Species at Risk Act
Recovery Strategy Report Series

Report on the Progress of Recovery Strategy Implementation for the Misty Lake Sticklebacks (*Gasterosteus aculeatus*) in Canada for the Period 2018 to 2022

Misty Lake Lentic Threespine Stickleback

Misty Lake Lotic Threespine Stickleback

2023

Canada

Recommended citation:

Fisheries and Oceans Canada. 2023. Report on the Progress of Recovery Strategy Implementation for the Misty Lake Sticklebacks (*Gasterosteus aculeatus*) in Canada for the Period 2018 to 2022. *Species at Risk Act* Recovery Strategy Report Series. Fisheries and Oceans Canada, Ottawa. iv + 15 pp.

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 and other related documents, please visit the Species at Risk Public Registry.

Cover illustration: Photographs of Misty Lake Lentic Threespine Stickleback and Misty Lake Lotic Threespine Stickleback (*Gasterosteus aculeatus*) from the lake (lentic form; top photo) and from the inlet stream (lotic form; bottom photo). Photos by Renaud Kaueffer, with the help of Maryse Boisjoly and Shahin Muttalib.

Également disponible en français sous le titre
« Rapport sur les progrès de la mise en œuvre du programme de rétablissement des épinoches (*Gasterosteus aculeatus*) du lac Misty au Canada pour la période 2018 à 2022 »

ISBN 978-0-660-68089-7
Catalogue no. En3-4/246-1-2023E-PDF

Preface

The *Species at Risk Act* (S.C. 2002, c.29) (SARA), requires reporting on the implementation of the recovery strategy for a species at risk, and on the progress towards meeting its objectives within 5 years of the date when the final recovery strategy was placed on the Species at Risk Public Registry, and every subsequent 5 years, until the recovery strategy is no longer required under SARA or the species' recovery is no longer feasible. This reporting must be done by the competent minister.

The Minister of Fisheries and Oceans is the competent minister under SARA for the Misty Lake Lentic Threespine Stickleback and Misty Lake Lotic Threespine Stickleback 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 to 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 and not all may be undertaken or show significant progress during the timeframe 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 Canada, 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 benefit of the Misty Lake Lentic Threespine Stickleback and Misty Lake Lotic Threespine Stickleback and Canadian society as a whole.

Acknowledgments

This progress report was prepared by Emma Branquinho and Maggie Boothroyd with input from Ahdia Hassan and Oliver Barker (Fisheries and Oceans Canada [DFO]). To the extent possible, this progress report has been prepared with inputs from Rowshyra Castaneda (DFO), Paul Grant (DFO), Heather Bettger (DFO), and Greg Wilson (British Columbia Ministry of Water, Land and Resource Stewardship). DFO would also like to express its appreciation to all individuals and organizations who have contributed to the recovery of the Misty Lake Lentic Threespine Stickleback and Misty Lake Lotic Threespine Stickleback.

Executive summary

The Misty Lake Lentic Threespine Stickleback and the Misty Lake Lotic Threespine Stickleback (herein referred to as Misty Lake Sticklebacks) (*Gasterosteus aculeatus*) were listed as endangered under the *Species at Risk Act* (SARA) in 2010. The "Recovery Strategy for the Misty Lake Sticklebacks (*Gasterosteus aculeatus*) in Canada" was finalized and published on the Species at Risk Public Registry in 2018.

The main threats identified for the Misty Lake Sticklebacks include: the introduction or invasion and subsequent establishment of aquatic exotic and invasive species that predate upon, or compete with, the Misty Lake Sticklebacks or degrade habitat quality; point and non-point source water pollution from contaminants such as hydrocarbons or pesticides, and increased sediment loads and degradation of water quality from land use activities in the watershed; non-conforming recreational use of the Misty Lake Ecological Reserve; riparian vegetation removal; water extraction; climate change; and excessive removal of individuals for scientific research.

