation into Northern Madtom use of artificial fish spawning reefs (Johnson et al. 2021). One further individual was captured by the USFWS on the Canadian side of the Detroit River in 2019. Northern Madtom was also captured in the St. Clair River during the course of sampling, but all of the sites were on the United States (U.S.) side of the border (see Johnson et al. 2021). Similarly, 1 specimen was captured within the U.S. waters of the St. Clair River in 2021 through fyke net sampling undertaken by USFWS (MacDougall pers. comm. 2022). In 2018, the Ontario Ministry of Natural Resources and Forestry (OMNRF) conducted a study to determine what gear types are required to effectively characterize the small fish community in the deep and semi-wadeable sections of the lower Thames River. A single Northern Madtom was captured in the semi-wadeable section of the river during electrofishing. Siamese trawls, seine, fyke, and small-mesh gill nets were also utilized in the survey.		
Population assessment: Conduct targeted sampling in areas lacking Northern Madtom records but possessing potentially suitable habitat. Sampling should be done during both the day and night using sampling techniques proven to detect Northern Madtom.	Inventory and monitoring	Barnucz and Drake (2021) conducted targeted sampling for Northern Madtom in the lower East Sydenham River in 2019. The sampling utilized a Siamese trawl in 40 field sites that spanned a gradient of lotic and lentic habitats between Dawn Mills and Dresden. The sampling occurred approximately 20 km downstream of Florence where Northern Madtom was detected in 1975. Northern Madtom was not captured during the survey, but Round Goby (*Neogobius melanostomus*) was found to be widespread. Future targeted sampling is planned between Alvinston and Florence, an area which encompasses the historical record of the species in the Sydenham River.	i	**DFO**, AI, OMNRF

Activity	Broad strategy	Descriptions and results	Recovery objectives	Participants[3]
		Balasingham et al. (2018) detected Northern Madtom eDNA in the Grand River. Further sampling with traditional methods is required to confirm these results, as the species is not known to occur in this waterbody.		
Population assessment: Establish a sampling protocol for Northern Madtom informed by the results of background surveys. Establish and implement a standardized index population and habitat monitoring program using the sampling protocol for Northern Madtom.	Inventory and monitoring	A long-term index population and habitat monitoring program has not been fully developed at this time; however, progress continues to be made in terms of investigations into optimal monitoring and sampling protocols. Balasingham et al. (2018) investigated the use of combined eDNA and Next Generation Sequencing (NGS) methods (metabarcoding) for analysing fish community composition, with an emphasis on detecting species at risk, including Northern Madtom. Evidence of the presence of Northern Madtom was obtained from both of the rivers surveyed (Sydenham and Grand rivers). The results highlight the potential for eDNA to be used alongside traditional capture-based methods for monitoring and mapping target species at risk. Lamothe et al. (2020) tested the utility of occupancy models for characterizing habitat associations and potential threats (invasive species) to Northern Madtom. They calculated that up to 16 repeated non-detections using benthic trawls are needed to be 95% confident that Northern Madtom is absent at a site, suggesting that current sampling approaches are likely inadequate. Recommendations included sampling at night to improve detection probability and avoidance of sampling in transition zones of fast-flowing rivers. Additionally, electrified trawls were suggested as an option to improve detectability of the species. Johnson et al. (2021) investigated the use of artificial fish spawning reefs by Northern Madtom in the St. Clair and Detroit rivers. This study explored Northern Madtom sampling strategies	i, iii	**DFO**, AI, Michigan Department of Natural Resources (MDNR), OMNRF, USFWS, USGS

