COSEWIC
Assessment and Status Report

on the

Vananda Creek Benthic and Limnetic Threespine Stickleback Species Pair
Gasterosteus aculeatus

in Canada

ENDANGERED
2010

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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Previous report(s):

COSEWIC. 2000. COSEWIC assessment and update status report on the Vananda Creek Stickleback Species Pair *Gasterosteus* spp. in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 17 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

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Production note:
COSEWIC acknowledges Todd Hatfield for writing the provisional status report on the Vananda Creek Threespine Stickleback, *Gasterosteus aculeatus*, prepared under contract with Environment Canada. The contractors' involvement with the writing of the status report ended with the acceptance of the provisional report. Any modifications to the status report during the subsequent preparation of the 6-month interim and 2-month interim status reports were overseen by Eric Taylor, Freshwater Fishes Specialist Subcommittee Co-chair.

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Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur la paire d'espèces d'épinoches benthiques et limnétiques à trois épines du ruisseau Vananda (*Gasterosteus aculeatus*) au Canada.

Cover illustration/photo:
Vananda Creek Benthic and Limnetic Threespine Stickleback Species Pair — Vananda Creek Limnetic (upper, 65 mm) and Benthic (lower, 85 mm) sticklebacks. The photo is of mature males, and the females of both species show similar differences in size and body shape (photo by G. Velema, by permission).

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COSEWIC
Assessment Summary

Assessment Summary – April 2010

Common name
Vananda Creek Limnetic Threespine Stickleback

Scientific name
Gasterosteus aculeatus

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. Status re-examined and confirmed in April 2010.

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COSEWIC
Executive Summary

Vananda Creek Benthic and Limnetic Threespine Stickleback Species Pair
Gasterosteus aculeatus

Name and classification

Vananda Creek Benthic and Limnetic Threespine Sticklebacks are distinct biological species derived from the Threespine Stickleback, but they have not been formally named. Limnetics primarily exploit plankton, and have traits that are considered adaptations to a zooplankton-consuming lifestyle. Benthics mainly eat benthic invertebrates in the littoral zone, and have a robust body form, wide gape and few, short gill rakers, traits considered to be advantageous in benthic feeding. Molecular genetic data strongly indicate that the pairs have arisen independently, despite similar appearance. Thus, a stickleback species pair from one watershed is genetically and evolutionarily distinct from pairs in other watersheds.

Distribution

Vananda Creek Benthic and Limnetic Threespine Sticklebacks are endemic to three lakes (Spectacle, Priest and Emily lakes) in a single watershed on Texada Island, BC.

Habitat

Vananda Creek Benthic and Limnetic Threespine Sticklebacks have different habitat requirements. In general, Benthic and Limnetic sticklebacks spawn in different microhabitats of littoral areas in the spring, feed and grow in littoral and pelagic areas in spring and summer, and overwinter in deep water habitats during the fall and winter.

Biology

Benthic and Limnetic sticklebacks have similar life histories, although with some differences. They are similar to other Threespine Sticklebacks in their overall mode of reproduction. Males construct nests, which they guard and defend, until fry are about a week old. Eggs take up to a week to hatch, depending on temperature, and another three to five days before larvae are free-swimming. Benthics build their nests under cover of macrophytes or other structures; limnetics tend to spawn in open habitats. In the wild, benthics reproduce earlier in the year than limnetics, but there is considerable overlap in their spawning times. There is strong assortative mating, but hybridization occurs naturally in the wild at a low level.

Limnetics are thought to mature on average as one-year-olds, and rarely live beyond a single breeding season. Reproductive females have multiple clutches in quick succession. Nesting males will mate with several to many females, and may nest more than once within a single breeding season. Although some benthics likely mate in their first year, many may delay mating until they are two-year-olds. They may live up to about five years, and mate in several breeding seasons. Reproductive females have fewer clutches within a breeding season than do limnetics. Like limnetics, benthic males will mate with several females, but it is not clear if they nest more than once within a single breeding season.

Population sizes and trends

There have been no direct population estimates of Vananda Creek Benthic and Limnetic Threespine Sticklebacks, but rough estimates of abundance have been extrapolated from measurements made in nearby Paxton Lake and are approximately 20,000 mature benthics and roughly 500,000 mature limnetics across the three lakes.

Threats and limiting factors

Threats to Vananda Creek Benthic and Limnetic Threespine Sticklebacks are varied. The greatest threat is the introduction of invasive species. The extirpation of the Hadley Lake species pair (found on nearby Lasqueti Island) and the collapse of the species pair in Enos Lake and in experimental ponds into hybrid swarms have highlighted the sensitivity of the pairs to certain types of environmental perturbation (e.g., introduction of invasive species and disruption of habitat complexity). Whereas population modelling indicates the sticklebacks are resilient to environmental perturbations, other observations indicate that continued reproductive isolation is contingent on environmental factors such as light transmission levels, turbidity levels, and aquatic plant density, which to date have been only qualitatively assessed. Yet, it is these other factors that appear to be dominant in maintaining the species as distinct from each other. In this context, the species pairs are not highly adaptable, and are not particularly resilient to environmental disturbance. Limits to Vananda Creek stickleback abundance are poorly understood. It is likely that the main limiting factor is food supply—the capability of the lakes to produce plankton and benthos—but there are no data to support this view. In any case, the primary factor determining conservation status is their extreme endemism, not population decline.

Special significance of the species

The significance of Vananda Creek Benthic and Limnetic Threespine Sticklebacks is primarily scientific and as a unique part of Canada’s biodiversity. Stickleback species pairs are widely regarded as a scientific treasure because they are among the youngest species on earth: they have likely arisen since the end of the last glaciation, less than 13,000 years ago. They are considered valuable and remarkable research subjects for the study of the origins and persistence of biodiversity.

Existing protection

Vananda Creek Benthic and Limnetic Threespine Sticklebacks are listed as Endangered under Schedule 1 of the *Species at Risk Act* resulting in a number of automatic prohibitions. They were assessed as Endangered by COSEWIC in 2010, and are “red-listed” by the Conservation Data Centre and BC Ministry of Environment. Under the BC Sport Fishing Regulations, it is illegal to fish for, or catch and retain Vananda Creek Benthic and Limnetic Threespine Sticklebacks.

Most land adjacent to Spectacle Lake is privately owned; the majority of land adjacent to Priest and Emily lakes is Crown land. At this time there are no habitat protection provisions specifically for Vananda Creek Benthic and Limnetic Threespine Sticklebacks, but they can benefit from more general regulations such as the habitat protection provisions of the federal *Fisheries Act* and the provincial *Riparian Areas Regulation*.

