RECOVERY POTENTIAL ASSESSMENT FOR THE LITTLE QUARRY LAKE STICKLEBACK SPECIES PAIR (*GASTEROSTEUS ACULEATUS*)

Context

After the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses an aquatic species as Threatened, Endangered or Extirpated, Fisheries and Oceans Canada (DFO) undertakes a number of actions required to support implementation of the *Species at Risk Act* (SARA). Many of these actions require scientific information on the current status of the wildlife species, threats to its survival and recovery, and the feasibility of recovery. Formulation of this scientific advice has typically been developed through a Recovery Potential Assessment (RPA) that is conducted shortly after the COSEWIC assessment. This timing allows for consideration of peer-reviewed scientific analyses into SARA processes including recovery planning.

The Little Quarry Lake benthic and limnetic Threespine Stickleback (*Gasterosteus aculeatus)* populations were designated Threatened by COSEWIC in 2015 based on their status as unique Canadian endemic stickleback populations confined to a single small lake in southwestern British Columbia (COSEWIC 2015). There has been no formal assessment of critical habitat or population size, although some of the conclusions drawn for definition of critical habitat in other stickleback species pairs may be relevant (Hatfield 2009; National Recovery Team for Stickleback Species Pairs 2006).

Little Quarry Lake benthic and limnetic sticklebacks do not receive habitat protection under the Canadian *Fisheries Act* or the British Columbia Sport Fishing Regulations (Government of British Columbia 2016). Crown Land surrounding Little Quarry Lake confers some protection through the British Columbia *Forest and Range Practices Act* and the provincial Riparian Areas Regulation. Provincial and global conservation status remains “not assessed”. Although the current British Columbia Red List contains four stickleback species pairs (Vananda Creek, Misty Lake, Enos Lake and Paxton Lake), the Little Quarry Lake species pair, which was described in 2008, is not yet listed (Gow et al. 2008; B.C. Conservation Data Centre 2016). All these pairs are globally unique; all, with the exception of the stream-lake pair in Misty Lake, are benthic-limnetic pairs.

In support of listing recommendations for the Little Quarry Lake stickleback species pair DFO Science has been asked to undertake a RPA, based on the national RPA Guidance. The advice in the RPA may be used to inform both scientific and socio-economic aspects of the listing decision, development of a recovery strategy and action plan, and to support decision making with regards to the issuance of permits or agreements, and the formulation of exemptions and related conditions, as per sections 73, 74, 75, 77, 78 and 83(4) of SARA. The advice in the RPA may also be used to prepare for the reporting requirements of SARA s.55. The advice generated via this process will update and/or consolidate any existing advice regarding the Little Quarry Lake stickleback species pair.

This Science Response Report results from the Science Response Process in February 2017 on the Recovery Potential Assessment – Little Quarry Lake Benthic and Limnetic Stickleback.

Analysis and Response

Objectives

The RPA provides up-to-date information and discusses associated uncertainties in the following areas:

- Biology, life history, distribution and abundance
- Habitat and residence requirements
- Threats and limiting factors to survival and recovery
- Recovery targets
- Scenarios for mitigation of threats and alternatives to activities
- Allowable harm

Biology, Life History, Distribution and Abundance

Element 1: Biology

The Little Quarry Lake benthic and limnetic sticklebacks are a *sympatric species pair*; they occupy the same general area but have become reproductively isolated through differences in behaviour and habitat preference. The benthic form is found in the littoral lake zone and the limnetic form in open, deeper waters. While the two forms appear to have evolved relatively recently from their marine ancestor, their evolutionary history is unclear and it is still not known whether multiple colonisations of the lake by a single marine species played a role (Jones et al. 2012). Whatever the mechanism, genetic analysis indicates strong genetic distinctness between the benthic and limnetic forms and justifies their description as designatable units (DU) within *Gasterosteus aculeatus* according to COSEWIC criteria for discreteness and evolutionary significance (Gow et al. 2008; COSEWIC 2011). Biologically if not taxonomically, they are distinct species and are members of a very small group of only four extant stickleback species pairs known to occur in coastal British Columbia Lakes. All have high scientific value as examples of recent parallel evolution; the existence of others cannot be ruled out.