The population and distribution objectives for the Misty Lake Sticklebacks are to:

- maintain, or where possible increase, abundance of each population (inlet, lake, outlet) relative to the 2016 observed population sizes[1]. The 2016 abundances are thought to be near historical levels and self-sustaining
- maintain the current spatial distribution of each population (inlet, lake, outlet) and maintain the 2 distinct forms by preventing an increase in hybridization that could lead to the collapse of the species pair into a hybrid swarm

The "Report on the Progress of Recovery Strategy Implementation for the Misty Lake Sticklebacks in Canada for the Period 2018 to 2022" (progress report) reports on the progress made by Fisheries and Oceans Canada (DFO) and its partners towards implementing the recovery strategy and achieving its objectives. During this time period, progress has been made towards:

- development and installation of public outreach signage on Misty Lake Sticklebacks and the Misty Lake Ecological Reserve
- research conducted to investigate reproductive isolation, parallel evolution, and genomic sequencing and analysis for the Misty Lake Sticklebacks
- publication of guidelines for scientific studies of Threespine Sticklebacks
- legal protection of Misty Lake Sticklebacks' critical habitat through 2 SARA critical habitat orders in 2018
- publication of the "Action Plan for the Misty Lake Sticklebacks (*Gasterosteus aculeatus*) in Canada" in 2020

Population monitoring has not occurred during this reporting period (2018 to 2022); therefore, the overall condition of the species pair is unknown. None of the performance indicators identified in the recovery strategy have been met and the status of the population and distribution objectives is unknown. Further work is required to support the survival and recovery of the Misty Lake Sticklebacks. Priority next steps may include the development and implementation of a standardized monitoring plan, development and implementation of an aquatic invasive species monitoring and prevention plan, research to better understand and

[1] Lake population (lentic form): 123,991 individuals (95% confidence intervals: 86,169 to 227,717); inlet population (lotic form): 14,991 individuals (95% confidence intervals: 5,481 to 18,855); outlet population (lentic form): 9,851 individuals (95% confidence intervals: 4,586 to 21,604). Abundance data from Oke et al. 2017.

mitigate threats associated with land use and water quality, and increased public outreach and education.

DFO remains committed to recovering the Misty Lake Sticklebacks. The work started and completed to date has built a strong foundation for continued research and recovery of the species pair over the next reporting period. Progress made to date would not have been achieved without the contribution of our partners. DFO looks forward to continued collaboration and welcomes the participation of additional partners.

Table of contents

1 Introduction

The “Report on the Progress of Recovery Strategy Implementation for the Misty Lake Sticklebacks in Canada for the Period 2018 to 2022” outlines the progress made towards meeting the objectives listed in the “Recovery Strategy for the Misty Lake Sticklebacks (*Gasterosteus aculeatus*) in Canada” (herein referred to as recovery strategy; Fisheries and Oceans Canada [DFO] 2018) during the indicated time period and is part of a series of documents for this species pair 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 2006), the “Recovery Potential Assessment for the Misty Lake Stickleback (*Gasterosteus* spp.) Pair” (herein referred to as recovery potential assessment; DFO 2010), the recovery strategy (DFO 2018), and the “Action Plan for the Misty Lake Sticklebacks (*Gasterosteus aculeatus*) in Canada” (herein referred to as action plan; DFO 2020).

Section 2 of the progress report provides an overview of key information on the threats to the species pair, 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 back to the recovery strategy (DFO 2018). Section 3 reports on the progress made towards the activities identified in the recovery strategy, to support achieving the population and distribution objectives. Section 4 summarizes the progress toward achieving the population and distribution objectives.

2 Background

2.1 COSEWIC assessment summary and threats to the species and its critical habitat

In 2006, COSEWIC assessed the Misty Lake Lentic Threespine Stickleback and Misty Lake Lotic Threespine Stickleback (*Gasterosteus aculeatus*), herein referred to as Misty Lake Sticklebacks, as endangered (COSEWIC 2006). The species pair was subsequently listed as endangered under Schedule 1 of the *Species at Risk Act* (SARA) in 2010, which led to the development and publication of the recovery strategy in 2018 (DFO 2018). The recovery strategy is consistent with the information provided in the COSEWIC status report (COSEWIC 2006) and was further informed by the recovery potential assessment (DFO 2010).

