Species at Risk Act
Recovery Strategy Report Series

Report on the Progress of Recovery Strategy Implementation for the Paxton Lake, Enos Lake, and Vananda Creek Stickleback Species Pairs (*Gasterosteus aculeatus*) in Canada for the Period 2007 – 2015

Paxton Lake, Enos Lake, and Vananda Creek Stickleback Species Pairs

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For copies of the progress report, or for additional information on species at risk, including COSEWIC Status Reports, residence descriptions, action plans, and other related recovery documents, please visit the Species at Risk Public Registry.

Cover illustrations: Stickleback Species Pair from Paxton Lake, British Columbia. Top photo shows gravid Benthic Paxton Stickleback; bottom photo shows gravid Limnetic Paxton Stickleback. Credit: Todd Hatfield (Solander Ecological Research).

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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 effective 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.

Reporting on the progress of recovery strategy implementation requires reporting on the collective efforts of the competent minister(s), 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).

The Minister of Fisheries and Oceans is the competent minister(s) under SARA for the Paxton Lake, Enos Lake, and Vananda Creek Stickleback Species Pairs and has prepared this 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 constituencies 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 Paxton Lake, Enos Lake, and Vananda Creek Stickleback Species Pairs for the benefit of the species and Canadian society as a whole.

Acknowledgements

This Progress Report was prepared by The Department of Fisheries and Oceans Canada. The Department of Fisheries and Oceans would also like to express its appreciation to all individuals and organizations who have contributed to the recovery of the Paxton Lake, Enos Lake, and Vananda Creek Stickleback Species Pairs.

Executive Summary

The Paxton Lake and Vananda Creek Stickleback Species Pairs were assessed as Endangered in 2000, and again in 2010 by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2010a and 2010b). The Enos Lake Stickleback Species Pair was assessed as Endangered in 2002, and again in 2012 (COSEWIC 2012). The Enos Lake, Paxton Lake, and Vananda Creek Stickleback Species Pairs were listed under the *Species at Risk Act* as Endangered in June of 2003. In October of 2007 the final *Recovery Strategy for Paxton Lake, Enos Lake, and Vananda Creek Stickleback Species Pairs (*Gasterosteus *spp.) in Canada* (NRTSSP 2007) was posted to the Species at Risk Public Registry. Fisheries and Oceans Canada, in cooperation with the Province of British Columbia's Ministry of Environment, is developing an Action Plan for the Paxton Lake and Vananda Creek Stickleback Species Pairs as part of the Government of Canada's ongoing commitment to the conservation of species at risk through the implementation of the *Species at Risk Act*.

Threats to the Paxton Lake, Enos Lake, and Vananda Creek Stickleback Species Pairs, as identified in the Recovery Strategy, include: exotic species, water management (leading to low water quality and quantity), and land-based development (leading to eutrophication, sedimentation, and habitat destruction/alteration). Impacts may also occur from fishing, recreation, disease, climate change, and pollution. The recovery goal for these species as identified in the Recovery Strategy is to "…secure the long-term viability of all extant populations of Species Pairs. It is likely that these species will always remain at some risk due to their extremely limited distribution."

This report documents the progress of Recovery Strategy implementation for the Paxton Lake, Enos Lake, and Vananda Creek Stickleback Species Pairs. It summarizes progress that Fisheries and Oceans Canada, and other interested parties have made towards achieving the goal and objectives set out in the Recovery Strategy, including:

- conducting new research and monitoring activities (including advancing studies to support the identification of critical habitat); and
- completing management activities that help Canadians reduce impacts on, and better understand threats to, the Paxton Lake, Enos Lake, and Vananda Creek Stickleback Species Pairs.

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1 Background

1.1 Species Status

Assessment Summary – April 2010

Common name:
Paxton Lake Benthic and Limnetic Threespine Stickleback

Scientific name:
Gasterosteus aculeatus

COSEWIC Status:
Endangered

Reason for designation:
This small freshwater fish is a unique Canadian endemic that is restricted to a single small lake in coastal British Columbia (BC). The wildlife species is highly susceptible to extinction from aquatic invasive species introductions that have been observed to cause rapid extinction of similar species in at least two other lakes. Invasive aquatic species continue to increase in lakes on adjacent Vancouver Island and the lower mainland of BC, and there is, therefore, a reasonable likelihood that invasives could be introduced into the habitat of the species over the next 10 years. This species is also susceptible to habitat loss and degradation from water extraction and land use activities in the surrounding landscape.

Occurrence:
British Columbia

Status history:
Designated Threatened in April 1998. Status re-examined and confirmed in April 1999. Status re-examined and designated Endangered in May 2000. Status re-examined and confirmed in April 2010.

***Species at Risk Act* status:**
Listed, Endangered

Assessment Summary – April 2010

Common name:
Vananda Creek Benthic and Limnetic Threespine Stickleback

Scientific name:
Gasterosteus aculeatus

COSEWIC status:
Endangered

Reason for designation:
This small freshwater fish is a unique Canadian endemic that is restricted to three small, interconnected lakes in coastal British Columbia (BC). The wildlife species is highly susceptible to extinction from aquatic invasive species introductions that have been observed to cause rapid extinction of similar species in at least two other lakes. Invasive aquatic species continue to increase in lakes on adjacent Vancouver Island and the lower mainland of BC, and there is, therefore, a reasonable likelihood that invasives could be introduced into the habitat of the species over the next 10 years. This species is also susceptible to habitat loss and degradation from water extraction and land use activities in the surrounding landscape.