Little Quarry Lake benthic and limnetic sticklebacks differ markedly in form and behaviour (Figure 1). The benthic (bottom-living) form is adapted for eating benthic invertebrates; it is larger overall than the limnetic form, with shorter dorsal and anal fins, smaller eyes and a shorter, more downward-oriented jaw. The limnetic form is adapted to eating free-swimming plankton in open water. Little is known of the behaviour of either form, but a functional outline can be cautiously inferred from more detailed observations made on the species pairs in Paxton Lake, Enos Lake (before 1990) and the Vananda watershed.

Figure 1. Little Quarry Lake benthic and limnetic Threespine Sticklebacks (with permission from Diana Rennison).

Element 2: Distribution and abundance

A key consideration in the designation of the Little Quarry Lake species pair as “Threatened” is their highly restricted distribution. Little Quarry Lake is a small water body (22 ha surface area) on Nelson Island in the central Strait of Georgia region in southwestern B.C. (Figure 2, 3).

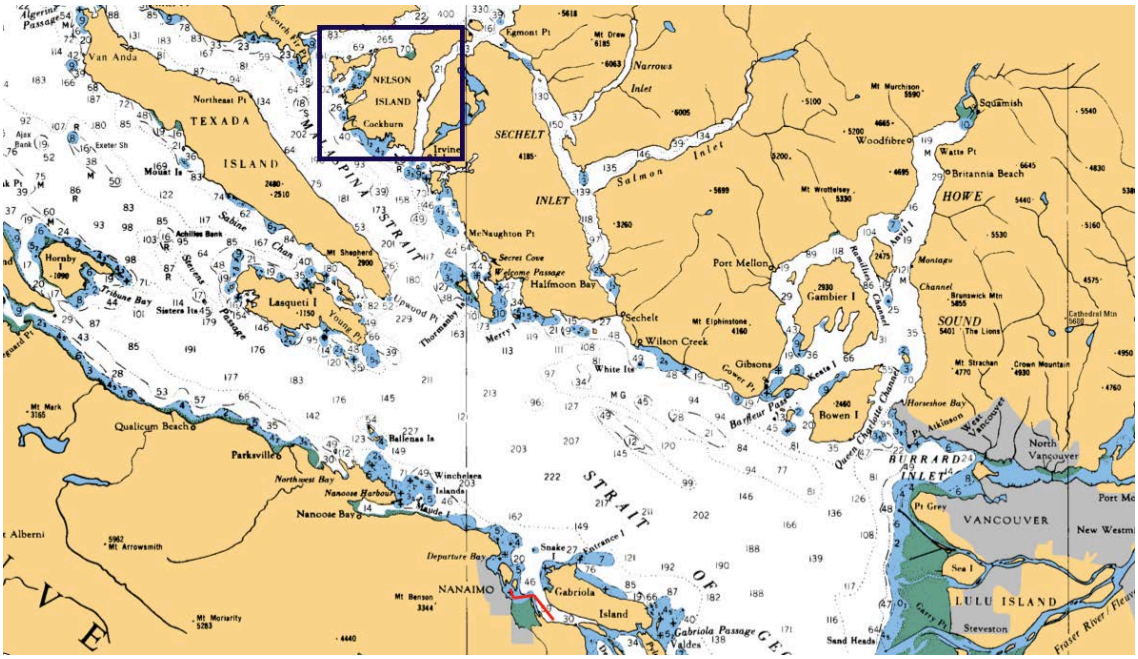

Figure 2. Location of Nelson Island

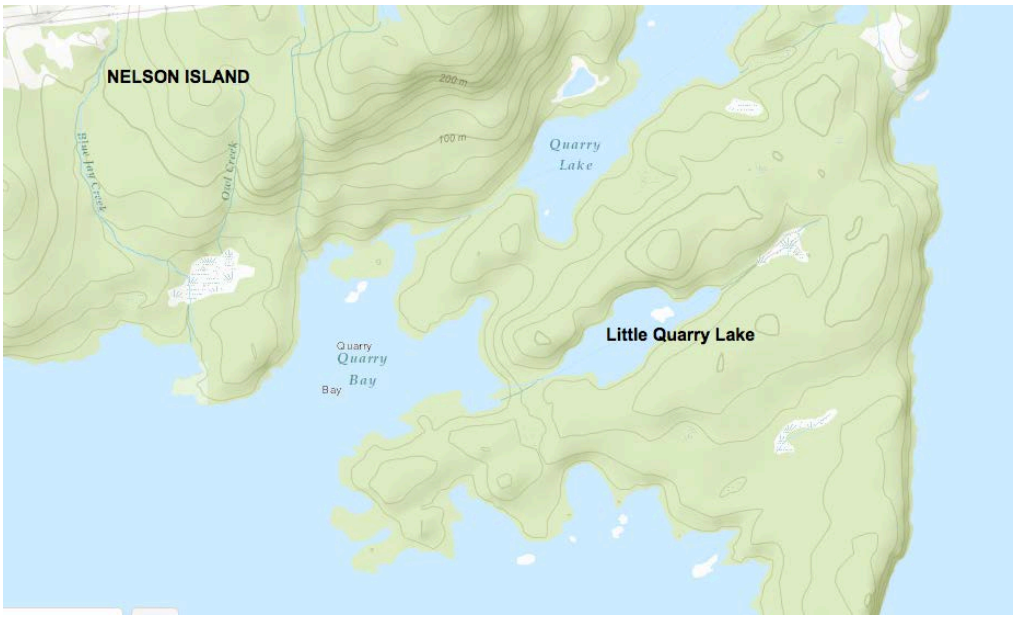

Figure 3. Detail: Nelson Island and Little Quarry Lake

Extent of occurrence (EOO) and index of area of occupancy (IAO) have both been estimated at 8 km^2 (COSEWIC 2015). The uniqueness of all the known stickleback sympatric species pairs strongly suggests that Little Quarry Lake stickleback will not be found anywhere else. Although they are likely to undertake short-term seasonal movements within the lake, migration beyond the lake is believed to be unlikely (COSEWIC 2015).

Abundance of Little Quarry Lake stickleback species pairs is unknown, although there is no reason to believe they are in decline. There has been no quantitative monitoring of either population, so trends are unknown. A one-time population estimate extrapolated from a single, unpublished mark-recapture study of Paxton Lake stickleback species pairs (Nomura[1] 2005) is noted in COSEWIC (2015). This estimate contains large confidence intervals and should be considered insufficient for purposes of recovery planning not only because of the study's design but also because there are significant differences between the two lakes in terms of size, productivity, prey biomass and macrophyte extent. A new estimate of abundance in Paxton Lake and Priest Lake (Vananda watershed), based on a mark-recapture study carried out by researchers from the University of British Columbia, is expected to be published in 2017 (D. Schluter, personal communication, 2017).

