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RECOVERY POTENTIAL ASSESSMENT FOR THE MISTY LAKE STICKLEBACK (*GASTEROSTEUS SPP.*) PAIR

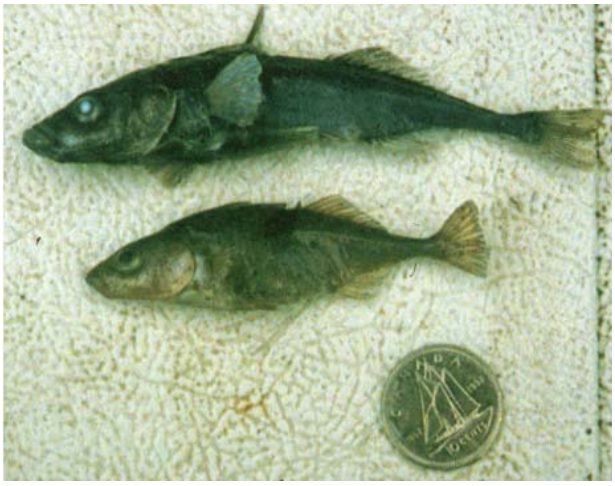

Figure 1. Misty Lake stickleback; lake form (upper), stream form (lower). (photo courtesy of Dr. E. Taylor, UBC)

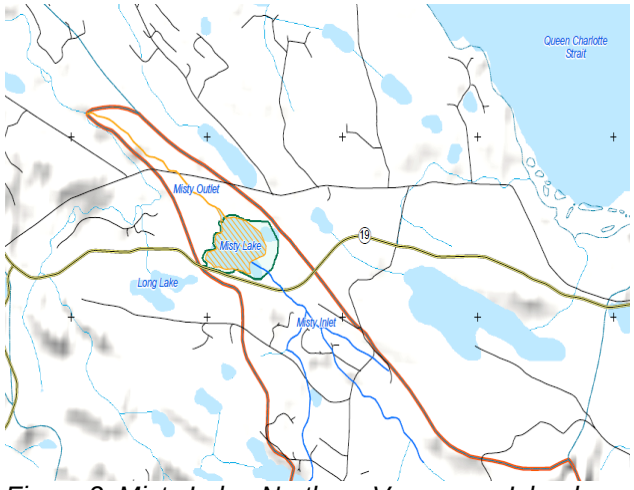

Figure 2. Misty Lake, Northern Vancouver Island, BC. (Courtesy Jacques Whitford)

Context :

The Misty Lake stickleback pair (Gasterosteus aculeatus) was designated Endangered by COSEWIC in 2006 because it is an endemic, highly divergent species pair restricted to a single lake-stream complex (COSEWIC 2006). It is presently being considered for listing under the Species At Risk Act (SARA). To support decision-making, information is required on the species' biology, population trends and targets, habitat requirements, threats to the survival or recovery and allowable harm. This Recovery Potential Assessment (RPA) was developed based on a peer-review by the Pacific Science Advice Review Committee (PSARC).

SUMMARY

- Misty Lake supports two separate forms of stickleback, usually referred to as a "stickleback pair." Threats to population persistence of the different forms include alien species, road run-off, logging, water withdrawal and climate change. Introduction of alien species is considered the most serious current threat to the pair populations.

- Current estimates of the lake and stream populations are highly uncertain and range from the low thousands to tens of thousands. A population size of 10,000 mature individuals for each inlet, outlet and lake form are recommended as appropriate targets for Misty Lake stickleback. Given the uncertainty in the population estimates and the high cost of error, a precautionary threshold for allowable harm of 5% is likely reasonable.

- Habitat threats and the potential for collapse of the pair populations from inter-breeding (hybridization) is the most important conservation risk. Identification of habitat requirements for survival of the pair should consider the role of habitat in maintaining reproductive isolation between the pair.