Activity	Broad strategy	Descriptions and results	Recovery objectives	Participants[3]
		in large river systems, and highlighted the importance of incorporating a temporal sampling strategy. The effectiveness of different bait types to catch Northern Madtom in minnow traps was evaluated. Significantly more Northern Madtom were captured with worms than with other bait types (dog food, cheese, no bait). As many madtom species are considered imperiled, generic monitoring and sampling protocols have been investigated that may be applicable to Northern Madtom. Wagner et al. (2019) assessed the effectiveness and biases of common sampling gear for five madtom species in Mississippi, including Brown Madtom (*Noturus phaeus*), Freckled Madtom (*Noturus nocturnus*), Piebald Madtom (*Noturus gladiator*), Least Madtom (*Noturus hildebrandi*), and Brindled Madtom (*Noturus miurus*). Detection probabilities and effort necessary to detect 5 species of madtom using 4 gear types (that is, backpack electrofisher, seine, dipnet, and Gee-style minnow trap) were evaluated. Electrofishing was generally the most efficient gear for detecting madtoms, followed by seining. Although seining was relatively efficient at capturing madtoms, it displayed a bias towards the capture of small individuals. Minnow traps and dipnetting generally performed poorly and failed to detect some species. Although this study was conducted in the southern U.S. on other madtom species, the results may provide insight on the effectiveness of various methodologies in detecting Northern Madtom. Schumann et al. (2021) evaluated the efficacy of a madtom monitoring approach in a laboratory-based study. They found that small passive integrated transponder (PIT) tags could be used on a surrogate species, Frecklebelly Madtom (*Noturus munitus*), without any negative impact on survivorship. Furthermore, their results show that PIT tags paired with radio-frequency identification (RFID)-enhanced artificial cover units may offer a		

Activity	Broad strategy	Descriptions and results	Recovery objectives	Participants[3]
		novel opportunity to describe the ecology and population dynamics of madtoms. These artificial cover units attract Madtom species, which could provide a novel means of assessing both the occupancy and abundance of madtom including Northern Madtom, a species that is difficult to detect using conventional sampling approaches.		
Habitat and life history requirements: Determine the seasonal habitat needs, including home range and species movement, of all life stages of Northern Madtom.	Research	Lamothe et al. (2020) found a positive association between Northern Madtom and gravel substrates, and observed that the species appeared to occupy transition zones between shallower banks and the inner deep channel of rivers. Johnson et al. (2021) recorded higher Northern Madtom catch rates with increasing water temperature and turbidity in the St. Clair and Detroit rivers; no relationship between catch rate and substrate type was observed. Additionally, they found that constructed artificial reefs are providing habitat for Northern Madtoms, and that the use of these sites does not differ from the use of nearby control sites. Rodríguez et al. (2021) used a joint species distribution model to quantify the responses of vulnerable freshwater fish species to four potential environmental stressors (turbidity, water velocity, dissolved oxygen, and water temperature). Northern Madtom where found to have an association with, or tolerance of, high water velocity and turbidity, but not with water temperature or oxygen concentration.	ii	**DFO**, AI, MDNR, OMNRF, USFWS, USGS
Threat assessment: Investigate the impacts of Round Goby and Zebra Mussel (*Dreissena polymorpha*) on Northern Madtom. Studies to include impacts on	Research	Lamothe et al. (2020) demonstrated a significant negative association between Round Goby and Northern Madtom in the St. Clair River. No significant negative association was recorded in the Thames River, but model-averaged estimates of Northern Madtom occupancy were lower when Round Goby was present. The invasive Tubenose Goby (*Proterorhinus marmoratus*) was detected in the St. Clair River (but not the Thames River), but no occupancy association was detected with Northern Madtom.	iv	**DFO**, AI, MDNR, USFWS, USGS

Activity	Broad strategy	Descriptions and results	Recovery objectives	Participants[3]
Northern Madtom spawning success.		Johnson et al. (2021) did not find a negative association between Round Goby and Northern Madtom occurrence in the Detroit and St. Clair rivers. The authors caution that the lack of negative association may be related to the water depth of their study sites. French and Jude (2001) demonstrated that diet overlap between Northern Madtom and Round Goby was dependent on water depth, with little diet overlap in deeper areas (5 to 7 m), which corresponds to the depths of the Johnson et al. (2021) study sites. The lack of diet overlap at 5 to 7 m was related to Round Goby consumption of large quantities of dreissenids, which may have buffered their predation on other organisms, including Northern Madtom (French and Jude 2001).		
Threat assessment: Investigate the impacts of physical habitat changes on Northern Madtom.	Research	The impact of physical habitat alterations (for example, dredging, sedimentation and shoreline hardening) to Northern Madtom remains to be investigated.	iv	**DFO**, AI
Threat assessment: Monitor the spread of Zebra Mussel in watersheds occupied by Northern Madtom.	Research	Dreissenid mussels are well established within the Huron-Erie corridor. DFO species at risk mussel sampling occurred at several sites within the Thames River where Northern Madtom are known to occur, which involves monitoring the presence or absence of dreissenids.	iv	**DFO**, OMNRF
Assessment of population genetics: Examine genetic relationships between populations as well as	Research	Samples have been collected from population genetics surveys conducted in the St. Clair, Thames, and Detroit rivers and analysis is currently underway.	v	**AI**, DFO