Occurrence:
British Columbia

Status history:
Designated Threatened in April 1999. Status re-examined and designated Endangered in May 2000 and in April 2010.

***Species at Risk Act* status:**
Listed, Endangered

Assessment Summary – May 2012

Common name:
Enos Lake Benthic and Limnetic Threespine Stickleback

Scientific name:
Gasterosteus aculeatus

COSEWIC Status:
Endangered

Reason for designation:
This small fish occurs in a single lake in south coastal British Columbia where it has now formed a hybrid swarm with a co-existing stickleback. Although it is possible that a small number of genetically pure fish still exist in the lake, the ongoing presence of an invasive crayfish, and associated habitat degradation, continue to place this species at a high risk of extinction.

Occurrence:
British Columbia

Status history:
Original designation (including both Benthic and Limnetic species) was Threatened in April 1988. Split into two species when re-examined in November 2002 and the Enos Lake Benthic and Limnetic Threespine Stickleback was designated Endangered. Status re-examined and confirmed in May 2012.

***Species at Risk Act* status:**
Listed, Endangered

1.2 Threats

1.2.1 Threats

Threats to the Paxton Lake, Enos Lake, and Vananda Creek Stickleback Species Pairs (hereafter referred to as Stickleback Species Pairs), as identified in Section 3 of the *Recovery Strategy for Stickleback Species Pairs* (Gasterosteus spp.) *in Canada* (NRTSSP 2007), include: exotic species, water management (leading to low water quality and quantity), and land-based development (leading to eutrophication, sedimentation, and habitat destruction/alteration). Impacts may also occur from fishing, recreation, disease, climate change, and pollution.

1.2.2 Activities Likely to Destroy Critical Habitat

Neither critical habitat nor activities likely to destroy critical habitat were identified for the Paxton Lake, Enos Lake, and Vananda Creek Stickleback Species Pairs in the Recovery Strategy; however, these will both be identified for the Paxton Lake and Vananda Creek Stickleback Species Pairs[1] in a forthcoming Action Plan.

2 Recovery

2.1 Recovery Goal and Objectives

The Recovery Goal and Objectives[2] (identified in Sections 7 and 8 of the Recovery Strategy respectively), are as follows:

Recovery Goal

Secure the long-term viability of all extant populations of Stickleback Species Pairs. It is likely that these species will always remain at some risk due to their extremely limited distribution.

Recovery Objectives

Short term:

1. Maintain self-sustaining populations of Stickleback Species Pairs in Paxton Lake and the Vananda Creek watershed.
2. Establish captive populations of the Enos Lake Species Pair.

Long-term:

1. Maintain self-sustaining populations of Stickleback Species Pairs in Paxton Lake and the Vananda Creek watershed.
2. Establish or recover a viable population of the Enos Lake Species Pair, preferably in Enos Lake.

[1] The extirpation of the Enos Lake Stickleback Species Pair has not been confirmed, although it is believed that the two species have collapsed into a hybrid swarm (Taylor et al. 2006; COSEWIC 2010a, 2010b).
[2] Referred to in the forthcoming Action Plan for the Paxton Lake and Vananda Creek Stickleback Species Pairs as “population and distribution objectives.”

3. Re-establish a Stickleback Species Pair in Hadley Lake from an extant population by restoring Hadley Lake habitat and introducing a Species Pair from an extant population on Texada Island.[3]

2.2 Performance Measures

Performance Measures (as outlined in the Recovery Strategy) are reproduced in detail in Section 3.3 of this document.

3 Progress towards Recovery

Section 46 of the *Species at Risk Act* requires the competent Minister to report on the implementation of the Recovery Strategy, and the progress towards meeting its objectives, within five years after it is included in the public registry and in every subsequent five-year period, until its objectives have been achieved or the species' recovery is no longer feasible. In the interest of capturing the most recent progress on the recovery of the Stickleback Species Pairs, this document includes actions completed up to September 2015.

[3] Recovery of the Hadley Lake Stickleback Species Pair is not reported on in this document, as they are not currently listed under the *Species at Risk Act*.

3.1 Research and Monitoring Activities

Table 1. Summary of achievements towards completing the Schedule of Studies and/or identification of critical habitat, as well as new research and monitoring activities conducted/ongoing since the completion of the Recovery Strategy in 2007

#	Strategy	Recovery Objectives Addressed	Activities Completed or Underway	Organizations Involved[4]
Activities from Schedule of Studies outlined in 2007 Recovery Strategy.				
1	Identify and fill information gaps (life-history and habitat use) that prevent objective definition of critical habitat.	All	• Refer to rows 2, 4 through 10, and 12 of Table 1.	Refer to rows 2, 4 through 10, and 12 of Table 1.
2	Determine acceptable minimum population levels for limnetics and benthics that will ensure species persistence.	Short-term: 1 Long-term: 1, 2, 3	• In 2015, the BC MOE and DFO initiated plans to conduct updated abundance and distribution estimates for the Paxton Lake and Vananda Creek SSP,[5] to assist in determining allowable harm estimates.	BC MOE;[6] DFO[7]
3	Develop water quality guidelines for species pair lakes.	Short-term: 1 Long-term: 1, 2, 3	• Refer to row 19 of Table 2.	Refer to row 19 of Table 2.
4	Map the present extent of littoral habitat and extent of macrophytes.	Short-term: 1 Long-term: 1, 2, 3	• In 2007, 2008 and 2009 the NN identified and mapped macrophyte vegetation in Enos Lake and produced a bathymetric map of Enos Lake.	NN;[8] GOC[9]
			• Jackson et al. (2013) determined species composition, and the extent of littoral habitat and macrophyte beds in Priest and Paxton lakes, and compared data to an existing baseline study conducted by the TSGA.	DFO; AWCL[10]