- Because of the importance of habitat in maintaining reproductive isolation of each form, potential critical habitat includes the lake, the full length of the inlet stream, 2.3 km of the outlet stream and all ephemeral streams.

- There remains high uncertainty on the amount of riparian habitat necessary for the survival of the species pair. Given this uncertainty, riparian buffer widths of 15-30 m around the lake and the inlet and outlet streams are recommended. Additional study of the relationship between stickleback pair survival needs and riparian functions may help to confirm the identified critical habitat in the future.

INTRODUCTION

The three-spined stickleback is widely distributed in a coastal band of marine and fresh waters in the Northern hemisphere (Figure 1). In British Columbia, three-spined stickleback are found in most coastal lakes and streams. Marine populations are generally confined to nearshore areas. This Recovery Potential Assessment (RPA) was developed from a peer-review process that occurred in April and October 2008 (Harvey 2009; Hatfield, 2009).

Misty Lake (50˚36' 32" N, 127˚15' 46" W) is located 15 km upstream of the Pacific Ocean in the Keogh River system. It is a small, shallow, tannin-stained lake whose outlet drains into the Keogh River on northern Vancouver Island (Figure 2). The Misty Lake ecosystem is rare but not diverse, and is little disturbed by human development.

Misty Lake supports two separate forms of stickleback, usually referred to as a "stickleback pair." Misty Lake stickleback is a parapatric (lake-stream) pair: one form lives in the lake, the other in the inlet and outlet streams. While lake fish may penetrate the stream for a short distance, stream forms are not found in the lake. It is one of only three clearly defined lake-stream pairs in Canada. The lake form of Misty Lake stickleback is larger than the stream form (Figure 1), and hybrids do not appear to be common.

The Misty Lake stickleback pair already receives some protection through the Misty Lake Ecological Reserve, formed in 1996 by the Government of British Columbia to protect habitat for the lake form and provide opportunities for biological research.

Stickleback pairs are very restricted in their distribution, and sensitive to changes in habitat or environmental factors. This sensitivity makes their conservation unusually challenging in that a population or species can be extirpated not only as a result of population decline of one or both forms but also through genetic hybridization between the two forms. The challenge is to identify which habitat attributes are most important to keep the species pair from interbreeding to the extent that the survival of the pair is not jeopardized.

ASSESSMENT

Phase I: Assessment of species status

Abundance, range and number of populations

There has been no systematic census of lake or stream sticklebacks in the Misty Lake system. Mark-recapture studies have been conducted in the inlet and outlet stream, but those studies focused on dispersal and were not designed for population estimation. Nevertheless, the results suggest population sizes of a few thousand fish in each stream. Sampling for genetic heterozygosity have resulted in estimates of effective population sizes N_e in the lake and stream that vary by more than an order of magnitude depending on the data and methods applied (Table 1).

Table 1. Estimates of effective population size N_e for Misty Lake and stream stickleback.

Location	Effective population size (N_e)	
	1	2
inlet	296	
inlet (lower)		5,561 - 9,029
inlet (upper)		3,624 - 5,018
outlet		5,134 - 14,616
lake	155 - 280	8,288 - 13,451

1. Eric Taylor, University of British Columbia, personal communication cited in Hattfied 2009
2. Hendry et al. (2002)

Hendry and Taylor (2004) report estimates of N_e for inlet and outlet streams that are a similar order of magnitude to those reported in Hendry et al. (2002).

Adult abundance can be expected to be 4 -10 times N_e. The range in abundance of adult fish in the lake and stream populations, therefore, ranges from the low thousands to more than 10,000. A useful comparison may be drawn from population estimates from Drizzle Lake on the Queen Charlotte Islands; another parapatric stickleback system. Based on mark-recapture methods, estimates for Drizzle Lake were 75,000 adult sticklebacks. Drizzle Lake is about three times larger than Misty Lake (112 ha vs. 36 ha). All else being equal, this suggests there may be sufficient habitat in Misty Lake to support about 20,000 stickleback. The genetic studies used only a small number of genetic markers on a sample of fish not randomly collected from throughout the lake. There are therefore no reliable, direct estimates of population abundance for lake and stream habitats of Misty Lake.