Activity	Broad strategy	Descriptions and results	Recovery objectives	Participants[3]
the amount of genetic variation within populations. Compare genetics of Canadian populations of Northern Madtom to populations in the U.S.				
Threat assessment: Investigate the impacts (lethal/sub-lethal) of pollutants in the Huron-Erie corridor, and nutrient loading in the Sydenham and Thames rivers, on Northern Madtom.	Research	Previous research (Boogaard et al. 2016) that examined the effects of granular Bayluscide[5] on a similar surrogate species, Tadpole Madtom (*Noturus gyrinus*), has suggested that applications over large areas may limit the success of avoidance behaviour and cause mortality. This study was described in the previous progress report for Northern Madtom (DFO 2018a) and in Andrews et al. (2021). A relative risk assessment of Bayluscide for Northern Madtom (Andrews et al. 2021), using Channel Catfish (*Ictalurus punctatus*) as a surrogate species, demonstrated a 53% mortality rate when specimens were exposed to concentrations of 0.057 mg/L over an eight-hour period, suggesting that the overall risk to Northern Madtom is very high in comparison to other listed fish species. Granular Bayluscide has been applied at sites that overlap with Northern Madtom distribution in the St. Clair, Thames, and Detroit rivers (Andrews et al 2021). Although information detailing where Bayluscide has been applied in recent years is currently unavailable, it was repeatedly applied between 2011 and 2017 at sites that overlap with Northern Madtom in the St. Clair and Detroit rivers with 5 applications occurring within areas identified as critical habitat (Andrews et al. 2021).	iv	**DFO**, USGS

[5] Bayluscide is a lampricide, which are pesticides designed to control the invasive Sea Lamprey (*Petromyzon marinus*).

Activity	Broad strategy	Descriptions and results	Recovery objectives	Participants[3]
		Gilroy et al. (2017) examined the concentration of halogenated phenolic compounds[6] (including polychlorinated biphenyls[7] [PCBs], polybrominated diphenyl ethers [PBDEs], pentachlorophenol [PCP], and Triclosan) in the plasma of Brown Bullhead (*Ameiurus nebulosus*), an Ictalurid species related to Northern Madtom, in the Great Lakes Areas of Concern (AOC) including the Detroit River AOC. These authors detected the aforementioned halogenated phenolic compounds in specimens of Brown Bullhead collected from the Detroit River AOC at Peche Island, although concentrations were generally lower at the other locations analyzed, which are situated further downstream in the Great Lakes watershed. Recent studies have explored changes in the tissue concentrations of contaminants including organics and metals/metalloids in Shorthead Redhorse (*Moxostoma macrolepidotum*), Yellow Perch (*Perca flavescens*), and Emerald Shiner (*Notropis atherinoides*) collected in 2002/2003 and 2014 within the St. Clair River (Muttray et al. 2020 and 2021). Sampling sites were located at the heavily industrialized area of Stag Island, downstream at the St. Clair Delta, and at a reference site in Lake Huron to examine changes over time. Tissue concentrations were not measured in Northern Madtom; however, Shorthead Redhorse is a species that is representative of the benthic niche[8], and as such may provide relative insight regarding the potential trends of contaminant levels within Northern Madtom. Specifically, Muttray et al. (2020) found that concentrations of the majority of organic contaminants, including PCBs, and organochlorine pesticides and by-products, decreased		

[6] A class of manufactured chemicals widely used as herbicides, pesticides, biocides, flame retardants, and wood preservatives (Dai et al. 2015).
[7] Polychlorinated Biphenyls, also known as PCBs, are a group of synthetic chemicals that are similar in structure with different degrees of chlorination that were not manufactured in Canada, but were used in a wide range of industrial activities. For more information see Polychlorinated Biphenyls (PCBs)
[8] Using habitat on the bottom of lakes or rivers