[4] This column is based on the best available information; DFO acknowledges the large network of people that contribute to recovery of this species, and regrets any potential omissions in Tables 1 and 2.
[5] Stickleback Species Pair.
[6] Province of British Columbia's Ministry of Environment.
[7] Fisheries and Oceans Canada.
[8] Nanoose Naturalists.
[9] Government of Canada.
[10] Acroloxus Wetlands Consultancy Ltd.

#	Strategy	Recovery Objectives Addressed	Activities Completed or Underway	Organizations Involved[4]
5	Determine crayfish effects on stickleback recruitment and critical habitat.	Short-term: 1 Long-term: 1, 2, 3	• Velema et al. (2012) studied behavioural observations of crayfish-stickleback interactions and stickleback nesting behaviour in aquaria. • Researchers conducted cattle tank experiments to evaluate impacts of spatial segregation (provided by macrophytes) on reproductive isolation of benthic and limnetic sticklebacks (Velema pers. comm. 2014). • Researchers studied growth rates in juvenile Paxton Lake Sticklebacks, as influenced by Signal Crayfish (Velema pers. comm. 2014).	BC MOE; UBC[11]
			• In 2007 and 2008, researchers conducted an enclosure study *in situ* on the effect of Signal Crayfish on the Enos Lake SSP and their habitat (Rosenfeld et al. 2008b; Ryper 2008), assisting in determining the feasibility of SSP re-introduction.	NN; BC MOE; UBC; BCFSP;[12] BCMFLNRO;[13] GOC; MUC; [14] BCCC[15]
6	Define acceptable levels of water fluctuations/drawdowns that will permit species pair persistence, based on extent of littoral habitat at different water levels, historic data, and a comparison between conditions in species pair lakes and single-species lakes.	Short-term: 1 Long-term: 1, 2, 3	• In 2007/2008 the NN calculated a lake level regime intended to minimize adverse effects on stickleback spawning and rearing.	NN; GOC
			• Jackson et al. (2013) studied records of water level changes over a five year period in Priest Lake.	DFO; AWCL[16]
7	Develop acceptable ranges of invertebrate production in the benthos and pelagic that will permit	Short-term: 1 Long-term: 1, 2, 3	• In 2007/2008 the NN studied zooplankton composition and abundance in Enos Lake.	NN

[11] University of British Columbia.
[12] British Columbia Forest Science Program.
[13] British Columbia Ministry of Forests, Lands, and Natural Resource Operations.
[14] Malaspina University College.
[15] British Columbia Conservation Corps.
[16] Acroloxus Wetlands Consultancy Ltd.

#	Strategy	Recovery Objectives Addressed	Activities Completed or Underway	Organizations Involved[4]
	species pair persistence, by comparison between species pair lakes and single-species lakes.			
General Approach: Delineation and protection of key habitats				
8	Conduct studies to identify critical habitat for the Stickleback Species Pairs.	Short-term: 1 Long-term: 1, 2	• Hatfield published a research document (2009) providing recommendations for defining Paxton Lake and Vananda Creek SSP critical habitat.	SER;[17] DFO
9	Determine the feasibility of restoring habitat in Enos and Hadley Lakes and introducing Species Pairs.	Short-term: 1 Long-term: 2, 3	• Researchers assessed the degree of SSP hybridization in Enos Lake using morphological and genetic assays, suggesting they have likely collapsed into a hybrid swarm (Taylor et al. 2006; Taylor unpubl.), assisting in determining the feasibility of re-introduction.	UBC; UU;[18] UWM;[19] University of Wales; BC MOE; DFO
			• In 2007, 2008 and 2009 the NN and MUC conducted exotic Signal Crayfish (*Pacifastacus leniusculus*) trapping in Enos Lake in order to remove individuals, and determine a crayfish population estimate (Ryper 2008), assisting in determining the feasibility of SSP re-introduction.	NN; MUC
General Approach: Designing and implementing sound monitoring program				
10	Develop and implement an ongoing long-term monitoring program.	Short-term: 1 Long-term: 1, 2	• In 2007/2008 the NN conducted the following in Enos Lake: o estimated the proportional composition of the stickleback population according to benthic, limnetic, benthic-hybrid, and limnetic-hybrid forms, and compared ratios to previous data; o recorded the distribution of stickleback; o identified stickleback association with substrate type; and, o measured lengths of captured stickleback.	NN
			• In 2007, 2008 and 2009 the NN conducted biophysical baseline monitoring in Enos Lake.	NN
			• Jackson and Gow (2008) conducted a baseline survey of aquatic vegetation in Paxton and Priest Lakes.	TSGA;[20] GOC

[17] Solander Ecological Research.
[18] University of Utrecht.
[19] University of Wisconsin-Madison.
[20] Texada Stickleback Group Association.