Date of Assessment: November 2006

Common Name (population): Misty Lake Lentic Stickleback

Scientific Name: *Gasterosteus* sp.

COSEWIC Status: Endangered

Reason for Designation: This lake-dwelling fish is part of an endemic, highly divergent species pair restricted to a single stream-lake complex on Vancouver Island with an extremely small area of occurrence. This species pair could quickly become extinct due to introduction of non-native aquatic species or perturbations to the habitat. Proximity of this complex to a major highway and public access make an introduction likely. Logging activities in the watershed, as well as highway use and related maintenance, could impact habitat quality to some degree.

Canadian Occurrence: British Columbia

COSEWIC Status History: Designated endangered November 2006. Assessment based on new status report.

Date of Assessment: November 2006

Common Name (population): Misty Lake Lotic Stickleback

Scientific Name: *Gasterosteus* sp.

COSEWIC Status: Endangered

Reason for Designation: This stream-dwelling fish is part of an endemic, highly divergent species pair restricted to a single stream-lake complex on Vancouver Island with an extremely small area of occurrence. This species pair could quickly become extinct due to introduction of non-native aquatic species or perturbations to the habitat. Proximity of this complex to a major highway and public access make an introduction likely. Logging activities in the watershed, as well as highway use and related maintenance, could impact habitat quality to some degree.

Canadian Occurrence: British Columbia

COSEWIC Status History: Designated endangered November 2006. Assessment based on new status report.

Section 4 of the recovery strategy provides information on the threats to the species' survival and recovery. These threats include:

- aquatic exotic, invasive, or introduced species
    - introduction/invasion and establishment of benthic fishes, crayfish, spiny-rayed fishes, bullfrogs or other aquatic invasive species

- water pollution
    - point source pollution from road run-off and rest stop
    - non-point source pollution and changes in water quality resulting from land use practices
- habitat loss and degradation
    - nonconforming recreational use of Misty Lake Ecological Reserve
    - riparian vegetation removal related to utility and transport corridors and land use
    - water extraction
- climate change
    - changes in precipitation, water flow, temperature, ice cover, timing, etc.
- disturbance or harm
    - unpermitted or excessive removal of individuals for scientific research

Critical habitat for the Misty Lake Sticklebacks has been identified, to the extent possible, in section 7 of the recovery strategy. The recovery strategy also provides examples of activities that are likely to result in the destruction of critical habitat (that is, threats to critical habitat). The list of activities provided in table 5 of the recovery strategy is neither exhaustive nor exclusive, and its inclusion has been guided by the relevant threats to habitat described in the recovery strategy. For more details on the activities likely to result in the destruction of critical habitat, consult the recovery strategy.

2.2 Recovery

This section summarizes the information from the recovery strategy on the population and distribution objectives necessary for the recovery of the Misty Lake Sticklebacks and on performance indicators that provide a way to define and measure progress toward achieving the population and distribution objectives.

Section 5 of the recovery strategy identified the following population and distribution objectives necessary for the recovery of the species pair:

- maintain, or where possible increase, abundance of each population (inlet, lake, outlet) relative to the 2016 observed population sizes[2]. The 2016 abundances are thought to be near historical levels and self-sustaining
- maintain the current spatial distribution of each population (inlet, lake, outlet) and maintain the 2 distinct forms by preventing an increase in hybridization that could lead to the collapse of the species pair into a hybrid swarm

Section 8 of the recovery strategy includes the following performance indicators:

- observe a stable or positive trend in population abundances by 2025 taking into account natural variation
- confirm stable spatial distribution of each population (inlet, lake, outlet) by 2025 and confirm that there has been no increase in the proportion of hybridized individuals in the populations

[2] Lake population (lentic form): 123,991 individuals (95% confidence intervals: 86,169 to 227,717); inlet population (lotic form): 14,991 individuals (95% confidence intervals: 5,481 to 18,855); outlet population (lentic form): 9,851 individuals (95% confidence intervals: 4,586 to 21,604). Abundance data from Oke et al. 2017.