Activity	Broad strategy	Descriptions and results	Recovery objectives	Participants[3]
		over the 12-year time period while dioxin-like PCBs tended to decline or remained consistent over the time period for Shorthead Redhorse and Yellow Perch at 2 of 3 locations. Overall their results indicate that current concentrations pose a low risk to the health of fish. Muttray et al. 2021 found that tissue concentrations of many of the metals/metalloids measured in 2002/2003 and 2014, such as mercury, vanadium, barium, magnesium, manganese, strontium, and zinc decreased over the time period; however, these trends differed among metals/ metalloids across locations and species. Overall, they found that concentrations of metals/metalloids fell below thresholds projected to impact fish health, suggesting that the health and reproductive capacity of all 3 species is not likely being affected (Muttray et al. 2021).		
Artificial propagation: If the need for population supplementation is determined, develop relocation and captive rearing techniques and incorporate into population-specific action plans as required. Conduct population genetics research prior to captive rearing and relocation.	Research	It remains unknown if population supplementation is desirable for Northern Madtom recovery. Lamothe et al. (2019) summarized the state of reintroduction science for SARA-listed fishes. They indicate that Northern Madtom would benefit from increased directed monitoring efforts to provide a better understanding of its distribution, habitat requirements, genetic structure, and movement patterns. This information is required to improve the odds of successful reintroduction.	v	**DFO**, OMNRF
Coordination of recovery implementation: Work with relevant organizations (for example, USFWS, CAs,	Management and coordination	"The Action Plan for the Sydenham River in Canada: An Ecosystem Approach" (DFO 2018b) contains measures to support the recovery of fish and mussel species, including a focus on Northern Madtom. To oversee the implementation of the action plan, the Sydenham River Recovery Team was formed, and is made up of DFO, Conservation Authorities (CAs), provincial	vi	**DFO**, AI, CAs, Ontario Land Trust Alliance (OLTA), OMNRF

Activity	Broad strategy	Descriptions and results	Recovery objectives	Participants[3]
Indigenous groups) and ecosystem- and single species recovery teams to share knowledge, implement recovery actions and obtain data on incidental sightings.		departments, and academic partners. Additionally, ongoing coordination of recovery actions are managed by the Ontario Freshwater Fish, and the Thames River recovery teams. The Essex-Erie Fish Species at Risk Recovery Program has been ongoing, involving collaboration among DFO, Essex Region Conservation Authority (ERCA), and Lower Thames Valley Conservation Authority (LTVCA) to implement habitat improvement and restoration activities within tributaries of Lake St. Clair and the Detroit River. LTVCA has coordinated freshwater mussel identification workshops, with DFO personnel providing the training. Workshops have been directed at Indigenous groups. The OMNRF has prioritized a number of recovery actions, including inter-organizational coordination efforts, within their Government Response Statement that align with recovery measures prescribed in the federal recovery strategy for Northern Madtom.		
Coordination of recovery implementation: Encourage municipalities to protect habitats that are important to Northern Madtom in their official plans.	Management and coordination	Municipal public works and planning departments have been included in aquatic species at risk outreach activities conducted by DFO. DFO has developed and distributed aquatic species at risk official plan guidance for municipalities (that is, Regional Planning Commissioners of Ontario) to incorporate into municipal official plan updates.	vi, vii	**DFO**, City of London, OMNRF, Regional Municipality of Chatham
Coordination of recovery implementation: Ensure planning and management agencies are aware of habitats	Management and coordination	Species at risk screening maps have been provided annually to CAs (through Conservation Ontario) that indicate where Northern Madtom critical habitat is located within a given jurisdiction or municipality to inform planning and permitting decisions. Additionally, DFO has provided a review of new species at risk Critical Habitat Orders, and a refresher to CAs, municipal	ii	**DFO**, CA, OMNRF