#	Strategy	Recovery Objectives Addressed	Activities Completed or Underway	Organizations Involved[4]
			• In 2008 and 2009 the TSGA conducted biophysical baseline monitoring in Priest and Paxton Lakes (Texada Stickleback Group n.d.).	TSGA
			• Harvey and Brown incorporated best collection and monitoring approaches into a draft *Species at Risk Act* multi-species compendium report (2013a, 2013b), which will inform the development and implementation of a comprehensive monitoring plan.	DFO
			• Jackson et al. (2013) measured sediment composition to detect potential heavy metal contamination and nutrient enrichment.	DFO; AWCL[21]
			• In 2015, researchers conducted morphological measurements in Priest and Paxton Lakes to: o confirm species identity and for general comparative and monitoring purposes; o continue efforts begun in 2013 and 2014 to estimate the rate at which hybrids between sympatric limnetics and benthics are produced, and the rate at which they are removed by natural selection.	UBC; NSERC[22]
11	Develop sound protocols for scientific investigations (e.g., limit use of hybrids in in situ experiments, limit number of fish collected each year, etc.).	All	• Rosenfeld et al. developed the "Guidelines for the Collection and In Situ Scientific Study of Stickleback Species Pairs (*Gasterosteus* spp.)" (2008a), which DFO applied to scientific research permitting processes under Section 73 of the *Species at Risk Act* from 2008 to 2014.	BC MOE; UBC; SER; DFO
			• In 2015, the BC MOE and DFO initiated updates to the "Guidelines for the Collection and In Situ Scientific Study of Stickleback Species Pairs (*Gasterosteus* spp.)" (2008a).	BC MOE; DFO
General Approach: Undertaking specific research activities to clarify threats				
12	Establish and support a "Research Action Group" to undertake specific research activities and	All	• Ormond et al. (2011) compared limnological and biotic attributes of SSP lakes with single stickleback species lakes.	BC MOE; UBC; BCFSP;[23] NSERCDC[24]

[21] Acroloxus Wetlands Consultancy Ltd.
[22] Natural Sciences and Engineering Research Council of Canada
[23] British Columbia Forest Science Program.
[24] Natural Sciences and Engineering Research Council of Canada Discovery Grant.

#	Strategy	Recovery Objectives Addressed	Activities Completed or Underway	Organizations Involved[4]
	provide detailed technical advice.		• Clarke and Schluter (2011) recorded body coloration observations (in both the visible and ultraviolet spectrum) and studied the adaptive significance of pelvic girdle loss in the benthic form of the Paxton Lake Stickleback. • Southcott et al. (2013) performed assortative mating trials with Paxton Lake and Vananda Creek SSP, including observations on nesting and reproductive behaviour. • Researchers measured gene expression in the eyes of Paxton Lake and Vananda Creek SSP, as related to colour vision (D. Schluter pers. comm. 2014). • Researchers initiated a new method for estimating the degree of hybridization and relative fitness within Paxton Lake and Vananda Creek SSP (Schluter pers. comm. 2014). • Researchers conducted a behavioural study to measure impacts of evolved differences between Paxton Lake and Vananda Creek SSP on the wider ecosystem, and a follow up study using all extant sticklebacks to test for parallel evolution of ecosystem effects (Schluter pers. comm. 2014). • Researchers recorded behavioural observations of sticklebacks, such as boldness, in response to stimuli of varying risk (Schluter pers. comm. 2014). • Researchers conducted a laboratory experiment investigating shoaling and schooling behaviour of Paxton Lake and Vananda Creek SSP (Schluter pers. comm. 2014). • Researchers conducted mating trials with Paxton Lake and Vananda Creek SSP to evaluate whether hybrid females prefer benthic or limnetic forms (allowing for a "genetic map" of female preference) (Schluter pers. comm. 2014). • In 2015, researchers investigated the evolution of visual acuity and neuromast density and conducted genotyping to generate an estimate of assortative mating and natural selection.	UBC
			• In 2011/2012 Lackey and Boughman (in prep.) tested egg fertilization success using artificial crosses within and between species.	SDEGWSF;[25] NSFCG[26]

[25] Sigma Delta Epsilon Graduate Women in Science Fellowship.
[26] National Science Foundation Career Grant.

#	Strategy	Recovery Objectives Addressed	Activities Completed or Underway	Organizations Involved[4]
			• Malek et al. (2012) conducted "association mapping" to locate genes segregating the forms in Enos Lake.	UBC; FHCRC[27]
			• Lackey and Boughman (2013a, 2013b) measured sexual selection and isolation through courtship trials to better understand forward and reverse speciation.	NSFCG; BCEA;[28] MSU[29]
			• Tinghitella et al. (2013) investigated the role of plasticity in female preferences in facilitating the loss of male signaling traits through courtship trials.	NSFCG; BCEA; MSU; UD;[30] UE[31]
			• Researchers sampled Paxton Lake and Vananda Creek Sticklebacks in order to re-sequence genomes (Schluter pers. comm. 2014).	UBC; MPI;[32] FHCRC; SU[33]
			• Arnegard et al. (2014) sampled the Vananda Creek SSP for stable isotope analysis to compare with single stickleback species systems. • Arnegard et al. (2014) performed lab crossing with Paxton and Vananda Sticklebacks to identify genes that distinguish the species in morphology and behaviour.	UBC; FHCRC; SU
			• Lackey and Boughman (2014) studied the effect of male stickleback nesting habitats on female mating preferences.	NSFCG; SDEGWSF; MSU
			• In 2015, researchers: o studied the effect of having one sensory modality occluded by environmental changes, and the resulting effect on assortative mating between species; o studied sexual selection and sexual isolation to understand forward and reverse speciation; and, o measured all sticklebacks studied for standard weight and length, photographed, and color scored.	MSU

[27] Fred Hutchinson Cancer Research Center.
[28] BEACON Center for Evolution in Action.
[29] Michigan State University
[30] University of Denver.
[31] University of Exeter.
[32] Max Planck Institute.
[33] Stanford University School of Medicine.