Element 3: life history

Males construct and guard nests and the developing fry, with the nests of benthic fish more likely to be under cover of macrophytes. Benthic fish may start reproducing earlier in the year than do limnetics; even if there is overlap, mating behaviour is assumed to work strongly against interbreeding. Further understanding of the role and strength of assortative mating between the species pairs can be expected to come from ongoing pond experiments carried out at the University of British Columbia (D. Schluter 2017, personal communication). Very few hybrids have been observed in fish collected in Little Quarry Lake (Gow et al. 2008). Hybridization is

[1] Nomura, M. 2005. Population study of Paxton Lake stickleback species pair – 2005. unpublished data report

known to occur at low rates (1-2%) in Paxton Lake and Priest Lake stickleback (D. Schluter, personal communication, 2017).

The general pattern for stickleback species pairs is for the limnetic form to mature as one-year-olds and die at the end of the breeding year, although they may mate with several females and nest more than once. The benthic form may reproduce later (in their second year) and over several successive years. Fry of both forms share the littoral area for initial feeding before limnetic fish move away from the shore (McPhail 2007).

Habitat and Residence Requirements

Element 4: Habitat properties

Functions, features, attributes

Habitat for the Little Quarry Lake stickleback species pair is necessary for the following functions:

- mate selection and spawning
- nest building and protection
- feeding, growth and rearing

Because the key element that maintains the uniqueness of the two members of the species pair is prevention of hybridization, mate recognition needs to be ensured through maintaining adequate light transmission. Light transmission may be increased or decreased by alterations in the riparian zone that affect turbidity. A riparian role in maintaining the long term persistence of stickleback species pairs through maintaining water quality has been proposed in several reports (Hatfield 2009; Richardson et al. 2010). Additional detail on habitat requirements for stickleback species pairs is found in the Proposed Recovery Plan for Stickleback Species Pairs (National Recovery Team for Stickleback Species Pairs, 2006).