Activity	Broad strategy	Descriptions and results	Recovery objectives	Participants[3]
that are important to Northern Madtom.		planners, consultants, and government agencies on DFO's integrated project review process.		
Threat management: Evaluate watershed-scale stressors to populations and their habitats, in cooperation with relevant ecosystem-based recovery teams and organizations.	Management and coordination	DFO has updated the watershed-scale analysis of stressors for the Sydenham River watershed within the Sydenham River action plan (DFO 2018b). In addition, CAs published their watershed report cards in 2018, which are drafted on a 5-year cycle. The ERCA reported that generally surface water quality was poor, but that conditions are steady or improving for the majority of the region. LTVCA reported steady surface water quality, while St. Clair Region Conservation Authority (SCRCA) reported total phosphorus levels above provincial guidelines.	vi, vii	**DFO**, **CA**, AI, Environment and Climate Change Canada (ECCC), Ministry of the Environment, Conservation and Parks (MECP), OMNRF
Threat management: Develop a management plan addressing potential risks and proposed actions in response to existing invasive species and to the arrival or establishment of new invasive species.	Management and coordination	No such management plan has been developed in the last 5 years; however, the Canadian Action Plan to Address the Threat of Aquatic Invasive Species was designed to minimize (and ideally eliminate) the introduction of harmful aquatic invasive species (AIS) and remediate the impact of those already in Canada. The 2015 *Aquatic Invasive Species Regulations* further empower DFO to prevent the introduction and spread of AIS and manage established species.	iv	**DFO**
Collaboration and information sharing: Collaborate with relevant groups, including Indigenous groups and recovery teams, to address recovery actions of benefit to Northern Madtom.	Stewardship and outreach	Collaboration with existing ecosystem recovery teams such as the Essex-Erie Fish Species at Risk, Thames River, Ontario Freshwater Fish, and the Sydenham River recovery teams has been ongoing to implement recovery measures. Similarly, many recovery actions have been implemented jointly with other organizations including the CAs, the OMNRF, and several academic partners.	vi, vii	**DFO**, **CA**, OMNRF, AI

Activity	Broad strategy	Descriptions and results	Recovery objectives	Participants[3]
Stewardship and habitat initiatives: Promote stewardship among landowners abutting aquatic habitats of Northern Madtom, as well as other local residents and Indigenous groups.	Stewardship and outreach	Federal funding is available annually through the Aboriginal Fund for Species at Risk (AFSAR), and the Habitat Stewardship Program (HSP). HSP funding is provided by DFO to support local stewardship initiatives led primarily by environmental non-government organizations (ENGOs) and CAs, while AFSAR funding supports the development of Indigenous capacity to participate actively in the implementation of SARA. Funding is also provided through the Canada Nature Fund for Aquatic Species at Risk (CNFASAR). CNFASAR is aimed at supporting stewardship projects that help recover and protect aquatic species at risk. Collectively, the activities supported facilitate the implementation of conservation measures, such as BMPs associated with water quality improvements and reduced sediment loading. With the aid of HSP funding, LTVCA has conducted outreach sessions and distributed educational materials to promote awareness of stewardship programs and species at risk. Additionally, the LTVCA and ERCA have initiated stewardship projects; for example, they have worked with landowners to restore riparian areas and wetlands, and stabilize streambanks. The LTVCA has evaluated watershed conditions and threats and used this information to compile a species at risk threat assessment throughout the lower Thames watershed. This project will aid in targeting habitat restoration and threat mitigation projects for maximal benefit to species at risk, including Northern Madtom. With the aid of CNFASAR funding, the SCRCA has engaged in outreach activities, such as the distribution of species at risk newsletters, the promotion of agricultural BMPs at agriculture events, conducting online events and producing videos, and through social media outreach. Additionally, stewardship projects focused on habitat improvement and creation (including livestock	vi, vii	**DFO**, **CA**, **ENGO**, OMNRF