Recent species trajectory for abundance, range and number of populations

There are no quantitative estimates of abundance trends for either the stream or lake populations. Based on the extent and quality of existing habitat there is no a priori reason to expect that historic abundance or range was significantly greater than it is at present.

Life history parameters

Reliable estimates of basic parameters such as mortality, fecundity or recruitment are not available. Importing knowledge from other stickleback populations requires caution because factors affecting productivity vary widely in B.C. sticklebacks. The life span of Misty Lake sticklebacks has been estimated only from size-frequency plots. Fish from the inlet appear to live up to two years, whereas lake and outlet fish can reach three years. Within the entire system, breeding fish appear to be one to three years old.

Habitat requirements and habitat use patterns

Aquatic habitat distribution

No attempt has been made to establish precise geographic boundaries of habitat important for the survival of the Misty Lake pair. Surveys of habitat availability have not been conducted for the lake or the inlet and outlet streams. The lake is relatively shallow, with a maximum depth of 6.7 metres, and mean depth of 1.7 metres. Based on extrapolations from bathymetric habitat for Paxton Lake, the size of habitat for different life stages available to Misty Lake stickleback are shown in Table 2. Misty lake is deeply stained, oligotrophic, and dense plant growths occur in the summer. The inlet and outlet stream join the lake through extended swampy transition zones of several hundred metres. Little in known about the habitat use patterns of either the upstream and downstream forms, but captures have been made about 2.3 km downstream and about 2.0 km upstream of the lake. The two forms of stickleback co-occur in the transition areas between the lake and stream, especially during the breeding season. Maximum habitat areas are ~6000 m^2 for the inlet and ~6600 m^2 for the outlet, based on mean stream width and capture extent.

Table 2. Estimates of habitat area (hectares) for different life stages in Misty Lake extrapolated from bathymetric information of habitat distributions for Paxton Lake.

lake area	littoral foraging area	pelagic foraging area	young-of year habitat	nesting habitat
35.86	4.33	14.98	8.63	2.62

The shallow bathymetry of the lake ensures abundant spawning habitat for the lake form, likely in excess of the amount extrapolated from Paxton Lake.

Breeding requirements

Both lake and stream forms breed from April through July. The shallow, littoral zone of the lake is a known breeding and rearing area. The darkly stained water of Misty Lake has made the observation of nests difficult, but it is assumed that stream forms breed predominantly in the stream and the lake form predominantly in the lake. The shallow bathymetry of the lake ensures abundant spawning habitat for the lake form. In the absence of systematic sampling, there are no conclusive data on how far the stickleback penetrate into the upper inlet. One estimate puts occupation of around 2 km of the outlet stream; stickleback were very scarce at a sampling location 1.6 km upstream. There is measurable gene flow between the lake and the outlet that may effectively limit the range of the outlet population. Gravid females of both forms have been caught in the swampy transition zone between the lake and the inlet stream, and it is likely that both forms breed in this area. The lake and outlet fish are more closely related to each other

than to inlet fish in general, although the upper and lower inlet fish are also distinct from each other.

Water Quality

Water quality is an important habitat feature although again there are no quantitative data to relate function to survival of the species. As a group, sticklebacks are tolerant of a fairly large range of water quality conditions. Egg survival may be affected by water temperature, dissolved oxygen and siltation. Variations in these factors are presumably more easily tolerated by the free-swimming juveniles and adults. The precise needs of species pairs are unknown, but are not believed to be outside the limits of other stickleback species. Altered nutrient status may lead to demographic collapse, or hybridization between the species pair by altering the relative fitness of the two forms. Maintaining reproductive isolation probably depends, to a great extent, on mate recognition, which is affected by light transmission. Changes in concentration of suspended solids, dissolved organic carbon (DOC) (e.g., tannins), or other aspects of water chemistry that affect light transmission may disrupt mate recognition.