3 Progress towards recovery

The recovery strategy for the Misty Lake Sticklebacks (DFO 2018) divides the recovery effort into 9 broad strategies:

1) determine the current distribution of key aquatic exotic, invasive or introduced species on Vancouver Island
2) develop and implement a Total Prevention Plan for aquatic invasive species
3) address information gaps that inhibit conservation of the Misty Lake Sticklebacks and their critical habitat
4) increase scientific understanding of the Misty Lake Sticklebacks through additional investigation into their natural history and threats to their persistence
5) continue to develop sound protocols for scientific investigations
6) manage and protect the habitat of the Misty Lake Sticklebacks
7) increase understanding of population trends and make linkages to threats
8) continue to develop and implement a long-term monitoring program to assess population response to management activities and/or threats
9) develop and implement educational outreach materials to foster awareness of the species and encourage active local involvement in stewardship and habitat protection.

Progress in carrying out these broad strategies is reported in section 3.1. Section 3.2 reports on the activities identified in the schedule of studies to identify critical habitat. Section 3.3 reports on the progress in meeting the performance indicators and other commitments (for example, action plan and critical habitat order) identified in the recovery strategy and information obtained through implementing the recovery strategy.

3.1 Activities supporting recovery

Table 1 provides information on the implementation of activities undertaken to address the broad strategies identified in the recovery planning table of the recovery strategy.

Table 1. Details of activities supporting the recovery of the Misty Lake Sticklebacks from 2018 to 2022.

#	Broad strategy	Descriptions and results	Participants[3]
1	Determine the current distribution of key aquatic exotic, invasive or introduced species on Vancouver Island	No specific action has been completed to determine the current distribution of key aquatic exotic, invasive or introduced species on Vancouver Island during this reporting period. However, the province of British Columbia (BC) supports an online public platform called iMapBC which stores thousands of geographic datasets, including the distribution of known aquatic invasive species (AIS) in BC. Misty Lake was identified as having high accessibility for AIS in the draft AIS prevention plan for Paxton Lake and Vananda Creek Stickleback species pairs (Guzek and Wilson, in prep). The "British Columbia Dreissenid Mussel Lake Monitoring Field Protocol" was published in 2021 by British Columbia Ministry of the Environment and Climate Change Strategy (BC ENV) to provide a framework for invasive mussel monitoring efforts within the province (BC ENV 2021). Monitoring for dreissenid mussels on Vancouver Island was completed by the Coastal Invasive Species Committee (CISC), BC ENV, and the Invasive Species Council of British Columbia (ISCBC); dreissenid mussels were not detected in the 2021 monitoring year.	**BC ENV**, CISC, ISCBC
2	Develop and implement a Total Prevention Plan for aquatic invasive species	An AIS plan specific to Misty Lake Sticklebacks has not been developed during this reporting period. However, an AIS prevention plan for Paxton Lake and Vananda Creek Stickleback species pairs is currently under development and is intended to be used as a guideline for other lakes where stickleback species pairs exist in BC, such as Misty Lake (Guzek and Wilson, in prep). While not specific to Misty Lake, the following programs have contributed to AIS prevention in BC during the reporting period:	BC ENV, ISCBC, BC IMISWG

[3] Lead participant(s) in bold; other participants are listed alphabetically. Not all activities have specific participants or recovery measures identified.