TECHNICAL SUMMARY 1
Vanande Creek Limnetic Threespine Stickleback

Gasterosteus aculeatus
Vananda Creek Limnetic Threespine Stickleback — épinoche limnétique à trois épines du ruisseau Vananda

Range of occurrence in Canada: BC
Endemic to Spectacle, Priest and Emily lakes, British Columbia

Demographic Information

Generation time	1 yr
Is there a continuing decline in number of mature individuals? (Trend is unknown but assumed stable based on repeated trapping over many years, but abundance was not estimated during these sampling events. Trapping has been most common in Priest Lake, and least common in Spectacle Lake.)	Unknown, but unlikely
Estimated percent of continuing decline in total number of mature individuals within 5 years	Not applicable as decline unlikely
Percent change in total number of mature individuals over the last 10 years.	Unknown
Percent change in total number of mature individuals over the next 10 years.	Unknown
Percent change in total number of mature individuals over any 10 year period, over a time period including both the past and the future.	Unknown
Are the causes of the decline clearly reversible and understood and ceased?	Not applicable
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence (This is an extreme endemic, restricted to a single small lake. McPhail (1992) lists the area of Paxton Lake at 17 ha.)	< 2 km²
Area of occupancy (AO) Index of Area of Occupancy (IAO) 1 X 1 km grid 2 X 2 km grid	0.63 km² 6 km² 16 km²
Is the total population severely fragmented?	No
Number of “locations”	1
Is there continuing decline in extent of occurrence?	No
Is there continuing decline in index of area of occupancy?	No
Is there continuing decline in number of populations?	No
Is there continuing decline in number of locations?	No
Is there continuing decline in area, extent or quality of habitat?	No
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations?	NA, one location
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each population)

Population	N Mature Individuals
A single estimate exists from 2005 for Paxton Lake which is nearby and contains a similar stickleback species pair: there were ~45,853 mature limnetic males (95% CI from ~25,000 – 83,000). Abundance estimates for Spectacle, Priest and Emily lakes are extrapolated from lake area to be 47,228, 181,577 and 29,345, respectively. Assuming a 1:1 sex ratio, these numbers could be doubled to obtain rough estimates of mature limnetics males and females across all three lakes.	~516,301
Total	~516,301

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years]. Simple PVA calculations were done as part of critical habitat determinations (see Hatfield 2008). Population modelling using an age-structured model indicated that Benthic sticklebacks are resilient to population perturbations from environmental stochasticity. In general, the modelling confirmed that high population growth rates allow sticklebacks to recover quickly from short-term, small to moderate environmental perturbations.	Not applicable

Threats (actual or imminent, to populations or habitats)

Immediate

- Water diversion and draw down
- Habitat loss and degradation from private land use practices

Potential

- Introduction of invasive species (although there are presently no invasive species in the Vananda Creek watershed, many species are present in nearby areas and the distribution of invasives has increased over the last 10-20 years). Empirical observations indicate that the probability of extinction of species pairs in the presence of invasives is 1.0 (2 of 2 cases).
- Excessive collection for research purposes

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? Not applicable, endemic	
Is immigration known or possible?	No
Would immigrants be adapted to survive in Canada?	Not applicable
Is there sufficient habitat for immigrants in Canada?	Not applicable
Is rescue from outside populations likely?	Not applicable

Current Status

COSEWIC: Endangered 2010

Status and Reasons for Designation

Status: Endangered	Alpha-numeric code: A3e
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.	

Applicability of Criteria:

Criterion A: Meets Endangered A3e. Highly susceptible to extinction from exotic species introductions.
Criterion B: Not applicable. Although EO << 5,000 km², IAO << 500 km² and there are fewer than 5 locations, there is no evidence of decline or extreme fluctuations in any of the indices relevant to sub-criteria b(i-v) or c(i-iv), respectively.
Criterion C: Not applicable. Exceeds criteria.
Criterion D: Meets Threatened D2 (single location susceptible to rapid declines in habitat area or quality or species abundance from potential exotic species introductions).
Criterion E: Not done.

TECHNICAL SUMMARY 2
Vananda Creek Benthic Threespine Stockleback

Gasterosteus aculeatus

Vananda Creek Benthic Threespine Stickleback — épinoche benthique à trois épines du ruisseau Vananda

Range of occurrence in Canada: BC
Endemic to Spectacle, Priest and Emily lakes, British Columbia

Demographic Information

Generation time	~ 2-3 yrs
Is there a continuing decline in number of mature individuals? (Trend is unknown but may be stable based on repeated trapping over many years, however abundance was not estimated during these sampling events.)	Unknown, but unlikely
Estimated percent of continuing decline in total number of mature individuals within 5 years	Not applicable, decline unlikely
Percent change in total number of mature individuals over the last 10 years.	Unknown
Percent change in total number of mature individuals over the next 10 years.	Unknown
Percent change in total number of mature individuals over any 10 year period, over a time period including both the past and the future.	Unknown
Are the causes of the decline clearly reversible and understood and ceased?	Not applicable
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence (This is an extreme endemic, restricted to a single small lake. McPhail (1992) lists the area of Paxton Lake at 17 ha.)	< 2 km^2
Area of occupancy Index of Area of Occupancy (IAO) 1 X 1 km grid 2 X 2 km grid	0.63 km^2 6 km^2 16 km^2
Is the total population severely fragmented?	No
Number of “locations”	1
Is there continuing decline in extent of occurrence?	No
Is there continuing decline in index of area of occupancy?	No
Is there continuing decline in number of populations?	No
Is there continuing decline in number of locations?	No
Is there continuing decline in area, extent or quality of habitat?	No
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations?	NA, one location
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each population)

Population	N Mature Individuals
A single estimate exists from 2005 for Paxton Lake (which is nearby and contains a similar stickleback species pair): there were ~3,300 mature benthic males. Abundance estimates for Spectacle, Priest and Emily lakes' males are extrapolated from lake perimeter to be 3,287, 5,577 and 1,584, respectively. Assuming a 1:1 sex ratio, these numbers can be doubled to obtain estimates of mature benthic males and females across all three lakes.	~20,896
Total	~20,896

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years]. Simple PVA calculations were done as part of critical habitat determinations (see Hatfield 2008). Population modelling using an age-structured model indicated that Benthic sticklebacks are resilient to population perturbations from environmental stochasticity. In general, the modelling confirmed that high population growth rates allow sticklebacks to recover quickly from short-term, small to moderate environmental perturbations.	Not applicable

Threats (actual or imminent, to populations or habitats)

Immediate
- Water diversion and draw down
- Habitat loss and degradation from land use practices

Potential
- Introduction of invasive species (although there are presently no invasive species in the Vananda Creek watershed, many species are present in nearby areas and the distribution of invasives has increased over the last 10-20 years). Empirical observations indicate that the probability of extinction of species pairs in the presence of invasives is 1.0 (2 of 2 cases).
- Excessive collection for research purposes

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? Not applicable	
Is immigration known or possible?	No
Would immigrants be adapted to survive in Canada?	Not applicable
Is there sufficient habitat for immigrants in Canada?	Not applicable
Is rescue from outside populations likely?	Not applicable

Current Status

COSEWIC: Endangered 2010

Additional Sources of Information: N/A

Status and Reasons for Designation

Status: Endangered	**Alpha-numeric code:** A3e
Reasons 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.	

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Criterion C: Not applicable. Exceeds criteria.
Criterion D: Meets Threatened D2 (single location susceptible to rapid declines in habitat area or quality or species abundance from potential exotic species introductions).
Criterion E: Not done.

PREFACE

Vananda Creek Benthic and Limnetic Threespine Sticklebacks *Gasterosteus aculeatus* are sympatric species that are endemic to three small lakes (Spectacle, Priest and Emily lakes) in a single watershed on Texada Island, British Columbia. The species were designated Threatened in April 1999. Status was re-examined in May 2000 and the designation changed to Endangered. Status was determined based primarily on an extremely restricted distribution and ongoing threats from invasive species and habitat loss and/or degradation from human disturbance. The species were listed as Endangered under *SARA* in 2003.

An increasing number and diversity of scientific studies have been completed on stickleback species pairs focusing largely on understanding the processes involved in their evolution, but also on the role of invasive species in posing risks to species pairs and the provision of the first quantifiable population size estimates. A recovery strategy, co-led by Fisheries and Oceans Canada – Pacific Region and the British Columbia Ministry of the Environment, was completed in 2007. The recovery strategy lists a series of threats, the greatest of which is introduction of invasive species. Two other species pairs (one in Hadley Lake on Lasqueti Island and another in Enos Lake on Vancouver Island) have been extirpated by introduced species. The land surrounding the lakes in the Vananda Creek watershed is a combination of private and Crown land, and there is some potential threat from land use and water use. A Wildlife Habitat Area, which is intended to limit impacts from forest harvest, has been proposed and is under formal consideration for some of the Crown land surrounding Priest and Emily lakes.
A recovery action group has been established on Texada Island and the group is monitoring Priest Lake water quality and undertaking a variety of biological studies. Stickleback species pairs continue to be intensively studied by researchers interested in ecology, evolution and genetics. In response to perceived high demand for collections of wild fish, the recovery team developed guidelines for limiting impacts from collecting activities. The guidelines are being used to manage collections under *SARA*.