#	Strategy	Recovery Objectives Addressed	Activities Completed or Underway	Organizations Involved[4]
			• In 2015, researchers measured phosphorus excretion rates to increase understanding of nutritional usage (excretion vs. assimilation) between the species pair populations, and determine how these differences affect the broader ecosystem.	UVIC[34]
13	If re-introduction is feasible, establish a captive breeding program for the Enos Lake Species Pair.	Short-term: 2 Long-term: 2	• Refer to row 9 of Table 1.	Refer to row 9 of Table 1.

[34] University of Victoria.

3.2 Management Activities

Table 2. Summary of activities undertaken to reduce or eliminate threats to the Stickleback Species Pairs, threats to critical habitat and/or threats to its residence

#	Strategy	Recovery Objectives Addressed	Activities Completed or Underway	Organizations Involved
General Approach: Establishing and supporting stewardship initiatives.				
14	Establish and support Recovery Implementation Groups (RIGs) or alternative working groups for Texada Island and Enos Lake.	Short-term: 1, 2 Long-term: 1, 2	• In 2007, 2008, and 2009 the NN collaborated with the Texada Island RIG to compare lake data collected.	NN; GOC
15	Develop and implement an information and education plan that includes the following elements: • Public education material regarding the threat of exotic species • Presentation materials for public schools • Educational signage for appropriate placement	All	• In 2006/2007 the TSGA: o organized an educational workshop held December 2006 at the Community Hall on Texada Island with over 15 scheduled speakers as well as educational (e.g., UBC, UW[35]), DFO, forestry, and other specialist attendees; and, o created 3 interpretive signs (posted at Priest Lake, Emily Lake, and the Texada Island ferry terminal) and 1,000 educational brochures for the Paxton Lake and Vananda Creek SSP. • In 2008/2009 the TSGA designed and created a centralized online hub for access to, and dissemination of, information concerning Paxton Lake and Vananda Creek SSP. • In 2011/2012 the TSGA created an educational video for Paxton Lake and Vananda Creek SSP aligned with BC school curricula, including suggested activities and an accompanying study guide; they presented the video at the International Conference on Stickleback Behavior and Evolution in Seattle, Washington.	TSGA; GOC

[35] University of Washington.

#	Strategy	Recovery Objectives Addressed	Activities Completed or Underway	Organizations Involved
			• In 2007/2008 the NN published articles on the Enos Lake Stickleback in the newsletters of BC Nature, Victoria Field Naturalists, and the Northwest Nanoose Residents Association. • In 2008/2009 the NN collaborated with a writer to publish a story on the Enos Lake sticklebacks in the Globe and Mail, and air a story on CBC[36] Radio, Victoria. • In 2007, 2008, and 2009 the NN: o developed and distributed brochures and signs for the Enos Lake Stickleback; and, o provided educational information on the Enos Lake SSP at public meetings (e.g. a one-day symposium at UBC hosted by the National Recovery Team for Non-Game Freshwater Fish).	NN; GOC
General Approach: Minimizing impacts from land and water use.				
16	Jointly develop land management strategies for crown and private lands.	Short-term: 1 Long-term: 1, 2, 3	• In 2007/2008 the TSGA evaluated remedial efforts in the vicinity of Texada Quarrying Ltd. holdings, including: mapping of watershed creeks, soil and slope analysis, vegetation type and cover analysis with associated risk analysis. • In 2007/2008 the TSGA conducted the following to manage Priest Lake's roadside habitat: o developed an agreement between local residents and landowners in the Vananda Watershed regarding future road maintenance; o completed a Priest Lake bypass road (bypassing an old alternate route near Priest Lake's shore); o partially deactivated an old alternate route near Priest Lake's shore; o received confirmation from many landowners to limit use of an old alternate route near Priest Lake's shore; o investigated riparian planting to stabilize an old alternate route near Priest Lake's shore; and o re-ditched and repaired property access roads	TSGA; GOC

[36] Canadian Broadcasting Corporation.