#	Broad strategy	Descriptions and results	Participants[3]
		• The British Columbia Inter-Ministry Invasive Species Working Group (BC IMISWG) published the BC Government Invasive Species Strategic Plan (BC IMISWG 2014) to provide guidance on the implementation of the provincial government's invasive species program. • ISCBC published a provincial framework for invasive species management: Invasive Species Strategy for British Columbia: 2018 to 2022 (ISCBC 2017). • ISCBC completed 2 literature reviews that summarized the impacts of invasive species on species at risk in BC and culturally important at-risk species: "A Systematic Assessment of Invasive Species Impacts to Species at Risk in British Columbia" (Tamburello and Litt 2021) and "Culturally Important At-Risk Species and Invasive Species" (ISCBC 2022). • The Invasive-Wise Tourism program was developed in 2019 and promotes the adoption of best practices for tourism operators to prevent the spread of AIS in BC. • The Don't Let it Loose campaign raises awareness of the ecological consequences of intentionally releasing plants and animals in Canadian lands and waters. • The Clean, Drain, Dry campaign educates the public on the best methods to prevent the spread of AIS through aquatic recreation activities.	
3	Address information gaps that inhibit conservation of the Misty Lake Sticklebacks and their critical habitat	No action has been taken to address information gaps during this reporting period. However, the "Action Plan for the Misty Lake Sticklebacks (*Gasterosteus aculeatus*) in Canada" (DFO 2020) was published on the Species at Risk Public Registry in 2020 and identifies 11 recovery measures to support survival and recovery of Misty Lake Sticklebacks and their critical habitat.	DFO
4	Increase scientific understanding of the Misty Lake Sticklebacks through additional investigation into their natural history and threats to their persistence	Misty Lake Sticklebacks were 1 of 4 Threespine Stickleback genomes to undergo genome sequencing, assembly and annotation for future genomic investigations in stickleback species (Berner et al. 2019). Haenel et al. (2021) investigated reproductive isolation in Misty Lake Sticklebacks through genomic analysis and demonstrated the efficacy of divergent selection in maintaining reproductive isolation between parapatric lake-stream populations at the genomic level.	Academia

#	Broad strategy	Descriptions and results	Participants[3]
		Misty Lake Sticklebacks have also been used in studies investigating parallel evolution, though evaluating methods of collecting morphological data (Haines et al. 2020) and exploring the repeatability of adaptive radiation (Paccard et al. 2020).	
5	Continue to develop sound protocols for scientific investigations.	An update to the existing protocol "Guidelines for the Collection and *In Situ* Scientific Study of Stickleback species pairs (*Gasterosteus* spp.) in British Columbia" (Rosenfeld et al. 2008) is underway (Woodruff et al. in prep). The update will incorporate new available information, including the 2016 population estimates reported on in the recovery strategy (DFO 2018). In 2018, Environment and Climate Change Canada (ECCC) published reference methods for measuring the acute lethal toxicity of effluents to Threespine Stickleback (ECCC 2018).	DFO, BC ENV, ECCC
6	Manage and protect the habitat of the Misty Lake Sticklebacks	Critical habitat for the Misty Lake Sticklebacks was identified to the extent possible, using the best available information, in section 7 of the recovery strategy (DFO 2018). Protection of Misty Lake Sticklebacks' critical habitat from destruction was accomplished in 2018 through 2 SARA critical habitat orders (one for lentic and one for lotic). The orders were made under subsections 58(4) and (5), which invoke the prohibition in subsection 58(1) against the destruction of the identified critical habitat (SOR/2018-208; SOR/2018-209) and was reported on in the action plan (DFO 2020). Misty Lake continues to be protected under the *Protected Areas of British Columbia Act*, through the establishment of the Misty Lake Ecological Reserve in 1996. Misty Lake Sticklebacks are under consideration for listing under BC's *Forest and Range Protection Act* and *Energy Resources Activities Act*. If listed, Wildlife Habitat Areas can be designated, which provide habitat protections by managing forestry activities to limit their impacts on the identified wildlife. The outcome of this process will be reported on in the next progress report.	**DFO, BC ENV, BC Parks**
7	Increase understanding of population trends	No action has been taken to increase understanding of population trends and make linkages to threats during this reporting period.	N/A

#	Broad strategy	Descriptions and results	Participants[3]
	and make linkages to threats		
8	Continue to develop and implement a long-term monitoring program to assess population response to management activities and/or threats	A long-term monitoring program of Misty Lake Sticklebacks has not yet been developed. The population abundance of Misty Lake Sticklebacks was last estimated in 2016 (Oke et al. 2017) and was reported on in the recovery strategy (DFO 2018). Total population abundance estimates for the Misty Lake Stickleback population were: • lake population (lentic form): 123,991 individuals (95% confidence intervals: 86,169 to 227,717) • inlet population (lotic form): 14,991 individuals (95% confidence intervals: 5,481 to 18,855) • outlet population (lentic form): 9,851 individuals (95% confidence intervals: 4,586 to 21,604)	BC ENV, DFO, University of British Columbia
9	Develop and implement educational outreach materials to foster awareness of the species and encourage active local involvement in stewardship and habitat protection	In 2018, BC ENV and BC Parks developed and installed interpretive signage on the Misty Lake Ecological Reserve and Misty Lake Sticklebacks. The signs were installed at the highway rest stop on Highway 19 at the southwest corner of the lake. In 2021, DFO developed public outreach signage for Misty Lake Sticklebacks describing the species pairs biology as well as SARA status and protections. The signs were installed at the highway rest stop on Highway 19 at the southwest corner of the lake, at the main access point and on the trail to the lake. Public education and outreach has been conducted to mitigate the threat of AIS (see row 2 of this table).	**BC Parks, BC ENV, DFO**