Critical habitat has been proposed for stickleback species pairs and the recommendations subjected to review by the Pacific Scientific Advice Review Committee (PSARC), Fisheries and Oceans Canada, one step in the final approval process. Consequently, although described from a scientific perspective, critical habitat has not yet been legally identified.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2010)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment Canada   Environnement Canada
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Canada

The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

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WILDLIFE SPECIES INFORMATION

Name and classification

Phylum:	Chordata
Class:	Actinopterygii (ray-finned fishes)
Order:	Gasterosteiformes
Family:	Gasterosteidae
Genus:	*Gasterosteus*
Limnetic Species	*Gasterosteus aculeatus*
Benthic Species:	*Gasterosteus aculeatus*

Common Name

English:	Vananda Creek Limnetic Threespine Stickleback
	Vananda Creek Benthic Threespine Stickleback
French:	épinoche limnétique du ruisseau Vananda
	épinoche benthique du ruisseau Vananda

Morphological description

The Vananda Creek Benthic and Limnetic Threespine Stickleback species pair (Figure 1) are postglacial derivatives of the Threespine Stickleback (*Gasterosteus aculeatus*). The Threespine Stickleback is a small (usually 35-55 mm) fish that is common in coastal marine and freshwater throughout the Northern Hemisphere (Scott and Crossman 1973; McPhail 2007). The marine form is assumed to be the ancestor of most freshwater forms, and is usually anadromous, meaning it returns to freshwater to reproduce (Schluter and McPhail 1992, 1993; McKinnon and Rundle 2002).
The Threespine Stickleback has a laterally compressed body with delicate pectoral and caudal fins. Individuals in most populations are well-armoured with calcified lateral plates, and pelvic and dorsal spines that can be rigidly locked in an erect position (Scott and Crossman 1973; Wooton 1976; Reimchen 1994). Freshwater populations are variable in extent of armour but usually have less than the marine form (Reimchen 1994). Body colour varies from silvery to mottled green and brown. Sexually mature males develop bright red throats during the breeding season, although in a few freshwater populations males turn completely black instead (McPhail 1969; Reimchen 1989).

Figure 1. Vananda Creek Limnetic male (top left) and female (top right) and Benthic male (bottom left) and female (bottom right) sticklebacks. The limnetics are about 65 mm total length and the benthics about 85 mm. (Photo by G. Velema, UBC, by permission).

Marine sticklebacks are phenotypically similar throughout their range, whereas freshwater sticklebacks are ecologically, behaviourally and morphologically exceptionally diverse (McPhail 1994). Three types of genetically and morphologically divergent “pairs” are known from coastal British Columbia (BC, McPhail 1994): parapatric anadromous and stream-resident pairs (i.e., spatial distribution is contiguous and only overlapping in a relatively small area of contact), sympatric benthic and limnetic pairs (i.e., spatial distribution is entirely or mostly overlapping), and parapatric lake and stream pairs. In each case these are referred to as “species pairs” because there is close contact between each member of the pair. Detailed descriptions of solitary freshwater populations, and of each kind of species pair, are provided in McPhail (1994).

Vananda Creek Benthic and Limnetic Threespine Sticklebacks (Figure 1) are one of five known sympatric pairs that occur in lakes on islands in a restricted area of the Strait of Georgia, BC (McPhail 1984, 1992; Schluter and McPhail 1992; McPhail 1993, 1994; Gow *et al.* 2008). In each case, limnetics primarily exploit plankton, and have morphological traits such as a fusiform body, narrow mouth and many, long gill rakers, which are traits considered adaptations to a zooplankton-consuming lifestyle (Schluter and McPhail 1992, 1993). Benthics mainly eat benthic invertebrates in the littoral zone, and have a robust body form, wide gape and few, short gill rakers, traits considered to be advantageous in benthic feeding (Schluter and McPhail 1992, 1993). The pattern of morphological and ecological divergence is similar in each of the lakes (Schluter and McPhail 1992; Gow *et al.* 2008), such that limnetics from different lakes look alike, as do benthics from different lakes. Most striking are the morphological and ecological similarities among populations of limnetics (and among benthics), but there are also some minor morphological differences between benthics and limnetic among lakes (McPhail 1994).

Spatial population structure and variability

A key research question has been whether sympatric stickleback species pairs are the result of a single speciation event or multiple, independent events. The question has been addressed most directly through the examination of microsatellite DNA variation in benthic and limnetic populations from different species pair lakes (Taylor and McPhail 2000). Phylogenetic and genetic distance analyses and the lack of similar species pairs in lakes adjacent to species pair lakes, support the idea that pairs of sympatric species have evolved multiple times. In other words, despite similar, but not identical, appearance among lakes, molecular phylogenies strongly indicate that the pairs are independently derived. Thus, a stickleback species pair from one watershed is genetically and evolutionarily distinct from pairs in other watersheds. Such independent evolutionary divergence presents considerable theoretical and practical challenge to assigning each species a distinct taxonomic name which is the principle reason why this has not yet taken place.

Vananda Creek Benthic and Limnetic Threespine Sticklebacks occur as three populations, one in each of three interconnected lakes (Spectacle, Priest and Emily lakes) in the Vananda Creek watershed. Within each lake, benthics and limnetics are each assumed to be panmictic populations (but distinct from each other); there is no *a priori* reason to think there is population structuring within a lake within each species. The genetic pattern among lakes in the Vananda watershed has been only partially examined. Spectacle and Priest lakes are essentially contiguous and are separated only by several 10s of metres of shallow marsh area. It is reasonable to assume that benthics and limnetics move frequently in both directions between Spectacle and Priest lakes. Emily Lake is downstream of, and 23 m lower in elevation than, Priest Lake and the two are separated by about 1 km of stream and marsh that is potentially navigable by sticklebacks (Taylor and McPhail 2000). Consequently, if movements occur between these two lakes, it seems likely that they would occur mostly in a downstream direction. Genetic studies using microsatellite markers indicate some, albeit minor, differences between Emily and Priest sticklebacks, which were interpreted as evidence of limited gene flow between each lake’s stickleback species (Taylor and McPhail 2000).

Another focus of research has been the intrinsic and extrinsic barriers to gene flow between benthics and limnetics within lakes. There appear to be no intrinsic barriers to gene flow between Vananda Creek Benthic and Limnetic Threespine Sticklebacks; however, this evidence comes from laboratory studies of the Paxton and Enos pairs: F_1 hybrids between benthics and limnetics are fully fertile and fitness in the laboratory is equivalent to that of the parental species (McPhail 1984, 1992, 1994; Hatfield and Schluter 1999). Backcrosses, however, may have slightly lower survival (Hatfield and Schluter 1999). Benthics and limnetics show strong assortative mating in the lab and in the wild (Ridgway and McPhail 1984; Nagel and Schluter 1998; Boughman 2001), and several studies strongly suggest that hybrids are selected against in the wild due to ecologically mediated selection against intermediate trophic morphology (Schluter and McPhail 1993; Schluter 1994, 1995; Hatfield and Schluter 1999; Gow *et al*. 2007).