#	Strategy	Recovery Objectives Addressed	Activities Completed or Underway	Organizations Involved
			near Priest Lake (including adding an emergency overflow culvert, and additional shield rock).	
			• In 2013 the BCMFLNRO established an 881 ha Wildlife Habitat Area (WHA #2-250) on provincial Crown land under the *Forest and Range Practices Act* (FRPA). • The BCMFLNRO also established a WHA (#2-250) in 2015 under the *Environmental Protection and Management Regulation* (B.C. Reg. 200/2014) of the *Oil and Gas Activities Act* encompassing the same geographic area as FRPA's WHA #2-250.	BCMFLNRO
17	Determine the potential impacts of recreational fishing in species pair lakes and develop mitigation measures as required.	Short-term: 1 Long-term: 1, 2, 3	• A forthcoming Action Plan for the Paxton Lake and Vananda Creek Stickleback Species Pairs addresses the need to research potential impacts of recreational lake usage on the Stickleback Species Pairs.	DFO
18	Determine potential impacts of gas operated motor boats on water quality in the species pair lakes and develop mitigation measures as required, and discourage impacts from lakeshore development and recreational use.	Short-term: 1 Long-term: 1, 2, 3		
19	Establish water quality objectives for all species pair lakes.	Short-term: 1 Long-term: 1, 2, 3	• In 2007/2008 the Nanoose Naturalists developed and submitted an Enos Lake water management plan to the key landowner in the watershed, and developed a "medium-term management plan" for the Enos Lake Stickleback Species Pair, which addresses (among others) water quality.	NN
			• A forthcoming Action Plan for the Paxton Lake and Vananda Creek Stickleback Species Pairs will consider the need to develop species and/or lake-specific water quality objectives, in order to address the species' biological needs and parameters that affect habitat quality.	DFO
20	Investigate potential water quality implications from use of explosives for mining activities within species pairs' watersheds.	Short-term: 1 Long-term: 1, 2, 3	• The TSGA coordinated a general risk assessment for watersheds in the vicinity of Texada Quarrying Ltd. Holdings; results were compiled in a report and shared as appropriate.	TSGA
21	Develop a comprehensive water	Short-term:	• Since the early 1990s, and most recently in 2013, the	BCMFLNRO

#	Strategy	Recovery Objectives Addressed	Activities Completed or Underway	Organizations Involved
	management plan for each basin.	1 Long-term: 1, 2, 3	BCMFLNRO has issued water licenses under the *Water Act* containing measures reducing impacts to the Enos Lake SSP (Wilson pers. comm. 2015).	
			• In 2008/2009 the TSGA: ○ engaged specialists to determine the structural integrity of existing dams in the Paxton Lake and Vananda Creek watersheds, and produced a report; ○ consulted with key water management stakeholders regarding plans for dam remediation; and, ○ received stakeholder commitments for dam remediation funds.	TSGA; GOC; VAID[37]
			• In 2007/2008 the NN: ○ developed and submitted an Enos Lake water management plan to the key landowner in the watershed; and, ○ worked with landowners to further incorporate water protection measures for Enos Lake into land development planning (continued in 2009).	NN; GOC
General Approach: Participation in the development and implementation of an exotic species management plan				
22	Support development and implementation of an exotic species management plan with direct links to stewardship groups.	Short-term: 1 Long-term: 1, 2, 3	• In 2007/2008 the NN developed a "medium-term management plan" for the Enos Lake SSP, addressing (among others) invasive species introductions.	NN; GOC
			• In 2015, DFO approved the *Aquatic Invasive Species Regulations* under the federal *Fisheries Act,* providing a suite of regulatory tools that can be used to prevent new introductions and manage spread of aquatic invasive species.	DFO
			• In 2015, the BC MOE and DFO initiated preparation of a monitoring plan for the presence of aquatic invasive species, and to prevent their establishment, in Paxton Lake.	BC MOE; DFO

[37] Van Anda Improvement District.

#	Strategy	Recovery Objectives Addressed	Activities Completed or Underway	Organizations Involved
			• Existing provincial procedures for rapid response to invasive species introductions (Province of British Columbia 2014, 2015) may be applied if necessary.	BC MOE

3.3 Summary of Progress towards Recovery

Action Planning

Fisheries and Oceans Canada, in collaboration with the Province of British Columbia's Ministry of Environment, is developing an Action Plan for Paxton Lake and Vananda Creek Stickleback Species Pairs as part of the Government of Canada's ongoing commitment to the conservation of species at risk through the implementation of the *Species at Risk Act*.

Report on Performance Measures

Performance measures (as outlined in the Recovery Strategy) and their outcomes are addressed below.

1. **Has a RIG or working group been established for each stickleback Species Pair? Are the RIGs adequately supported with funding and technical expertise? Has an Action Plan been developed? Are the RIGs achieving the goals outlined in the Recovery Strategy?**

   Groups such as the Nanoose Naturalists (for the Enos Lake watershed) and the Texada Stickleback Group Association (TSGA; for the Paxton Lake and Vananda Creek watersheds) perform the functions of RIGs. Funding is largely obtained on a year-to-year basis. Members provide technical expertise and in-kind support. A total of seven Habitat Stewardship Program projects have been funded by the Government of Canada between these two groups to date.

   An Action Plan for the Paxton Lake and Vananda Creek Stickleback Species Pairs is currently under development by Fisheries and Oceans Canada in cooperation with the Province of British Columbia's Ministry of Environment, as per section 48(1) of the *Species at Risk Act*.

   The goal of the Recovery Strategy may never be fully achieved due to the Stickleback Species Pairs' extremely limited distribution. However, in the timeframe of this report many achievements (outlined in Tables 1 and 2) have contributed to the recovery of the Paxton Lake and Vananda Creek Stickleback Species Pairs. While several completed activities were targeted at the Enos Lake Stickleback Species Pair, recent research suggests these species have likely collapsed into a hybrid swarm (Taylor et al. 2006; Taylor unpubl.). Recovery of the Hadley Lake Stickleback Species Pair is not reported on here, as they are not currently listed under the *Species at Risk Act*.