3.2 Activities supporting the identification of critical habitat

Table 2 provides information on the implementation of the studies outlined in the schedule of studies to identify critical habitat found 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 2. Status and details of the implementation of the schedule of studies outlined in the recovery strategy for the Misty Lake Sticklebacks.

Study	Timeline	Status	Descriptions and results	Participants[4]
Study population and distribution	5 years (2016 to 2021)	Completed	Population abundance was last estimated in 2016 for the Misty Lake Sticklebacks (see table 1: row 8; Oke et al. 2017) and reported on in the final recovery strategy (Fisheries and Oceans Canada [DFO] 2018). Oke et al. (2017) confirmed the known extent of occurrence in the outlet stream and identified an additional area of occurrence in the inlet stream. These results informed the identification of critical habitat in the final recovery strategy as well as the known distribution (DFO 2018). Sampling further upstream within the inlet tributaries was not possible due to accessibility issues, but future studies may further expand the known distribution of the lotic form (Oke et al. 2017).	Academia, DFO
Develop a monitoring program to determine summer and winter habitat use by adults and juveniles,	5 years (2018 to 2023)	Not started	A monitoring program for Misty Lake Sticklebacks has not yet been developed or implemented.	N/A

[4] Lead participant(s) in bold; other participants are listed alphabetically. Not all activities have specific participants or recovery measures identified.

Study	Timeline	Status	Descriptions and results	Participants[4]
population size, and life history information				
Continue researching mechanism of reproductive isolation	5 years (2018 to 2023)	In progress	Haenel et al. (2021) investigated the mechanism of reproductive isolation in Misty Lake Sticklebacks through genomic analysis. Results demonstrated how divergent selection can drive and maintain reproductive isolation between the parapatric lake-stream populations, while highlighting the fragility from ecological disturbance.	Academia

3.3 Summary of progress towards recovery

3.3.1 Status of performance indicators

Table 3 provides a summary of the progress made toward meeting the performance indicators outlined in section 8 of the recovery strategy. Each indicator has been assigned 1 of 4 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 toward meeting 1 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 3. Summary of progress made toward meeting the performance indicators outlined in the recovery strategy for the Misty Lake Sticklebacks for the period 2018 to 2022.

Performance indicator	Status	Details
Observe a stable or positive trend in population abundances by 2025 taking into account natural variation	not met	Population abundance was last estimated in 2016 for the Misty Lake Sticklebacks (see table 1: row 8; Oke et al. 2017) and was used to determine the population and distribution objectives for the recovery strategy (Fisheries and Oceans Canada [DFO] 2018).

Performance indicator	Status	Details
		There has been no subsequent monitoring of Misty Lake Sticklebacks, therefore more recent population abundance is unknown, as are population trends. Development of a standardized monitoring plan for the Misty Lake Sticklebacks was identified as a high priority recovery measure in the action plan (DFO 2020).
Confirm stable spatial distribution of each population (inlet, lake, outlet) by 2025 and confirm that there has been no increase in the proportion of hybridized individuals in the populations	not met	There has been no monitoring of the Misty Lake Sticklebacks, therefore spatial distribution and trends in hybridization rates are unknown. Development of a standardized monitoring plan for the Misty Lake Sticklebacks was identified as a high priority recovery measure in the action plan (DFO 2020).