Aquatic plants

Aquatic plants are probably important for nest cover and production of macro-invertebrate food, and could be considered important habitat. The identification of critical habitat should consider its role in maintaining reproductive isolation between the different population forms. The collapse of the sympatric species pair in Enos Lake is thought to be associated with reduced macrophyte coverage after introduction of crayfish, in addition to other factors related to water quality.

The riparian zone

The riparian zone offers three important functions: streambank and lakeshore stability, instream cover, and food sources. Riparian areas on lakes contribute to the energy base of aquatic ecosystems through inputs of leaves and other organic material. Of special significance to stickleback species pairs is the role of the riparian zone in preventing sediment inputs from upslope activities (e.g., logging) that disturb surface sediments which may be transported to the lake in surface runoff. These sediment inputs have the potential to trigger increased hybridization if they occur during the breeding season.

In the absence of a detailed assessment of riparian widths and ecological function in the Misty Lake system, the Riparian Areas Regulation under the B.C. Provincial Fish Protection Act and supporting methodologies provide guidance for recommending riparian buffer widths. For lakes and wetlands where the existing or potential vegetation type is trees (the Misty Lake case) the recommended widths are 30 m for shade, 15 m for large woody debris supply and for litter fall and insect drop. For sticklebacks, woody debris, litter and insect drop are probably more important than shade. Riparian buffer widths of 15 to 30 m on the lake and inlet stream and a portion of the outlet stream known to be occupied by the stream form are considered reasonable in the absence of a quantitative assessment in Misty Lake.

Population and distribution targets

The average minimum viable population size for vertebrates is estimated to be about 7,000 mature individuals (2000-10,000 adults) for long-term persistence (40 generations) at a probability level of 99% (Reed et al 2003). A population threshold of $N_e \geq 1000$ is considered appropriate to ensure long term genetic viability. The effective population size $N_e \geq 1000$ (10,000 mature fish) is considered to be a realistic population target for each inlet, outlet and lake form.

Expected population trajectories

In the absence of direct estimates of life history parameters to simulate population trajectories, quantitative models were not applied. Realizing long-term population trajectories of the pair populations at or above 10,000 mature fish in each of the stream and lake habitats depends on the extent that habitat features are preserved to prevent collapse from hybridization.

Residence requirements

Males build several nests during the breeding season, and females produce several clutches of eggs. There is no evidence that Misty Lake stickleback require a "residence" (i.e. permanent den or nest) as defined in Species at Risk Act.

Phase II: Scope for management to facilitate recovery

Probability that the recovery targets can be achieved

Sticklebacks are typically resilient and productive, with a minimum doubling time of <1.25 years, compared with 1.4 - 4.4 years for sockeye salmon (Froese and Pauly 2008). The target rate for sustainable harvest of Fraser River populations of sockeye salmon is an annual removal of 67% of the mature population (age 4 individuals), which corresponds to a removal of 14% of the total population (all ages). This comparison suggests that an annual stickleback removal rate of <10% for each of the inlet, outlet and lake forms should not compromise their viability. Given the uncertainty in the population estimates and the high cost of error, a more precautionary threshold for allowable harm of 5% is likely reasonable.

Magnitude of each major potential source of mortality

Alien species

The extinction of genetically unique populations of stickleback from Hadley Lake, Lasqueti Island BC was the result of introducing brown bullhead *Ameiurus nebulosus*, to the lake, and illustrates the potential consequences of introducing an alien species into habitat that supports a stickleback pair. The mechanism was likely straightforward predation or interference with nesting. The brown bullhead is presently confined to the southern third of Vancouver Island. The impact of an introduced species and the potential for habitat impacts may also lead to less reproductive isolation and more interbreeding (Rosenfeld and Hatfield 2006). The hybridization of stickleback pair in Enos Lake, Vancouver Island, likely has been affected by the introduction of crayfish. The likelihood of an alien species invasion in Misty Lake is high and the consequences serious. The main uncertainty relates to the degree of protection already afforded by the ecological reserve, which prohibits fishing and therefore reduces the motivation by recreational fishers to introduce alien species into Misty Lake. At present, the only known invasive species in Misty Lake is the common pet shop turtle *Trachemys scripta elegans*.