Hybridization between Vananda Creek Benthic and Limnetic sticklebacks occurs naturally in the wild, and there appears to be a small amount of ongoing gene flow between the two species. Based on examination of morphological traits and allozyme frequencies, McPhail (1984, 1992) estimated that about 1% of adults in Enos and Paxton Lakes were hybrids. More recently, with the use of microsatellite markers, Gow *et al.* (2007) found that the proportion of hybrids in Priest Lake was considerably higher; approximately 20% of juveniles in Priest Lake were identified as hybrids. The proportion of hybrids, however, declined through the life cycle to about 4% of adults, suggesting extrinsic selection against hybrids.

Designatable units

The Benthic and Limnetic sticklebacks from the Vananda Creek watershed warrant designatable unit status within *Gasterosteus aculeatus* because they satisfy the "discrete" and "significance" criteria of COSEWIC (COSEWIC 2009). First, both are genetically distinct from other sticklebacks as evidenced by an assemblage of allozyme, microsatellite, and morphological data (e.g., McPhail 1992; Taylor and McPhail 2000). In addition, the Vananda Creek watershed pair is only one of three existing cases (occurring in three different watersheds on two different islands) of sympatric pairs in *Gasterosteus* despite the sampling of hundreds of coastal lakes (McPhail 1994). In addition, all three sets of pairs have evolved independently from one another (Taylor and McPhail 2000). The existence of a sympatric pair in the Vananda Creek watershed is, therefore, the result of a unique evolutionary divergence. This unique divergence meets the significance criterion in that it supports the view that Benthic and Limnetic sticklebacks in the Vananda Creek watershed exist within a unique ecological and evolutionary setting: divergent populations in sympatry with the associated adaptations (feeding and reproductive) that are crucial to their persistence in sympatry. Also, given that Benthic and Limnetic sticklebacks in Vananda Creek act as distinct biological species (they are genetically, ecologically, morphologically, and behaviourally distinct in sympatry), they merit recognition as two DUs independent from *G. aculeatus* as a whole.

It is also appropriate and important that the status of both members of the pair be assessed in the same report for several reasons. First, the significance of the Vananda Creek stickleback pair rests on their distinctions and persistence in sympatry; neither form considered in isolation from the other is particularly unique within *Gasterosteus aculeatus*. Second, interactions between them may contribute to their evolution and persistence. Third, the Limnetic and Benthic sticklebacks share common threats to their habitats, especially breeding habitats, and disturbance to such habitats could lead to increased hybridization between Limnetic and Benthic sticklebacks as has been documented for other sympatric pairs of *Gasterosteus* (Taylor *et al.* 2006).

Special significance

The significance of Vananda Creek Benthic and Limnetic Threespine Sticklebacks is primarily scientific and as a unique component of Canada's biodiversity. Stickleback species pairs are widely regarded as a scientific treasure; they are as valuable to science as cichlid fish species in the Great Lakes of Africa, and Darwin's finches in the Galapagos Islands. In large part this is because they are among the youngest species on earth; strong evidence suggests that the species pairs have arisen since the end of the last glaciation, a mere 13,000 years ago (Schluter and McPhail 1992; McPhail 1994). The speed with which these distinct fish species evolved has intrigued and excited scientists around the world. They are a remarkable research subject and are being used to understand the biological and physical processes that give rise to the biodiversity we see around us. Newspapers, magazines and scientific journals have published the story of the discovery of these species, and regularly report on the results of ongoing scientific studies.

There is no direct commercial value of Vananda Creek Benthic and Limnetic Threespine Sticklebacks. The species are part of Canada's native fauna, with their own intrinsic value including their contribution to biodiversity, education, and science.

DISTRIBUTION

Benthic-limnetic species pairs are found in the Vananda Creek and Paxton Lake watersheds on Texada Island, and Little Quarry Lake on Nelson Island. Two other pairs have recently been physically extirpated (Hadley Lake on Lasqueti Island, Hatfield 2001) or collapsed through hybridization (i.e., genomic extirpation within Enos Lake on Vancouver Island, Kraak *et al.* 2001; Taylor *et al.* 2006).

Global range

Vananda Creek Benthic and Limnetic Threespine Sticklebacks are endemic to three lakes: Spectacle, Priest and Emily lakes, on Texada Island, British Columbia (Figure 2). [Note: Spectacle Lake is sometimes referred to as Balkwill Lake and Emily Lake is sometimes known as Turtle Lake.]

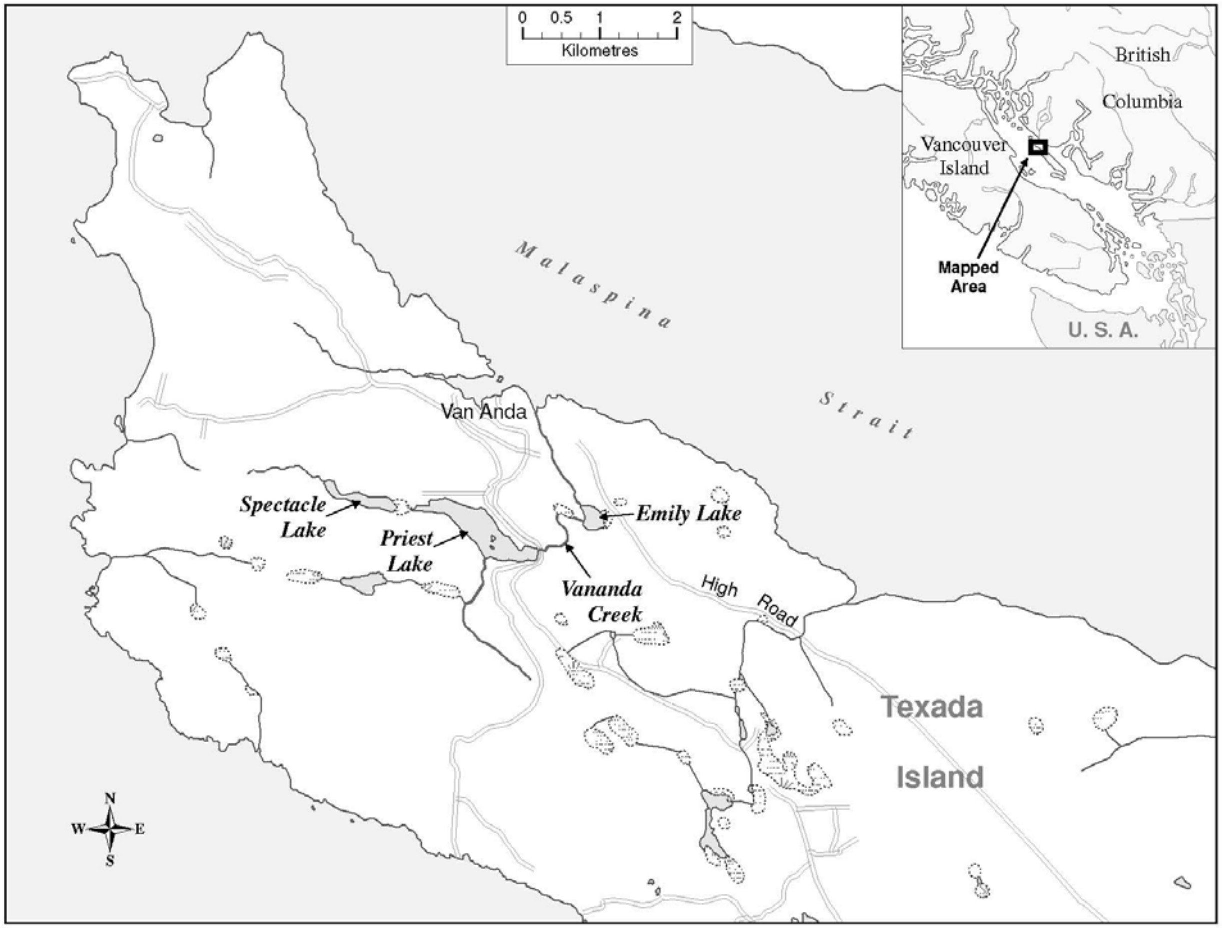

Figure 2. Distribution of Vananda Creek sticklebacks in Canada.