Adequate gently sloping littoral zones with macrophyte cover are needed to ensure that both pair populations have access to segregated nesting and juvenile rearing habitat. Although it is not known how performance of reproductive functions varies quantitatively with habitat availability, the extent of littoral habitat in Little Quarry Lake is a possible limiting factor and is further discussed below (Element 10: Natural factors that could limit survival and recovery).

A key biotic feature of habitat in Little Quarry Lake is the depauperate fish community, a feature that is not common to all lakes with stickleback species pairs (a frequent cohabiting species is cutthroat trout). There are no other known fish species in Little Quarry Lake. Potential effects of alteration of that community are discussed below (Element 8: Assessment and prioritization of threats).

Habitat features that enable feeding and growth include adequate and continued littoral and pelagic productivity. Abiotic attributes that affect productivity specifically in Little Quarry Lake are also discussed below as potential limiting factors (Element 10: Natural factors that could limit survival and recovery). While declining productivity may be detrimental, productivity can also be detrimental if it increases too much (e.g. eutrophication). In general, alteration of benthic or pelagic production outside of their historic range could alter relative growth, size, and survival of limnetics vs. benthics, potentially affecting relative population size as well as individual body size, both of which are important in mate discrimination.

While the lakes that support stickleback species pairs do not differ significantly from those that contain solitary stickleback species, the pairs' need to remain reproductively isolated makes them more sensitive to habitat and environmental changes (COSEWIC 2015).

Little Quarry Lake is roughly similar to other species pair lakes in some ways (elevation, size, depth and connection to the sea by a high gradient stream) but there are some significant differences. The outlet stream, for example, appears to have been dammed for decades; the dam itself is granite rubble and appears stable (D. Schluter 2017, personal communication). Little Quarry Lake also has relatively low values for conductivity, alkalinity, dissolved organic carbon and total dissolved solids – all of which affect productivity. Dissolved oxygen is, however, significantly higher than in other species pair lakes (Ormond et al. 2011). The relative littoral area in Little Quarry Lake is also significantly smaller than that for other species pair lakes, and the bottom drops off more steeply (COSEWIC 2015). It is not known whether any of these attributes represent carrying capacity limits.

The littoral area contains most of the macrophyte cover and breeding habitat. Table 1 captures the functions, features and associated attributes of habitat for Little Quarry Lake sticklebacks. Obtaining quantitative values for associated attributes would require further study and clarification.

Table 1. Functions, features and attributes of required habitat for Little Quarry Lake Threespine Sticklebacks

FUNCTION	FEATURES	ATTRIBUTES
Mate selection and spawning	• Littoral zone • Macrophyte cover	• Adequate light transmission • Low slope. Not known if slope is limiting.
Nest building and protection	• Littoral zone • Macrophyte cover	• Low slope. Not known if slope is limiting.
Feeding, growth and rearing	• Depauperate fish community • Littoral and pelagic productivity	• No other fish species in lake • Not known if lake chemistry values are limiting

Element 5: Spatial extent

Little Quarry Lake benthic and limnetic sticklebacks require access both to littoral areas and open waters for feeding and reproduction. These habitats comprise the lake in its entirety.

Element 6: Spatial configuration constraints

Given the historic damming of the outlet stream from Little Quarry Lake it is considered unlikely that there has been any recolonization by marine stickleback species (COSEWIC 2015). The single inlet stream is theoretically an access point for invasive freshwater species, although these are more likely to arrive through direct introductions into the lake itself (Element 8: Assessment and prioritization of threats). Little Quarry Lake is not connected to the neighbouring (and considerably larger) Quarry Lake, which does not contain a stickleback species pair. Within Little Quarry Lake itself, sticklebacks do not encounter any barriers to access to limnetic and littoral areas.

Element 7: Residence

SARA defines a residence as “a dwelling place, such as a den, nest or other similar area or place that is occupied or habitually occupied by one or more individuals during all or part of their

life cycles, including breeding, rearing, staging, wintering, feeding or hibernating" (Statutes of Canada 2002). The residence must support a life cycle function, there must be an element of investment in the creation or modification of the structure, and it must be occupied by one or more individuals.