3.3.2 Completion of action plan

The “Action Plan for the Misty Lake Sticklebacks (*Gasterosteus aculeatus*) in Canada” was published in 2020 (DFO 2020). It is a comprehensive document that outlines measures that provide the best chance of achieving the population and distribution objectives for the species pair, including the measures to be taken to address the threats to the species pair and monitor its recovery.

3.3.3 Critical habitat identification and protection

For the Misty Lake Sticklebacks, critical habitat was identified to the extent possible, using the best available information, in section 7 of the recovery strategy (DFO 2018). Protection of Misty Lake Sticklebacks’ critical habitat from destruction was accomplished in 2018 through 2 SARA critical habitat orders (1 for each species in the pair) made under subsections 58(4) and (5), which invoke the prohibition in subsection 58(1) against the destruction of the identified critical habitat (SOR/2018-208; SOR/2018-209).

3.3.4 Recovery feasibility

Based on the current best available information, the recovery of the Misty Lake Sticklebacks is determined to be feasible (DFO 2018). No new information has been gathered that would suggest the Misty Lake Sticklebacks no longer meets the feasibility criteria laid out in the recovery strategy.

4 Concluding statement

Within this reporting period (2018 to 2022), through the implementation of the activities identified in the “Recovery Strategy for the Misty Lake Sticklebacks (*Gasterosteus aculeatus*) in Canada” (DFO 2018), some progress has been made in recovering the Misty Lake Sticklebacks, including:

- development and installation of public outreach signage on Misty Lake Sticklebacks and the Misty Lake Ecological Reserve
- research conducted to investigate reproductive isolation, parallel evolution, and genomic sequencing and analysis for the Misty Lake Sticklebacks
- publication of guidelines for scientific studies of Threespine Sticklebacks
- legal protection of Misty Lake Sticklebacks’ critical habitat through 2 SARA critical habitat orders in 2018
- publication of the “Action Plan for the Misty Lake Sticklebacks (*Gasterosteus aculeatus*) in Canada” in 2020

Population monitoring has not occurred for Misty Lake Sticklebacks during this reporting period (2018 to 2022). None of the performance indicators identified in the recovery strategy have been met and the status of the population and distribution objectives are unknown. Further work is required to support the survival and recovery of the Misty Lake Sticklebacks. Priority next steps may include, but are not limited to:

- developing and implementing a long-term population monitoring program to enable measurement of performance indicators and population and distribution objectives

- developing and implementing an aquatic invasive species monitoring and prevention plan for Misty Lake
- researching threats associated with land use and water quality, and implementation of effective threat mitigation
- increasing public outreach and education to promote awareness of Misty Lake Sticklebacks and for local stewardship and habitat protection

DFO remains committed to recovering the Misty Lake Sticklebacks. The work started and completed to date has built a strong foundation for continued research and management of this species pair over the next reporting period. Progress made to date would not have been achieved without the contribution of partners including the Invasive Species Council of British Columbia, British Columbia Ministry of the Environment and Climate Change Strategy, the Coastal Invasive Species Committee, the British Columbia Inter-Ministry Invasive Species Working Group, Environment and Climate Change Canada, BC Parks, and the University of British Columbia. DFO is looking forward to continuing this successful collaboration and welcomes the participation of additional partners.

5 References

Berner D., M. Roesti, S. Bilobram, S.K. Chan, H. Kirk, P. Pandoh, G.A. Taylor, Y. Zhao, S.J.M. Jones, and J. DeFaveri. 2019. De Novo Sequencing, Assembly, and Annotation of Four Threespine Stickleback Genomes Based on Microfluidic Partitioned DNA Libraries. Genes.10(6):426.

British Columbia Inter-Ministry Invasive Species Working Group. 2014. Invasive Species Strategic Plan. BC Government. 8 pp.

British Columbia Ministry of Environment and Climate Change Strategy. 2021. British Columbia Dreissenid Mussel Lake Monitoring Field Protocol. Ecosystems Branch BC Ministry of Environment and Climate Change Strategy. 36 pp.

COSEWIC. 2006. COSEWIC assessment and status report on the Misty Lake Sticklebacks *Gasterosteus* sp. (Misty Lake lentic Stickleback and Misty Lake lotic Stickleback) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 27 pp.