Activity	Broad strategy	Descriptions and results	Recovery objectives	Participants[3]
		restriction fencing, tree and shrub planting, and wetland creation) have been funded. The LTVCA has engaged in outreach relating to threats to aquatic species at risk, projects that can be undertaken to benefit these species, agricultural BMPs, and funding available to landowners to help facilitate the completion of stewardship projects. LTVCA staff participated in consultation meetings to assist the Chippewas of the Thames First Nation to develop an Agricultural Management Plan. Additionally, stewardship restoration initiatives were completed that included wetland and prairie riparian buffer creation, along with the installation of rock chutes intended to stabilize drain embankments and to reduce erosion.		
Habitat improvement/ restoration: Work with landowners and other interest groups to implement BMPs in areas that will provide the most benefit. Encourage the completion and implementation of EFPs and NMPs.	Stewardship and outreach	Through partnerships with CAs, DFO staff has promoted the implementation of BMPs via presentations, project reviews, and site meetings with the agricultural community, drainage engineers, and the Ontario Drainage Superintendents Association. The use of BMPs is encouraged through project reviews and recommended mitigation approaches on rural properties, including livestock restrictions (exclusion fencing), milkhouse washwater system installations, riparian buffers, streambank stabilization, wetland creation or enhancement, well decommissioning, septic upgrades, and sediment control/trapping to prevent run-off and improve water quality. The Species at Risk Farm Incentive Program, through the Ontario Soil and Crop Improvement Association (OSCIA), includes information on what BMP farm activities can help species at risk, including information on cost-share opportunities. Completed projects have resulted in streambank protection and enhancement (for example, riparian buffer plantings, erosion control work, exclusionary fencing for livestock) and wetland restoration.	iv, vi, vii	**CAs**, DFO, OSCIA

Activity	Broad strategy	Descriptions and results	Recovery objectives	Participants[3]
		The HSP and CNFASAR provide support for local stewardship initiatives, which are typically led by CAs. For example, the LTVCA has engaged in outreach activities that encourage landowners in priority areas to implement habitat improvement and BMP projects to benefit aquatic species at risk, including Northern Madtom.		
Habitat improvement/ restoration: Develop and implement a strategy for communicating with target land users/stakeholders with respect to recovery activities as required.	Stewardship and outreach	Cancelled – the ongoing communications to stakeholders that have already been described largely achieve this objective.	vii	
Habitat improvement/ restoration: Facilitate access to funding sources for landowner and local community groups and Indigenous groups engaged in stewardship activities.	Stewardship and outreach	The aforementioned HSP, CNFASAR and AFSAR programs are key sources of funding that DFO makes available for stewardship projects targeting species at risk, including Northern Madtom. Both HSP and AFSAR are promoted annually by DFO to applicable CAs, Indigenous groups, and other key stakeholders.	vii	**DFO**, **OMNRF**, CAs
Habitat improvement/ restoration: Provide clear communications addressing funding opportunities and landowner concerns and responsibilities under SARA and the provincial	Stewardship and outreach	DFO has delivered presentations (for example, at the Latornell Conservation Symposium), which include new aquatic species at risk listings, national maps, and species at risk funding program opportunities.	vii	**DFO**, CAs

Activity	Broad strategy	Descriptions and results	Recovery objectives	Participants[3]
Endangered Species Act, 2007 (ESA).				
Invasive species awareness: Increase public awareness of the impacts of invasive species on the natural ecosystem and encourage the use of existing invasive species reporting systems. Anglers should be reminded that it is illegal to dump the contents of their bait buckets into a waterbody, regardless of where the bait originated.	Stewardship and outreach	AIS information has been disseminated through the Watercraft Inspection Program and educational outreach material distributed by DFO (public postings and direct engagement). Furthermore, through HSP-funded projects, CAs continue to focus outreach activates on AIS public education and awareness. EDDMapS Ontario, or Early Detection and Distribution Mapping System Ontario, is a digital tool used to report and track invasive species across the province of Ontario. EDDMapS provides a central location for members of the public, as well as researchers from partner organizations, to upload coordinates and relevant information pertaining to invasive species detections in Ontario. The province of Ontario released Ontario's Sustainable Bait Management Strategy in July 2020, which describes a new approach to managing baitfish and leeches that will reduce the ecological risks associated with the use and movement of bait in Ontario. Commercial bait harvesters and dealers will be required to take a standardized training course designed to increase harvester and dealer awareness of non-target species, including AIS and species at risk, and to identify actions to avoid spreading AIS or harming species at risk.	iv, vii	**DFO**, **CA**, Ontario Federation of Anglers and Hunters (**OFAH), OMNRF**

3.2 Activities supporting the identification of critical habitat

Table 4 provides information on the implementation of the studies to identify critical habitat that are outlined in the schedule of studies in the recovery strategy. Each study has been assigned 1 of 4 statuses:

1) Completed: the study has been carried out and is concluded
2) In progress: the planned study is underway and has not concluded
3) Not started: the study has been planned but has yet to start
4) Cancelled: the planned study will not be started or completed

Table 4. Status and details of the implementation of the schedule of studies outlined in the recovery strategy for the Northern Madtom.