Both benthic and limnetic Little Quarry Lake sticklebacks spend a limited period constructing and guarding nests in the littoral area. As a result, the concept of residence, as defined under SARA, does apply. However the spatial and temporal variability of nest construction prevent the identification of the location of the residence.

Threats and Limiting Factors

Element 8: Assessment and prioritization of threats

There are two primary threats to the benthic and limnetic stickleback populations in Little Quarry Lake. They are discussed here in no particular order. A shorter mention of a number of less severe threats follows.

Threat 1: Invasive species

Introduction of an invasive species into Little Quarry Lake can have consequences that directly impact the maintenance of genetic separation between the benthic and limnetic populations. As already stated in Element 4 (Habitat Properties), any change to biotic or abiotic habitat that enables hybridization between the two populations undermines their genetic uniqueness and persistence as separate populations.

Invasive animal species (primarily fish or invertebrate species) can compete with or prey on sticklebacks in Little Quarry Lake, but are likely to cause the most damage through alteration of what is currently a remarkably simple ecosystem in which sticklebacks are the only known fish species.

Both pathways are illustrated in the loss of two other unique stickleback species pairs. In Hadley Lake, introduction of the Brown Bullhead *Ameiurus nebulosus* likely caused extinction through predation. In Enos Lake, the introduced American Signal Crayfish *Pacifastacus leniusculus* more likely had its effect through altering habitat by making mate recognition more difficult and disrupting macrophyte beds that formerly facilitated segregation of nesting and rearing areas, although it may also have disrupted breeding in limnetic males (Velema et al. 2012). The result was rapid hybridization between benthic and limnetic forms, and consequent loss of their genetic uniqueness (references summarized in COSEWIC 2015).

Introduction of an invasive plant species such as Eurasian milfoil *Myriophyllum spicatum* could disrupt nesting areas and reduce light transmission. Introduction of pathogens or an invasive aquatic species such as water milfoil can result from uncleaned sampling equipment. Milfoil is unlikely to be introduced by boats and trailers, neither of which are likely to enter Little Quarry Lake after visiting a different, infested water body.

There is no recreational fishery in Little Quarry Lake and the lake itself is small and difficult to access. Although neither characteristic eliminates the threat of deliberate introduction of vertebrate or invertebrate invasive species, anyone doing so deliberately would need to overcome multiple logistic and geographic barriers. The addition of new homes to currently vacant lots in the Quarry Harbour strata (see "Other threats", below), as well as increased use of the 200 contiguous common acres in the strata, do however increase the potential for human access to the lake.

Threat 2: Scientific sampling

The rarity of stickleback species pairs and their significance to the understanding of evolutionary selection guarantee continued scientific interest that can involve *in situ* studies or removal of animals from both populations.

Based on professional opinion, collection for scientific purposes is believed to have been a significant and potentially leading source of mortality for other benthic-limnetic stickleback species pairs (Recovery Team for Non-Game Freshwater Fish Species 2008). Scientific sampling affects the population not only by removing adult fish but also, in the case of males, eliminating nest protection and allowing predation on eggs and larval fish.

Although Little Quarry Lake is remote and its sticklebacks have only been collected in modest numbers to date, by a single research group (D. Schluter, personal communication 2017), the lack of any estimate of abundance means that quantitative assessment of this threat is currently impossible for Little Quarry Lake sticklebacks.Until the size of the population from which collections are made is known, limits for removal of adults should remain conservative.

Other threats

Little Quarry Lake is surrounded by Crown Land and a small portion of a timber tenure owned by A&A Trading Ltd. There is no housing or land-based development around the lake. COSEWIC (2015) considers any risk to Little Quarry Lake habitat from logging to be negligible.

Since the mid-1980s, water has been piped out for domestic use by homes in the Quarry Harbour Strata, a development that extends below the lake outlet to encompass 39 sub-dividable oceanfront lots and 200 common acres fronting Quarry Bay and Malaspina Strait to the southwest (Strata Plan VR1481; Figure 4). Water is currently extracted by gravity feed only, with treatment limited to chlorination (Nelson Island is not on the electrical grid). Water extraction is managed by the strata and is exempt from the Water Utility Act and the Utilities Commission Act due to remoteness and terrain (Government of British Columbia 1984). Strata common property encircles the southwest end of the lake and includes access to the water extraction and treatment station (Figure 5).