2. **Has a Research Action Group been established? Is it supported with adequate funding and technical expertise? Is it meeting the research needs identified in the Recovery Strategy?**

   A "Research Action Group" was established in 2003, consisting primarily of researchers from the University of British Columbia. In more recent years, multiple stewardship groups (such as the Nanoose Naturalists and the TSGA) have conducted research activities and provided technical expertise. Funding is largely obtained on a year-to-year basis. Refer to row 12 of Table 1 for details of research activities conducted between 2007 and 2015.

3. Have monitoring programs been implemented? How long has a monitoring program been in place? Is it effective? Is funding secure for the long term?

A regularly scheduled, comprehensive monitoring program has not been implemented for any watersheds; however, several monitoring activities have been achieved by stewardship groups and researchers (refer to Table 1 for details). For example, in Enos Lake the following has been conducted: biophysical baseline monitoring; surveys of stickleback distribution, body length, and habitat associations; mapping of macrophyte vegetation and bathymetry; an assessment of the degree of hybridization between benthics and limnetics; and, a survey of zooplankton composition and abundance. In Paxton and Priest Lakes the following has been conducted: biophysical baseline monitoring; surveys of species composition and the extent of littoral habitat and macrophyte beds; measurements of sediment composition; estimations of the rate at which hybrids are produced and removed by natural selection; and, morphological measurements. In Priest Lake a review of water level changes over a five year period has also been conducted. In 2015, the BC MOE and DFO initiated plans to conduct updated abundance and distribution estimates for the Paxton Lake and Vananda Creek Stickleback Species Pairs, to assist in determining allowable harm estimates.

Best collection and monitoring approaches were incorporated into draft *Species at Risk Act* multi-species compendium reports (Harvey and Brown 2013a, 2013b), which will inform the development and implementation of a comprehensive monitoring plan.

Where the wild capture of sticklebacks in the Paxton Lake and Vananda Creek watersheds is permitted under section 73 of the *Species at Risk Act*, the location and morphological characteristics of these individuals are often recorded, and may serve as a reference for future monitoring studies.

Effectiveness of monitoring protocols remains to be evaluated following a comparison of data and methods from multiple years. Funding for monitoring is largely obtained on a year-to-year basis.

4. Has an effective exotic species management plan been developed and implemented? Has an emergency action plan been developed and approved? Are there resources available to carry it out?

No exotic species management plan or emergency action plan has been developed for Stickleback Species Pairs specifically; however, extensive research on the exotic Signal Crayfish has been conducted (refer to rows 5 and 9 of Table 1) and is expected to inform such plans, once initiated. In addition, the Nanoose Naturalists developed a “medium-term management plan” for the Enos Lake Stickleback Species Pair, addressing (among others) invasive species introductions. In 2015, DFO approved the *Aquatic Invasive Species Regulations* under the federal *Fisheries Act*, providing a suite of regulatory tools that can be used to prevent new introductions and manage spread of aquatic invasive species. Also in 2015, the BC MOE and DFO initiated preparation of a monitoring plan for the presence of aquatic invasive species, and to prevent their establishment, in Paxton Lake. Existing provincial procedures for rapid response to invasive species introductions (Province of British Columbia 2014, 2015) may also be applied if necessary.

5. Has a defensible decision been reached to re-establish a Species Pair in Enos Lake and/or Hadley Lake? Has the role of crayfish in hybridization been unambiguously

determined? Is extirpation of exotics feasible and desirable? Have factors permitting reintroduction of Species Pairs been unambiguously identified?

A formal decision has not yet been made regarding re-establishment of a Stickleback Species Pair in Enos Lake. Decisions regarding re-establishment of a Hadley Lake Stickleback Species Pair are not reported on here, as they are not currently listed under the *Species at Risk Act*.

Several documents have been written on the potential role of crayfish in stickleback hybridization (e.g. Taylor et al. 2006, Rosenfeld et al. 2008b, Velema 2010, Taylor unpubl., Velema et al. 2012; Ryper 2008). Factors permitting stickleback reintroduction aside, preliminary attempts at crayfish extirpation by removal elsewhere (e.g., Hein et al. 2006, Freeman et al. 2009) and in Enos Lake (refer to row 9 of Table 1 for details) suggest feasibility is low.

6. Has critical habitat been defined for stickleback Species Pairs?

Critical habitat identification for the Paxton Lake and Vananda Creek Stickleback Species Pairs will be identified in a forthcoming Action Plan. Critical habitat will be informed by departmental guidance on the identification of critical habitat and the publicly available research document *Identification of Critical Habitat for Sympatric Stickleback Species Pairs and the Misty Lake Parapatric Stickleback Species Pair* (Hatfield 2009), which reflects the outcomes of the related peer review process undertaken through DFO's Canadian Science Advisory Secretariat.

7. Have water quality objectives been established and communicated to relevant regulators and stakeholders?

In 2007/2008 the Nanoose Naturalists developed and submitted an Enos Lake water management plan to the key landowner in the watershed, and developed a "medium-term management plan" for the Enos Lake Stickleback Species Pair, which addresses (among others) water quality. In 2008/2009 the TSGA consulted with key water management stakeholders regarding plans for dam remediation in Priest, Emily and Paxton lakes. And, in 2009, the Nanoose Naturalists continued work with landowners to further incorporate water protection measures programs for Enos Lake into land development planning.