Study	Timeline	Status	Descriptions and results	Participants[9]
Conduct studies to determine the habitat requirements for each life stage of Northern Madtom.	2022 to 2025	In progress	Studies investigating Northern Madtom habitat associations are ongoing and are contributing to an improved understanding of the life history of the species. Well defined life stage specific habitat requirements have yet to be determined.	**Fisheries and Oceans Canada (DFO)**, academic institutions (AI), Ontario Ministry of Natural Resources and Forestry (OMNRF), United States Fish and Wildlife Service (USFWS), United States Geological Survey (USGS)
Survey and map habitat quality and quantity within historical and current sites, as well as sites adjacent to currently occupied habitat.	2022 to 2025	Not started	DFO has not undertaken such studies since the publication of the recovery strategy.	**DFO**, OMNRF

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

Study	Timeline	Status	Descriptions and results	Participants[9]
Conduct additional Northern Madtom surveys to fill in distribution gaps, and to aid in determining population connectivity and home ranges/territories.	2019 to 2025	In progress	Targeted surveys for Northern Madtom occurred in the lower East Sydenham River, while additional sampling is planned further upstream. To adequately address this measure, further sampling might be conducted in: • the lower Detroit River • the area within the Detroit River between Fighting Island and Belle Island • the lower Thames River • the Grand and North Sydenham rivers to confirm recent, positive eDNA detections	**DFO**, OMNRF
Create a population-habitat supply model for each life stage.	2023 to 2027	Not started	Further understanding of life stage specific habitat requirements are required before this study can be completed.	**DFO**
Based on information gathered, review population and distribution goals. Determine amount and configuration of critical habitat required to achieve goal if adequate information exists. Validate population-habitat supply model and refine critical habitat descriptions as necessary.	2023 to 2027	Not started	The information gathering stage is still ongoing.	**DFO**

3.3 Summary of progress towards recovery

3.3.1 Status of performance indicators

Table 5 provides a summary of the progress made towards meeting the performance indicators outlined in table 2. Each indicator has been assigned one of four statuses:

1) Not met: the performance indicator has not been met, and little to no progress has been made
2) Partially met, underway: moderate to significant progress has been made towards meeting one or more elements of the performance indicator, and further work is ongoing or planned
3) Met: the performance indicator has been met and no further action is required
4) Met, ongoing: the performance indicator has been met, but efforts will continue as needed to achieve the objectives outlined in the species' recovery strategy

Table 5. Summary of progress made towards meeting the performance indicators outlined in the recovery strategy for the Northern Madtom.

Performance indicator	Status	Details
Completion of background surveys required to fully describe all extant populations by 2015.	Met, ongoing	Targeted surveys were reported in the initial progress report (DFO 2018a). Further surveys are required to allow for abundance estimates.
Completion of activities outlined in the schedule of studies for the complete determination of critical habitat within the proposed timelines.	Partially met, underway	This performance indicator has been partially met; two of the scheduled studies are currently in progress (table 4).
Population and habitat monitoring program established by 2014 (within regions currently identified as critical habitat).	Not met	The development of a standardized index population and habitat monitoring program has not yet occurred.

Performance indicator	Status	Details
Report results of research on the impacts/effects of competition by Round Goby by 2014.	Partially met, underway	Research has been conducted that investigates associations between Northern Madtom and Round Goby that has already been described in table 3. Further research is required to describe modes of impact of Round Goby on Northern Madtom.
Report results of additional research that assists with the evaluation of impacts/effects of threats to Northern Madtom by 2016.	Partially met, underway	Research has been undertaken that examines the effects of granular Bayluscide on surrogate madtom species (Boogaard et al. 2016), and DFO has undertaken a relative risk assessment of Bayluscide for Northern Madtom (Andrews et al. 2021), using Channel Catfish as a surrogate species.
Quantification of BMPs (for example, number of NMPs or EFPs established) implemented to address threats by 2014.	Met, ongoing	Stewardship projects, many of which are funded through HSP, have been, and continue to be, undertaken within watersheds occupied by Northern Madtom. A variety of BMPs are key to many of these activities and are expected to reduce watershed level threats to the species.
Report on the feasibility (and need) for relocations and captive rearing of Northern Madtom.	Not met	Currently on hold; background work to support this indicator has been proposed (for multiple species) within the Sydenham River action plan (DFO 2018b).
Collaboration with all ecosystem recovery teams and other stakeholders.	Met, ongoing	Collaboration has been ongoing with members of the Essex-Erie and Sydenham River recovery teams (for example, academic partners, ERCA, LTVCA, SCRCA and UTVCA and the OMNRF).
Document any changes in public perceptions and support for identified recovery actions through guidance identified in the communications strategy (by 2015).	Not met	The communications strategy implemented at the watershed-level has been cancelled, in light of ongoing communications to stakeholders.