The present risk of deleterious drawdown of water for domestic use appears to be slight and water management and use risk is characterized as negligible by COSEWIC (2015).

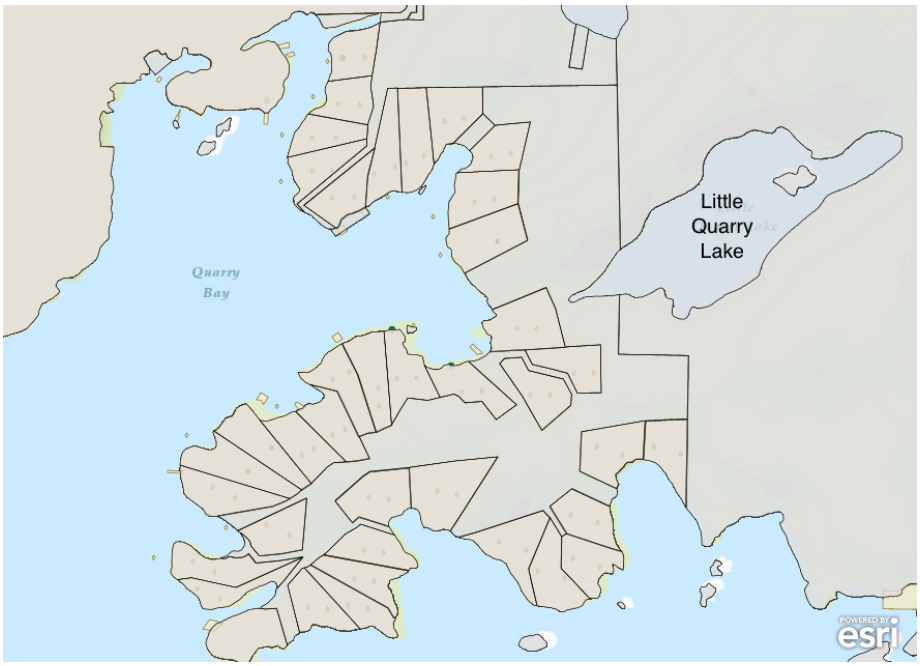

Figure 4. The Quarry Harbour Strata (SCRD 2017)

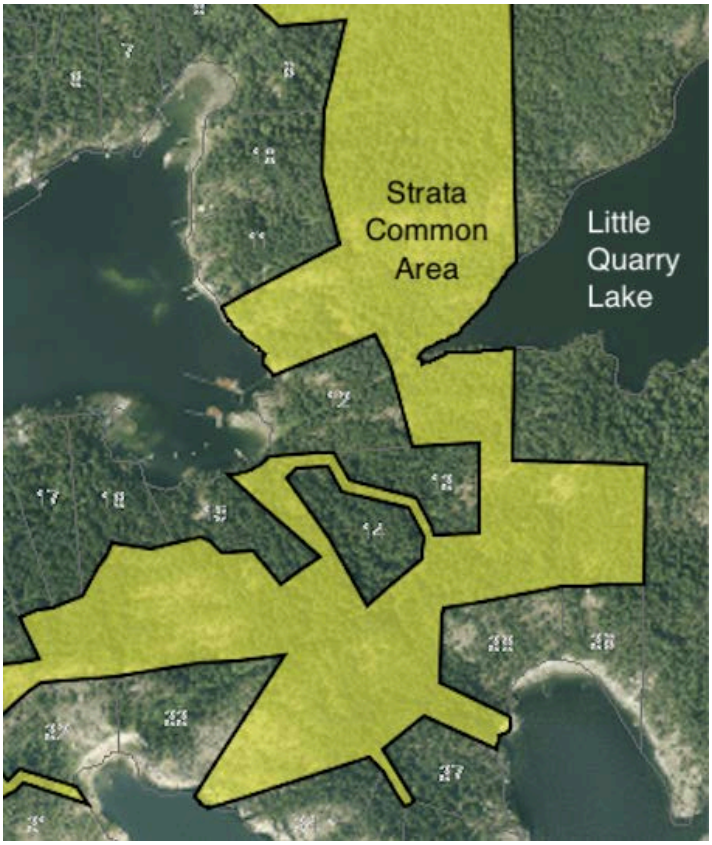

Figure 5. Common Area in the Quarry Harbour Strata (SCRD 2017)