Canadian range

The Canadian range of Vananda Creek Benthic and Limnetic Threespine Sticklebacks comprises three lakes (Spectacle, Priest and Emily lakes) on Texada Island, BC (Figure 2), which are joined by Vananda Creek. The Canadian and Global range are identical. The extent of occurrence for each form is less than 2 km^2, and the area of occupancy less than 0.63 km^2. An index of area of occupancy calculated using a 1 km × 1 km overlaid grid was estimated to be less than 6 km^2, and less than 16 km^2 using a 2 km × 2 km grid (COSEWIC 2009).

HABITAT

Habitat requirements

Solitary stickleback populations (i.e., those populations for which a single form inhabits a lake) are widely distributed and generally tolerant of significant changes in habitat or water quality. In contrast, stickleback species pairs are highly restricted in their distribution and sensitive to changes in habitat or other environmental factors. As evolutionarily young species that are not yet intrinsically reproductively isolated from one another (i.e., they can produce viable hybrids), environmental changes can disrupt barriers to hybridization and lead to collapse of co-existing species into a hybrid swarm (e.g., Taylor *et al*. 2006). Therefore, habitat requirements for stickleback species pairs include those same features that limit size or viability of solitary populations (e.g., juvenile rearing area, nesting habitat area), but also those features of the environment that prevent hybridization. In other words, habitat needs for species pairs include features whose alteration or loss will lead to reduction in abundance to an unviable population level, or breakdown of reproductive barriers sufficient to cause collapse into a hybrid swarm. These needs include moderate littoral and pelagic productivity, absence of invasive species, maintenance of natural light transmission levels, and maintenance of natural littoral macrophytes. The latter two are probably especially important for maintaining mate recognition and are discussed in greater detail in Hatfield (2008).

There have been few direct studies of the habitat requirements of the Vananda Creek species pair. They are assumed to be ecologically similar to species pairs in Paxton and Enos Lakes, and the following descriptions are based on *in situ* and laboratory-based studies of those pairs.

Vananda Creek Benthic and Limnetic Threespine Sticklebacks have similar life histories, but different habitat requirements (McPhail 1993, 1994). These requirements vary throughout the year, and are described here for each major life stage. In general, Benthic and Limnetic sticklebacks spawn in different microhabitats of littoral areas in the spring, rear in littoral and pelagic areas in spring and summer, and overwinter in deep water habitats during the fall and winter.

Spawning habitat

Benthic and Limnetic sticklebacks spawn in the shallow littoral area of lakes (McPhail 1994). Males construct nests, which they guard and defend, until fry are about a week old. Benthics build their nests under cover of macrophytes or other structure; limnetics tend to spawn in open habitats (McPhail 1994; Hatfield and Schluter 1996).

Juvenile feeding habitat

Immediately after leaving the protection of paternal care, both benthic and limnetic fry use the littoral zone, where there is abundant food and cover from predators. The extent of habitat partitioning by benthic and limnetic fry is not known. In Paxton Lake, limnetic juveniles are common along steep, rocky, unvegetated littoral shoreline compared to benthic juveniles, which shelter around macrophytes (Gow pers. comm. 2008). Eventually, limnetics move offshore to feed in pelagic areas (Schluter 1995).

Adult feeding habitat

Adult limnetics (with the exception of nesting males) feed on zooplankton in the pelagic zone of the lake, whereas adult benthics feed on benthic invertebrates in the littoral zone (Schluter 1995). Productive littoral and pelagic habitats are required for the persistence of benthic-limnetic pairs. Maintenance of the ratio of pelagic to littoral productivity is also thought to be important.

Overwintering habitat

By late summer, individuals move to deeper habitats where they overwinter. Little is known about habitat requirements of benthics and limnetics during this stage, except that trapping and seining consistently indicate use of deeper water by early fall.

Habitat trends

Trends in habitat quantity and quality can be assessed only qualitatively because there has been no long-term monitoring of habitat in lakes within the Vananda Creek watershed. A monitoring program began in June 2006, which measures the following on a monthly basis on Priest Lake and nearby Paxton Lake: surface temperature and pH, temperature and oxygen profiles, Secchi depth, and turbidity. No significant changes have been identified as a result of this monitoring (Atwood pers. comm. 2009).

Priest Lake is the domestic water supply for the town of Van Anda and existing water licences permit substantial water extraction from Priest and Emily lakes, for domestic and industrial purposes, but there are only four fairly small diversion licences (500 gallons/day) for Spectacle Lake for domestic use (see details under **Threats and Limiting Factors** section). Records of past water use are not available, so historic trends in water use cannot be determined accurately.

Land-based activities still have the potential to negatively affect within-lake habitats. For example, road building or other construction can increase sedimentation via surface water inflows to the Vananda Creek watershed. Mining and forest harvest have been extensive in the watershed, but the influences of these land uses on stickleback and their habitats have not been quantified.

Habitat protection/Ownership

Lands adjacent to Spectacle, Priest and Emily lakes are a combination of Crown and private: most of the land around Spectacle Lake is private, whereas the majority around Priest and Emily lakes is Crown land. At this time there are no habitat protection provisions for the specific habitats of Vananda Creek Benthic and Limnetic Threespine Sticklebacks, although a local stewardship group has been established specifically to monitor and address threats to stickleback species pairs on Texada Island, and planning for a Wildlife Habitat Area, to provide some protection on Crown land (forest), is underway (see section on **Existing protection or other status designations**). In addition, the Vananda Creek watershed in general is afforded some protection from the federal *Fisheries Act* as well as the *BC Forest and Range Practices Act.*

BIOLOGY

As noted earlier, there has been little direct study of the Vananda Creek species pair. They are assumed to be ecologically similar to species pairs in Paxton and Enos Lakes. The following descriptions are based on *in situ* and laboratory-based studies of those pairs.

Life cycle and reproduction

Benthic and Limnetic sticklebacks have similar life histories (McPhail 1993, 1994) and timing of major life history events (Table 1).

Table 1. Life history timing for benthic-limnetic stickleback species pairs (National Recovery Team for Stickleback Species Pairs 2007).

		Jan				Feb				Mar				Apr				May				Jun				Jul				Aug				Sep				Oct				Nov				Dec			
Species	**Life Stage**	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Limnetic	Spawning														x	x	x	x	x	x	x	x																											
	Incubation															x	x	x	x	x	x	x	x																										
	Juvenile rearing																x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x														
	Adult rearing							x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x														
	Overwintering	x	x	x	x	x	x																													x	x	x	x	x	x	x	x	x	x	x	x	x	x
Benthic	Spawning											x	x	x	x	x	x	x	x																														
	Incubation												x	x	x	x	x	x	x	x																													
	Juvenile rearing													x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x														
	Adult rearing							x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x														
	Overwintering	x	x	x	x	x	x																													x	x	x	x	x	x	x	x	x	x	x	x	x	x
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
		Jan				Feb				Mar				Apr				May				Jun				Jul				Aug				Sep				Oct				Nov				Dec			

Life history information for both benthics and limnetics comes from observations of wild and laboratory-reared populations, but the data are mostly anecdotal. Limnetics are thought to mature on average as one-year-olds, and rarely live beyond a single breeding season. In the lab, reproductive females have multiple clutches in quick succession, and are thought to do the same in the wild. Nesting males will mate with several to many females, and may nest more than once within a single breeding season.