A forthcoming Action Plan for the Paxton Lake and Vananda Creek Stickleback Species Pairs will consider the need to develop species and/or lake-specific water quality objectives, in order to address the species' biological needs and parameters that affect habitat quality.

8. Has a water management plan been completed and implemented?

In 2007/2008 the Nanoose Naturalists developed an Enos Lake water management plan and submitted it to the key landowner in this watershed. A forthcoming Action Plan for the Paxton Lake and Vananda Creek Stickleback Species Pairs will also consider the need to develop and implement projects to promote water conservation and the adoption of best practices for water use in the Paxton Lake and Vananda Creek watersheds.

Since the early 1990s, and most recently in 2013, the BCMFLNRO has issued water licenses under the *Water Act* containing measures reducing impacts to the Enos Lake SSP (Wilson pers. comm. 2015).

9. Have captive populations been established for the Enos Lake Species Pair? Is the captive population thriving? Have genetic goals been established for the breeding program and are they being achieved?

UBC discontinued their captive breeding program (Schluter pers. comm. 2015) as genetic marker data and morphological measurements indicated further breeding of pure individuals would be infeasible. A population descended from pure Enos Lake limnetics existed at Murdo-Frazer Park as of 2014; however, it appears that over generations it is evolving away from the pure limnetic phenotype (Schluter pers. comm. 2015).

The status of a captive population, as well as genetic goals for a breeding program, is dependent on the establishment of an initial recovery-based captive breeding program. Further consideration of a recovery-based captive breeding program cannot proceed until the degree of Enos Lake Stickleback Species Pair hybridization is confirmed (refer to Performance Measure #5).

10. Have educational materials been produced? Has public perception and awareness been affected? How many classes have received educational presentations? Has public perception and awareness been affected? How many educational signs have been erected? Has public perception and awareness been affected?

In addition to presentations at various meetings, a website, video with study guide, and over 1,500 brochures have been created for educational purposes (refer to row 15 of Table 2 for details). Specifically, students at Islandwood Elementary School on Vancouver Island received educational presentations, though the exact number of classes is unknown. An educational sign has been erected at Enos, Priest, and Emily lakes and at the Texada Island ferry terminal. Across the seven projects that received funding from the Habitat Stewardship Program for these species, it is estimated that over 45,000 people have been reached by various education and outreach initiatives; however, changes in public perception and awareness have yet to be evaluated.

11. **Are the minimal regulatory changes implemented (with respect to "[determining] the potential impacts of recreational fishing in Species Pair lakes and develop[ing] mitigation measures as required")?**

Additional research is required prior to initiating regulatory changes. A forthcoming Action Plan for the Paxton Lake and Vananda Creek Stickleback Species Pairs will address the need to research potential impacts of recreational lake usage on the Stickleback Species Pairs.

12. Has a literature review been conducted and communicated to the Recovery Team? Have water quality samples been taken of runoff from mining sites? Have the samples been analyzed and results effectively communicated?

A literature review on the potential water quality implications from the use of explosives for mining activities has not been completed for all watersheds. The TSGA did, however, coordinate a general risk assessment for watersheds in the vicinity of Texada Quarrying Ltd. Holdings; results were compiled in a report and shared as appropriate. Water quality samples of runoff from mining sites have not been taken.

13. Are gas powered boat motors allowed on Species Pairs' lakes?

Additional research is required prior to initiating regulatory changes. A forthcoming Action Plan for the Paxton Lake and Vananda Creek Stickleback Species Pairs addresses the need to research potential impacts of recreational lake usage on the Stickleback Species Pairs.

14. **Have forest harvest and land management criteria been developed? Have WHAs been established? Is forest harvest and land development meeting the criteria?**

A forthcoming Action Plan for the Paxton Lake and Vananda Creek Stickleback Species Pairs addresses the need to identify and evaluate land use planning and management options. An evaluation of achievements toward meeting forest harvest and land development criteria has therefore yet to be completed.

The British Columbia Ministry of Forests, Lands and Natural Resource Operations established an 881 ha Wildlife Habitat Area (WHA #2-250) on provincial Crown land for the Vananda Creek Benthic and Limnetic Sticklebacks under the Government Actions Regulation (B.C. Reg. 582/2004) of the *Forest and Range Practices Act* in 2013. The BCMFLNRO also established a WHA (#2-250) in 2015 under the Environmental Protection and Management Regulation (B.C. Reg. 200/2014) of the *Oil and Gas Activities Act* encompassing the same geographic area as FRPA's WHA #2-250.

15. Have scientific investigation protocols been set and communicated? Have they been implemented?

Harvey and Brown (2013a, 2013b) incorporated best collection and monitoring approaches into a draft *Species at Risk Act* multi-species compendium report, which will inform the development and implementation of a comprehensive monitoring plan for Paxton Lake and Vananda Creek Stickleback Species Pairs. Rosenfeld et al. (2008a) also developed the "Guidelines for the Collection and In Situ Scientific Study of Stickleback Species Pairs (Gasterosteus spp.)," which DFO applied to scientific research permitting processes under Section 73 of the Species at Risk Act from 2007 - 2014. In 2015, the BC MOE and DFO initiated plans to update the "Guidelines for the Collection and In Situ Scientific Study of Stickleback Species Pairs (Gasterosteus spp.)" (2008a). Additional protocols may also be required as part of provincial permitting processes.

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