Element 9: Activities most likely to threaten habitat properties identified in Element 4

Introduction of invasive species

Introduced invasive species have the potential to alter the simple faunal community in Little Quarry Lake through competition or predation; the end result could be hybridization between the benthic and limnetic forms that results in their losing the genetic distinctness that is the basis for their uniqueness. Previous experience with other stickleback species pairs shows that the effects of invasive species can lead to extinction (Hadley Lake; from predation and competition) or collapse of the two distinct populations into a hybrid swarm (Enos Lake; from biased hybridization).

Collection for scientific purposes

Scientific collection is not expected to alter habitat.

Water extraction

While water extraction for domestic use was rated as a negligible threat by COSEWIC (2015), the potential exists for increased demand for water as more housing is built within the Quarry Harbour Strata. It is not possible to estimate the severity of habitat alteration.

Element 10: Natural factors that could limit survival and recovery

Comparison of Little Quarry Lake with other B.C. lakes that support species pairs or solitary stickleback populations reveals some significant differences in habitat partitioning and abiotic factors (Ormond et al. 2011). While dissolved oxygen is highest in Little Quarry Lake, water conductivity, alkalinity, dissolved inorganic carbon and total dissolved solids are the lowest of any species pair lake, suggesting that high productivity may not be required for persistence of the two populations, although it may in fact be limiting (COSEWIC 2015). The relative littoral area (breeding habitat for both forms and feeding habitat for the benthic form) is also much smaller in Little Quarry Lake than in other species pair lakes. The amount of littoral habitat – which includes cover-providing benthic macrophytes -- may thus also be limiting to the species pair.

Element 11: Potential ecological impacts of threats; monitoring and knowledge gaps

There are presently no co-occurring fish species in Little Quarry Lake, so the stickleback populations can be considered the main targets of any ecological change, or beneficiaries of abatement. Introduction of any invasive species will thus have a profound ecological impact on the lake's simple ecological community through competition, predation or hybridization.

The lack of a strongly supported abundance estimate or any consistent monitoring constitute major knowledge gaps that affect many aspects of recovery planning, from setting population targets to estimating the magnitude of limiting factors and the estimation of the effects of changes in habitat.

Recovery Targets

Elements 12-15: Targets for Recovery

In the absence of any knowledge of abundance, distribution within the lake, abundance trends and dynamics, population and distribution target(s) can only be recommended as "Maintain current distribution and abundance."

The supply of suitable benthic and limnetic habitat appears to meet the demands of the species at present, although it is not known whether the abiotic habitat characteristics described in Element 10 constitute limiting factors.

As an assumed low-population species that can expected always to be at risk because of endemism and its dependence on reproductive isolation between the two populations, Little Quarry Lake sticklebacks may, however, be better considered in terms of survival than of recovery. For this species, the first objective of SARA (to "prevent wildlife species from being extirpated or becoming extinct") is most appropriate. Survival is defined as "the achievement of a stable (or increasing) state where a species exists in the wild in Canada and is not at significant risk of extirpation or extinction as a direct or indirect result of human activity." Survival criteria are provided in Government of Canada (2016). Little Quarry Lake sticklebacks are likely to remain above the "survival threshold" defined in the aforementioned report as long as the non-natural threats outlined in this RPA (Criterion 6) are mitigated.

Scenarios for Mitigation of Threats and Alternatives to Activities

Element 16: Feasible mitigation measures and reasonable alternatives to the activities that are threats to the species and its habitat (Elements 8 and 10)

The two main threats to Little Quarry Lake sticklebacks are introduction of invasive species and collection for scientific purposes.

Aquatic Invasive species

Introduction of aquatic invasive species into B.C. lakes can be inadvertent or deliberate. Remoteness and limited access provide some defense against introductions but are not guarantees. If the trend in visits is upward – for example, through improved access or recreational reputation -- the risk of introductions increases.