Benthics delay sexual maturation relative to limnetics. Although some individuals likely mate in their first year, many may delay mating until they are two-year-olds. They may live up to about five years, and mate in several breeding seasons. In the lab, reproductive females have fewer clutches within a breeding season than do limnetics, and are thought to do the same in the wild. Nesting males will mate with several to many females, and may nest more than once within a single breeding season; the sex ratio of both benthics and limnetics is approximately 1:1.

Benthics and limnetics are similar to other threespine sticklebacks in their overall mode of reproduction (McPhail 1994). Males construct nests, which they guard and defend, until fry are about a week old. Eggs take up to a week to hatch, depending on temperature, and another three to five days before larvae are free-swimming (McPhail 2007). The nests and contents remain vulnerable to predators of different kinds, including other sticklebacks (Foster 1994). Benthics build their nests under cover of macrophytes or other structure; limnetics tend to spawn in open habitats (McPhail 1994; Hatfield and Schluter 1996).

In the wild, benthics reproduce earlier in the year than limnetics, but there is considerable overlap in their spawning times (Table 1). There is strong assortative mating (Ridgway and McPhail 1984; Nagel and Schluter 1998; Boughman 2001), but as noted above, hybridization occurs naturally in the wild.

Immediately after leaving the nest, both benthic and limnetic fry use inshore areas, where there is abundant food and cover from predators. Eventually limnetics move offshore to feed in pelagic areas (Schluter 1995). The timing of this movement is likely influenced by a combination of relative growth rates and predation risk in littoral and pelagic habitats (Schluter 2003). Benthics remain in littoral areas throughout their life.

Adult limnetics (with the exception of nesting males) feed on zooplankton in the pelagic zone of the lake, whereas adult benthics feed on benthic invertebrates in the littoral zone (Schluter 1995). By late summer individuals begin moving to deeper water habitats where they overwinter. There are some observations to indicate that Priest Lake has high concentrations of H_2S at depth during fall and winter (Atwood pers. comm. 2009) and presumably sticklebacks avoid these depths.

Physiology

Physiological requirements and tolerances for Vananda Creek Benthic and Limnetic Threespine Sticklebacks have not been described. In general, Threespine Sticklebacks occur in a wide array of environments and they are known to have broad tolerances of many water quality characteristics (e.g., turbidity, water velocity, temperature, depth, pH, alkalinity, calcium and total hardness, salinity, conductivity, etc.). Waterbodies in the Vananda Creek watershed are clear, slightly alkaline, moderately productive, and presumably minimally affected by toxic inputs. Concerns have been expressed (e.g., National Recovery Team for Stickleback Species Pairs 2007) that deviations from these natural conditions pose a threat to persistence of the species pair, but the concern is usually expressed in connection with reproductive isolation between benthics and limnetics (e.g., mate recognition), rather than physiological tolerance *per se*.

Dispersal/Migration

Vananda Creek Benthic and Limnetic Threespine Sticklebacks do not migrate beyond the limits of watercourses in the Vananda Creek watershed. Spectacle, Priest and Emily lakes are the primary habitats, but a few individuals may move between lakes via connecting streams. The connection between Spectacle and Priest lakes is short, shallow marsh and is probably passable in both directions throughout much of the year. The connection between Priest and Emily lakes is also low gradient (~23 m elevation over ~1 km) and possibly passable but is likely somewhat of a dispersal barrier (Taylor and McPhail 2000). That Emily Lake is the most isolated of the three lakes is supported by the observation that limnetics in Emily Lake have a much higher proportion of individuals that have only two dorsal spines rather than the regular three, and a low (but detectable) number of individuals that have a full complement of lateral plates (D. McPhail, pers. comm. 2010). At present a culvert at the outlet of Priest Lake likely allows only downstream passage of sticklebacks (Atwood pers. comm. 2009), and it is generally unknown what effect such one-way dispersal might have on the interactions between pairs within the different lakes. Within each lake, there are short-distance, seasonal movements associated with spawning, feeding and overwintering.

Interspecific interactions

Sympatric stickleback species pairs have evolved and persisted in the presence of only one other fish species, Coastal Cutthroat Trout (*Oncorhynchus clarkii clarkii*; Vamosi 2003), which is present in the Vananda Creek watershed. Maintaining a simple ecological community appears to be necessary for persistence of the sympatric pairs, as underscored by the rapid extinction of the Hadley Lake species pair (within two years) following introduction of Brown Bullhead (*Ameiurus nebulosus*; Hatfield 2001) and the collapse of the Enos Lake pair following invasion of American Signal Crayfish (*Pacifastacus leniusculus*; Taylor *et al.* 2006, Rosenfeld *et al.* 2008).

Current predation of sticklebacks in the Vananda watershed is from piscivorous Coastal Cutthroat Trout, numerous invertebrates that feed on young sticklebacks, and piscivorous birds (e.g., Heron (*Ardea herodias*), Kingfisher (*Megaceryle alcyon*) and Common Loon (*Gavia immer*)). Their presence at current levels of abundance, however, is not considered a threat to the sticklebacks.

The greatest interspecific competitors for limnetics are likely benthics, and vice versa. Several studies have demonstrated character displacement between benthics and limnetics, and competition between the two species (Schluter and McPhail 1993; Schluter 1994, 1995).

Adaptability

Lakes in the Vananda Creek watershed have been subjected to varying human disturbance, including damming of the outlet stream (Priest and Emily lakes), and water extraction for nearby mining (Emily Lake). The lakes' immediate surroundings have been affected by surface (limestone quarrying) and underground mining (gold, iron ore early in the 1900s), forest harvest, and associated road building and pipeline construction. These disturbances probably cause fluctuations in water levels leading to variation in habitat area, loss of riparian function, sedimentation, and other potential changes in water quality. Vananda Creek Benthic and Limnetic Threespine Sticklebacks have survived these disturbances, although each event may have influenced stickleback abundance. Consequently, the extent to which benthics and limnetics can be considered "adaptable" in response to such disturbances is unknown.

Simple population viability analyses were completed to determine critical habitat needs for benthic sticklebacks (Hatfield 2008). Benthics were selected for these analyses because they mature later, have lower natural abundance, and generally lower reproductive potential than limnetics; results are therefore more conservative than if limnetics' vital rates had been used in the models. Population modelling using an age-structured model indicated that benthic sticklebacks are resilient to population perturbations from environmental stochasticity. In general, the modelling confirmed that high population growth rates allow sticklebacks to recover quickly from short-term, small to moderate environmental perturbations.

It is fairly straightforward to raise populations of Benthic and Limnetic sticklebacks in captivity where facilities are available. Both species from Enos and Paxton lakes have been successfully raised in laboratory tanks and experimental ponds at the University of British Columbia (UBC) over multiple generations, and Vananda Creek Benthic and Limnetic Threespine Sticklebacks have been kept in the laboratory for shorter periods. It has been considerably more difficult to raise benthics and limnetics together. For example, in experimental ponds at UBC benthics and limnetics from Paxton Lake hybridized at very high levels, which ultimately led to collapse into a hybrid swarm.

The collapse of the species pair in Enos Lake and in the UBC experimental ponds has highlighted the sensitivity of the pairs to habitat structure and/or certain types of environmental perturbation (e.g., introduction of invasive species and direct effects of predation or indirect effects of changes in habitat quality—see Taylor *et al.* 2006). Whereas population modelling indicates the sticklebacks are resilient to environmental perturbations, other observations indicate that continued reproductive isolation is contingent on environmental factors, which to date have been only qualitatively assessed. Yet, it is these other factors that appear to be dominant in maintaining the species pairs. In this context, the species pairs are not highly adaptable, and are not particularly resilient to environmental disturbance.