DFO (Fisheries and Oceans Canada). 2010. Potential Recovery Assessment for the Misty Lake stickleback (*Gasterosteus* spp.) pair. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2009/058.

DFO (Fisheries and Oceans Canada). 2018. Recovery Strategy for the Misty Lake Sticklebacks (*Gasterosteus aculeatus*) in Canada. *Species at Risk Act* Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa. vi + 41 pp.

DFO (Fisheries and Oceans Canada). 2020. Action Plan for the Misty Lake Sticklebacks (*Gasterosteus aculeatus*) in Canada. *Species at Risk Act* Action Plan Series. Fisheries and Oceans Canada, Ottawa. iv + 13 pp.

ECCC (Environment and Climate Change Canada). 2018. Biological Test Method: Reference Method for Determining Acute Lethality Using Threespine Stickleback, Method Development and Applications Unit, Science and Technology Branch, Ottawa, Ontario, Report EPS 1/RM/10, Second Edition. xiv + 40 pp.

Guzek, E., and G. Wilson. 2021. In Prep. Draft Invasive Species Prevention and Monitoring Plan for Threespine Stickleback Species Pair (*Gasterosteus spp*.) Lakes of Texada Island. Unpublished Fisheries Project Report No. RD xxx, Ecosystems Branch, Province of British Columbia Ministry of Environment and Climate Change Strategy. Report prepared for British Columbia Ministry of Environment and Climate Change Strategy, and Fisheries and Oceans Canada. 70 pp.

Haenel, Q., K.B. Oke, T.G. Laurentino, A.P. Hendry, and D. Berner. 2021. Clinal genomic analysis reveals strong reproductive isolation across a steep habitat transition in stickleback fish. Nature Communications 12:4850.

Haines, G.E., Y.E. Stuart, D. Hanson, T. Tasneem, D.I. Bolnick, H.C.E. Larsson, and A.P. Hendry. 2020. Adding the third dimension to studies of parallel evolution of morphology and function: an exploration based on parapatric lake-stream stickleback. Ecology and Evolution 10:13297-13311.

Invasive Species Council of British Columbia. 2017. The Invasive Species Strategy for British Columbia (2018–2022). 11 pp.

Invasive Species Council of British Columbia. 2022. Culturally Important At-Risk Species and Invasive Species. Literature Review prepared by the Invasive Species Council of BC. 28 pp.

Oke, K.B., M. Lu, and A.P. Hendry. 2017. Population size and geographical extent of Misty Lake lotic and lentic threespine stickleback. A report prepared for Fisheries and Oceans Canada and the Province of British Columbia.

Paccard, A., D. Hanson, Y.E. Stuart, F.A. von Hippel, M. Kalbe, T. Klepaker, S. Skúlason, B.K. Kristjánsson, D.I. Bolnick, A.P. Hendry, and R.D.H. Barrett. 2020. Repeatability of adaptive radiation depends on spatial scale: regional versus global replicates of stickleback in lake versus stream habitats. Journal of Heredity 111:43-56.

Rosenfeld, J., D. Sneep, T. Hatfield, D. McPhail, J. Richardson, D. Schluter, E. Taylor, and P. Wood. 2008. Guidelines for the Collection and In Situ Scientific Study of Stickleback Species Pairs (Gasterosteus spp.). The Recovery Team for Non-Game Freshwater Fish Species in British Columbia. Report prepared for Fisheries and Oceans Canada, Vancouver, British Columbia. 6 pp.

Tamburello, N., and A. Litt, 2021. A Systematic Assessment of Invasive Species Impacts to Species at Risk in British Columbia. Report prepared for the Invasive Species Council of BC (ISCBC). 27 pp + Appendices.

Woodruff, P., M. Nantel, and G. Wilson. 2021. In Prep. Draft Guidelines for the Collection and In Situ Scientific Study of Stickleback Species Pairs (Gasterosteus spp.) in British Columbia. British Columbia Ministry of Environment and Climate Change Strategy. Unpublished Report Prepared for Fisheries and Oceans Canada. 13 pp.