Little Quarry Lake is a small, low elevation lake located in a relatively remote area. But its remoteness is not absolute. The larger Quarry Lake nearby is used for recreational fishing, and Little Quarry Lake itself can be accessed at the water treatment station approximately 250 m from Quarry Bay. Most of the 39 lots in Quarry Harbour strata presently carry some sort of improvement (docks and/or houses) reflected in the 2015 real estate assessment (Sunshine Coast Regional District 2017). Because not all the lots are improved, and all can be subdivided, the area may see an increase in building and occupancy. Demand for domestic water from Little Quarry Lake can be expected to rise, as could visits to the lake, and simple chlorination may need to be augmented by pumping and filtration. Increased population with increased water demand may lead to an increase in the number of visits to Little Quarry Lake. Currently, however, there are no proposed development applications in the area (Y. Siao 2017, personal communication).

Homeowners in the Quarry Harbour strata represent a community of people committed to living in a remote environment, although most will likely remain summer users. Acting as stewards for unique fauna in their area is in their best interests, and the community is already strongly inclined that way (M. Jackson 2017, personal communication). Liaison of recovery actions through the Strata Council is feasible and the council's cooperation will be important in raising awareness of the Little Quarry Lake sticklebacks within the community and with visitors, as well as in informal monitoring related to maintenance and upgrading of water supply infrastructure.

The main access point to the lake (at the water intake) is a good candidate for signage. Development and maintenance of messaging is highly feasible and can be expected to involve the strata council and local partners, for example the Ruby Lake Lagoon Nature Reserve Society (M. Jackson 2017, personal communication).

Scientific collection

At present, the only protection from excessive removal or interference for scientific purposes afforded to Little Quarry Lake sticklebacks are the guidelines developed by the Recovery Team for Non-Game Freshwater Fish Species in British Columbia (2008). Collection is recommended by these authorities to be limited to the northeastern half of the lake. The recommended lethal sampling limit for Little Quarry Lake is 235 mature fish of each species and sex (470 for juveniles). These limits are calculated based on an abundance extrapolated from the single mark-recapture study for Paxton Lake already described (and potentially to be updated), and should be be considered as best guesses in the face of severe data limitations.

Given the high level of uncertainty concerning abundance of the species, these guidelines should be revisited. The guidelines do not make it clear whether these limits are annual or single-collection limits, or whether the numbers apply to each collector or to the total removals by all collectors. Clarification would aid in permitting. Restriction of sampling to the northeastern half of the lake may also be inadvisable, as the southwest part of the lake includes the normal access point (D. Schluter 2017, personal communication).

Of equal importance to sampling limits and methods is the maintenance of records when sampling. If record-keeping is consistent between operators and over time, those records can contribute to provision of an index of abundance that goes some way to filling knowledge gaps mention above (Element 11). Sampling protocols and record-keeping thus need to be standardized with this end in mind.

Element 17-21 :

Not applicable to Little Quarry Lake sticklebacks due to knowledge gaps on abundance, trends and limiting factors.

Allowable Harm Assessment

Element 22: Maximum human-induced mortality and habitat destruction that the species can sustain without jeopardizing its survival

Allowable harm to Little Quarry Lake sticklebacks should be restricted to sampling for scientific purposes. At present, permitting is informed by guidelines that provide quantitative recommendations for removal of adults and juveniles that are based on extrapolations of very limited data on a different stickleback population and do not specify temporal parameters. This RPA therefore recommends that the criteria for allowing harm for scientific collections of Little Quarry lake sticklebacks be revisited and refined as follows:

1. Current recommended mortalities be qualified by specifying the time period within which they can be allowed, and revised in the light of any new information on abundance;
2. Collection be restricted to the southwest half of the lake, unless clear justification can be made for restricting collection to the northeast side;
3. Scientific collections should employ a standardized data collection and maintenance methodology that facilitates development of an index of population abundance and trends.

Conclusions

Little Quarry Lake sticklebacks are a sympatric species pair and they have been assessed as threatened by COSEWIC. This RPA recommends options for listing and recovery under SARA. They are confined to one small lake on Nelson Island, BC. The primary identified threat is the introduction of an aquatic invasive species that would compete or prey directly on them or alter the habitat that they rely upon. The species is likely to meet the survival threshold as described

in the proposed national policy on survival and recovery. Allowable harm should be restricted to scientific sampling based on certain criteria.

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