POPULATION SIZES AND TRENDS

Search effort

Threespine sticklebacks are common in coastal marine and fresh water throughout the Northern Hemisphere. Physically and reproductively isolated populations exist in numerous low-elevation lakes, but stickleback species pairs have been found in only seven lakes in five watersheds within a highly confined geographic area in southwestern British Columbia. To date, genetic data indicate that benthics and limnetics from each watershed were independently derived from a marine ancestor (i.e., the pair in Vananda Creek is different from all other sympatric species pairs). Biologists have surveyed hundreds of lakes along the BC, Washington and Alaskan coasts and found stickleback species pairs in only this area of BC. Vananda Creek Benthic and Limnetic Threespine Sticklebacks are considered unique BC endemics.

Abundance

There have been no direct population estimates of Vananda Creek Benthic and Limnetic Threespine Sticklebacks, so abundance has been extrapolated from measurements made in nearby Paxton Lake. Estimates of abundance in Paxton Lake were made in summer 2005, using mark-recapture methods, and the modified Peterson estimator (Nomura 2005). The estimate for benthic sticklebacks in June was considered most robust.

The estimates for Paxton Lake (Table 2) were based on standard mark-recapture techniques, which have a number of assumptions, such as closed population, sufficient longevity of marks, equal survival of marked and unmarked individuals, and capture success that is unrelated to presence of a mark or prior capture. Specifically in the case of sticklebacks, these estimates apply to individuals that can be caught with Gee (minnow) traps and therefore exclude young-of-the-year (fish less than 1 year old). This method of capture likely underestimates abundance of limnetics, especially limnetic females, which tend to be somewhat trap "shy" and use primarily pelagic habitats. The abundance estimate of about 3,300 mature benthic males was somewhat surprising since Paxton Lake sticklebacks have been relatively easy to catch in Gee traps, and there had been a tacit assumption that abundance was higher. The estimate spurred the development of collecting guidelines that recommend limits for lethal and non-lethal sampling in species pair lakes and restrict sampling to half of each lake (Recovery Team for Non-Game Freshwater Fish Species in BC 2008—see **Threats and limiting factors** section).

Table 2. June 2005 abundance estimates of Paxton Lake benthics and limnetics (Nomura 2005).

	Benthic			Limnetic			Both species
	Reproductive Males	**Other**	**Total**	**Reproductive Males**	**Other**	**Total**	**Total**
N	3,332	29,307	29,380	45,853	8,199	58,800	66,599
Lower CI	2,243	21,360	4,421	25,806	2,593	34,712	53,208
Upper CI	5,305	41,428	39,230	83,981	15,603	102,295	85,483

(Note: the term "other" refers to both females and males that were not in nuptial colour, since they were difficult to differentiate in the field with non-lethal techniques.)

Abundance estimates for Spectacle, Priest and Emily lakes were obtained by extrapolating those from those for Paxton Lake after accounting for differences in lake area for limnetics (because they inhabit open water areas) and lake perimeter for benthics (because they live in the littoral zone, Table 3). Spectacle Lake is approximately the same size as Paxton Lake, so the estimates are similar. Priest Lake is considerably larger than Paxton Lake, so the estimates are almost two times higher. Emily Lake is smaller than Paxton Lake, and the estimated population sizes are smaller. (Note: the true level of uncertainty of abundance estimates for lakes other than Paxton Lake is not known—abundance estimates, and the lower CI and upper CI, are all extrapolated from the Paxton Lake estimate).

Table 3. Estimates of abundance for (a) mature benthics and (b) mature limnetics for each lake in the Vananda Creek watershed (males and females, assuming a 1:1 sex ratio). These projected estimates are based on a single mark-recapture estimate of mature benthic and limnetic males in Paxton Lake in June 2005. All estimates, including 95% confidence intervals, are calculated by multiplying the Paxton Lake estimates by a factor that corrects for lake perimeter, for benthics, and lake area, for limnetics, and multiplying by 2 to account for both sexes. The area of Paxton Lake is 11.2 ha and its perimeter is 2,277 m (Hatfield 2008).

(a)

Lake	Perimeter (m)	Mature Benthic	Lower CI	Upper CI
Spectacle	2,268	6,637	4,468	10,568
Priest	3,868	11,319	7,620	18,024
Emily	1,091	3,193	2,149	5,084

(b)

Lake	Area (ha)	Mature Limnetic	Lower CI	Upper CI
Spectacle	11.5	94,457	53,160	173,000
Priest	44.3	363,156	204,383	665,129
Emily	7.2	58,861	33,031	107,495

Fluctuations and trends

There has been no systematic monitoring of abundance in Spectacle, Priest and Emily lakes, so population trends are unknown. Benthic and Limnetic sticklebacks, however, have been intensively studied by zoologists at UBC for the last two decades or more (e.g., Schluter and McPhail 1992; McPhail 1994; Taylor and McPhail 1999). Throughout this time both species in Priest Lake have remained fairly easy to trap in large numbers in Gee traps. Sampling has been more sporadic in Spectacle and Emily lakes.

Rescue effect

The global range of Vananda Creek Benthic and Limnetic Threespine Sticklebacks is entirely within a single small watershed within Canada, so the concept of rescue effect does not apply to these species.

ABORIGINAL TRADITIONAL KNOWLEDGE

At the time of this writing Aboriginal traditional knowledge (ATK) collection and verification protocols are still being finalized. Consequently, no ATK is presently available.

THREATS AND LIMITING FACTORS

Threats to Vananda Creek Benthic and Limnetic Threespine Sticklebacks have been described in the National Recovery Strategy (National Recovery Team for Stickleback Species Pairs 2007). As noted in the Recovery Strategy, the discussion of threats is based primarily on professional opinion, not on quantitative risk assessment. This is because there is an absence of information on the effects of different threats on population vital rates (e.g., hybridization, growth, survival, reproductive success, and the probability and consequences of different invasive species introductions). The threats analysis is nevertheless thought to be robust.

Invasive species

The primary threat to persistence of stickleback species pairs is spread of invasive species. (The term “invasive species” in this context refers to any species that is translocated (usually by humans) to a location where it does not occur naturally and causes harm to native species. Thus, a species that is native to BC but does not occur naturally in the watershed of a species pair and causes harm to the species pair would be deemed an invasive species in this context.) The species pairs appear to depend critically on the maintenance of several ecological factors, including a simple fish community. Species pairs occur in lakes that naturally have only stickleback and Coastal Cutthroat Trout (Vamosi 2003).

The Hadley Lake species pair quickly (within 2 years) became extinct following the introduction of Brown Bullhead (*Ameiurus nebulosus*), which is thought to have preyed on or interfered with nesting stickleback, ultimately leading to complete recruitment failure (Hatfield 2001). The Hadley Lake species pair had an estimated total population size of about 50,000 mature adults (Hatfield 2008). Bullhead were introduced to Hadley Lake in the early 1990s and all stickleback were absent by 1995 (Hatfield 2001). This highlights the vulnerability of the stickleback species pairs and the speed with which a pair can be affected by an introduced species. The Enos Lake species pair has collapsed due to hybridization (Kraak *et al.* 2001; Taylor *et al.* 2006), and the concurrent appearance of the American Signal Crayfish has been implicated as the major factor diving this collapse. The mechanism by which the crayfish affected sticklebacks appears to be through littoral habitat disturbance and alteration (Taylor *et al.* 2006; Rosenfeld *et al.* 2008).