3.3.2 Completion of action plans

The ecosystem-based Sydenham River action plan (DFO 2018b) includes recovery activities that will benefit Northern Madtom (for example, stewardship actions to address threats within the East Sydenham River).

3.3.3 Critical habitat identification and protection

Using the best available information, critical habitat has been identified for Northern Madtom populations in the following areas (Edwards et al. 2012):

1. Lower Thames River
2. Detroit River (Peche Island)
3. Detroit River (Fighting Island)

Surveys conducted within the Huron-Erie corridor, and the Thames and Sydenham rivers, continue to improve understanding of Northern Madtom distribution. Further research should be carried out to better refine critical habitat to fully achieve the recovery objectives. Studies are needed that identify and characterize habitat use by different life stages, availability and location of habitat, and movement patterns of Northern Madtom.

As stated in the initial progress report (DFO 2018a), a Critical Habitat Order made under subsections 58(4) and (5) of SARA was published (in 2016) in the *Canada Gazette, Part II*. The order is intended to satisfy the obligation to legally protect critical habitat by triggering the prohibition in subsection 58(1) of SARA against the destruction of any part of the species' critical habitat in the lower Thames and Detroit rivers, as identified in the recovery strategy.

3.3.4 Recovery feasibility

Currently, there is no need to review the recovery feasibility for this species, considering that no new information has been gathered that would suggest that Northern Madtom populations within Canadian waters no longer meet the feasibility criteria laid out in the recovery strategy. For example, enough reproducing individuals and suitable habitat still exist to support recovery objectives, and threats to the species can be, or have been, addressed through restoration efforts and the promotion of BMPs.

4. Concluding statement

Overall, recovery activities conducted over the last five years have helped provide a better understanding of the distribution of Northern Madtom in the Detroit and Thames rivers. Targeted sampling failed to detect the species in a poorly sampled reach of the lower East Sydenham River; however, another section of the river was identified for future targeted sampling. Research activities have continued to refine appropriate sampling strategies, such as gear types and sampling effort for the species, which differ between the Thames and Sydenham rivers versus the St. Clair and Detroit rivers. Recent evidence points to a negative association between the invasive Round Goby and Northern Madtom but further investigations will be required to elucidate the mechanisms of this relationship.

DFO staff has engaged in a variety of outreach activities that have targeted Conservation Authorities (CAs), municipal officials, consultants, environmental non-government organizations,

and the general public with information related to DFO's integrated project review process, official plan guidance, and species at risk funding opportunities. Valuable stewardship activities continue to occur in watersheds occupied by Northern Madtom. Activities have focused on strengthening BMPs related to agricultural activities prominent in the catchment area of the Thames River. The stabilization of streambanks and improvements to riparian zones are expected to benefit habitat quality in areas of Northern Madtom residence and in areas upstream, which influence water quality throughout the system. CAs continue to play a vital role in implementing stewardship projects, and in engaging and educating the public on species at risk.

Although Northern Madtom critical habitat was identified in the recovery strategy, further understanding of the species distribution and habitat requirements gained over the past 5 years may allow a refinement of critical habitat identification in future recovery documents. Additional research is necessary to better understand significant threats to the species (for example, contaminants, physical habitat alteration, and siltation), and life stage specific habitat requirements. The accomplishments of the last decade have built a strong foundation for the continued research and management of this species over the next reporting period. The involvement of multiple stakeholders has been key to much of this progress; DFO is looking forward to continuing this successful collaboration and welcomes the participation of additional partners.

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