The threat of species introductions applies also to a number of other invasive species that are in nearby lakes and spreading throughout the region (Hatfield and Pollard 2006). These species include Largemouth and Smallmouth bass (*Micropterus salmoides* and *M. dolomieu*), Pumpkinseed Sunfish (*Lepomis gibbosus*), and Yellow Perch (*Perca flavescens*), which can be spread by anglers and other members of the public. Bradford *et al.* (2008a, b) conducted qualitative risk assessments and concluded that for most regions of BC the probability of becoming widely established once arrived is high or very high, and the likely magnitude of ecological impact in small water bodies is very high. Potential threats also include the spread of amphibians like the predaceous Bullfrog (*Rana catesbeiana*) and invasive aquatic vegetation such as Eurasian Milfoil (*Myriophyllum spicatum*) and Purple Loosestrife (*Lythrum salicaria*). The effects of invasive plants are unclear, but they could reduce the abundance of native plants to which sticklebacks are better adapted for use as nesting habitat (for Benthic sticklebacks).

Quantifying the threat of invasive species to Vananda Creek Benthic and Limnetic Threespine Sticklebacks has not been undertaken, but there are a number of indications that the likelihood of introduction is high over a reasonable timeframe (i.e., 10 years or less). Although the species pair lakes are in a rural setting, they are readily accessible to the public. The main road on Texada Island runs adjacent to the eastern shore of Priest Lake and there is a publicly accessible boat launch. Boating and angling activity is light, but there is year-round use of Priest Lake by anglers targeting native Coastal Cutthroat Trout. Source populations for non-native fish species occur in many nearby lakes on the mainland, Vancouver Island, and other islands in the Strait of Georgia. In fact, from 1980-2000 the distribution of invasive Smallmouth Bass has increased from 19 to 30 lakes and of Pumpkinseed Sunfish from 33 to 41 lakes on Vancouver Island alone (Hatfield and Pollard 2006). From 2000-2010, invasives have continued to spread. For instance, a total of 89 lakes on Vancouver Island now include one or more exotic (and probably invasive) species, Smallmouth Bass are now found in 50 lakes (vs. 30 in 2000), Pumpkinseed Sunfish are now found in 55 lakes/streams and for the first time Largemouth Bass have been recorded in three lakes (S. Pollard, pers. comm. 2010). In addition, the Hadley Lake pair is located on an even more remote island (Lasqueti Island) and Brown Bullhead became established in that lake leading to the extirpation of the Hadley Lake species pair. There are no significant technical barriers to introducing non-native species should one wish to do so.

Water use

Existing water licences permit substantial water extraction from Priest and Emily lakes, for domestic and industrial purposes; there are four fairly small diversion licences (500 gallons/day) for Spectacle Lake for domestic use. Priest Lake is the domestic water supply for the town of Van Anda. The total volume of water being used at present is not known, but licensed annual diversion amounts total around 15% of Priest Lake volume and about 82% of Emily Lake volume. Additional licences allow storage on the lakes through maintenance of small dams. Inflows to all the lakes are small due to limited catchment area and runoff. Large fluctuations (up to 5 m), such as those noted by Larson (1976) on nearby Paxton Lake, have impacts on littoral productivity and pelagic volume and would be expected to have a direct effect on sticklebacks, limiting both spawning and feeding habitats. The larger licences that were granted for industrial purposes do not appear to be in use at present, but they remain “active” in that the licences have not been retired. The historical use of these licences and their effects on stickleback habitat are not known.

Land use

There have been numerous land-based development activities within the Vananda Creek watershed: forest harvest, subsurface mining (early in the 1900s), pipeline and road building, and housing development (National Recovery Team for Stickleback Species Pairs 2007). The main concerns from such activities include cumulative impacts on water quality and habitat destruction or alteration. The greatest of these risks appears to be introduction of suspended sediments (i.e., increased turbidity), but at present, the risk is difficult to gauge. Forestry-related activities are likely the largest potential contributor of suspended sediments from land use; these activities are ongoing in all three sub-basins on private and Crown lands.

Collections for research

Stickleback species pairs have been the focus of intense scientific study since the 1980s and there is an increasing demand for wild stock for use in laboratory-based studies and for permits to conduct *in situ* scientific study. Collecting activities have the potential to be a significant source of mortality for adult fish, and constitute a threat to the species pairs that should be carefully managed. The Recovery Team for Non-Game Freshwater Fish Species in BC (2008) produced guidelines for the collection of stickleback species pairs that recommend limiting the number of individuals removed from species pair lakes, limiting collecting activities to only half of each lake, thorough cleaning of all sampling gear, and prohibitions on the use of hybrids or invasive species in any *in situ* studies.

Other

Impacts may occur from other activities, including illegal bait release by anglers, pollution from recreational boating, introduction of disease, effects of climate change (warming and increasing drought conditions) and pollution from surface water inflow. These threats are of concern to the Recovery Team, but are believed to present a lower risk at present than the threats noted above.

Limits to Vananda Creek stickleback abundance are poorly understood. It is not known whether abundance is limited by food production, cover, predation, spawning habitat or other factors. It is likely that the main limiting factor is food supply—the capability of each lake to produce plankton and benthos—but there are no data to support this view. In any case, benthics and limnetics are thought to be locally abundant, and not in apparent decline; the primary factor determining conservation status is their extreme endemism, not population decline.

EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

Vananda Creek Benthic and Limnetic Threespine Sticklebacks are listed as Endangered under Schedule 1 of the *Species at Risk Act* (SARA). In addition, they are "red-listed" by the Conservation Data Centre and BC Ministry of Environment. Under the BC Sport Fishing Regulations, it is illegal to fish for, or catch and retain Vananda Creek Benthic and Limnetic Threespine Sticklebacks.

Vananda Creek Benthic and Limnetic Threespine Sticklebacks may benefit from the *Fisheries Act*, which provides DFO with powers, authorities, duties and functions for the conservation and protection of fish and fish habitat (as defined in the *Fisheries Act*). The *Fisheries Act* contains provisions that can be applied to regulate flow needs for fish, fish passage, killing of fish by means other than fishing, the pollution of fish-bearing waters, and harm to fish habitat. Environment Canada has been assigned administrative responsibilities for the provisions dealing with regulating the pollution of fish-bearing waters while the other provisions are administered by DFO.

Despite the above, at this time there are no habitat protection provisions specifically for Vananda Creek Benthic and Limnetic Threespine Sticklebacks. The Recovery Team for Stickleback Species Pairs has, however, identified proposed critical habitat for the species pairs, and a report has been accepted by the Pacific Scientific Advice Review Committee (DFO). The report recommended critical habitat identification of the entire wetted area of Spectacle, Priest and Emily lakes, plus a riparian buffer and is subject to further approval processes. Consequently, although from a scientific perspective critical habitat has been proposed, it is not yet identified from a legal perspective. The *BC Forest and Range Practices Act*, which has provisions to protect fish habitat from forestry activities, applies to Crown lands in the Vananda Creek watershed. In addition, the provincial *Riparian Areas Regulation* provides some protection for riparian areas around the lakes. Planning for a Wildlife Habitat Area is underway, and will include measures for protection of riparian areas upstream of the Emily Lake outlet, and other upslope areas that may increase sediment input if disturbed during forestry activities. One of the primary concerns in this case is increased suspended sediments in species pair lakes, which may damage stickleback habitat or lead to increased hybridization (see, for example, Taylor *et al.* 2006). Wildlife Habitat Areas, however, only apply to forestry-related practices on Crown land and have no authority on private lands in the Vananda Creek watershed.

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COLLECTIONS EXAMINED

No museum collections were examined for this report.