Road run-off

Misty Lake is closely approached by Highway 19 as are a number of logging roads. The main point source of impact on the lake is the highway rest stop and associated facilities at the southwest corner of the lake. Construction of the rest station involved brush removal and addition of fill, some of which has now been cleaned up; however, it remains a source of

chemical runoff as well as a convenient access point for the introduction of alien species. The probability of runoff is high, as is the uncertainty in its consequences, which depend on amount, composition and location.

Forestry

Misty Lake lies within the Keogh-Cluxewe Resource Management Zone, currently designated an Enhanced Forestry Zone. Misty Lake and its inlet and outlet streams are bordered by a mix of Crown and privately owned land. The inlet stream corridor has been heavily logged in the past. Satellite photos show some remaining old growth to the north and west. The current Forest Stewardship Plan for the license holder, identifies these areas as "subject to cutting permit", including three locations near the inlet stream.

Runoff from logging roads can raise the level of sediment in rivers and lakes. Misty Lake stickleback may be sensitive to changes in water turbidity if mate selection and zooplankton productivity are controlling factors in avoiding hybridization, as they are believed to be for benthic-limnetic pairs. A decrease in levels of DOC caused by logging near wetlands could erode barriers to hybridization by affecting visibility and mate selection. If the stream form uses shallow areas to breed, it may be affected by transient increases in filamentous algal growth that follow opening up of the stream canopy by logging.

Cumulative logging effects, particular to the inlet population, could be a concern due to sedimentation, erosion and altered stream flows. The fact that the population has persisted despite more than 50 years of deforestation in the watershed, suggests logging is a low to moderate risk. Whether the pair populations would have persisted in a regime of lower productivity during that period is unknown.

Water extraction

Water extraction can raise temperatures and eliminate nesting habitat. This impact appears to be much less of an issue for Misty Lake than it is for the limnetic-benthic pairs. Misty Lake is small and shallow, so any extraction of water could reduce littoral habitat believed important for nesting of the lake form. Protection of the lake in the ecological reserve prevents such extraction, but the majority of the inlet and outlet streams are outside the reserve boundaries. The only water licenses currently existing for the watershed are on the Cluxewe River (for use in asphalt manufacture) and an Enterprise License held by B.C. Hydro on the Keogh River. Neither would appear to pose any threat to Misty Lake stickleback. The probability of harm is therefore low.

Scientific study

Misty Lake sticklebacks are periodically removed by pole seine or trap for collection of tissue samples or laboratory experimentation. The numbers are insignificant and the removal of less that 5% of the total population is unlikely to impact long-term persistence and therefore is considered allowable harm.

Climate change

Onset and duration of breeding in stickleback are strongly influenced by temperature. Timing of reproduction can be expected to change in response to significant warming. The impact and uncertainty of future climate change on survival of the pair population is high.

Current quantity and quality of habitat

Presently, estimates of the adult abundance for each form, although highly uncertain, range from a few thousand, and less than the theoretical minimum viable population (10,000), to tens of thousands. If the former is true then, from a population abundance perspective alone, all the existing habitat is required to ensure population persistence with a 99% probability. If the latter is true then there would be greater latitude for habitat impacts. The greater concern is the potential for hybridization.

Because hybridization is the main threat to the existence of the pair populations, the identification of critical habitat should consider its role in maintaining reproductive isolation. Maintenance of reproductive isolation probably depends to a great extent on mate recognition, which is affected by light transmission. Changes in water quality that affect light transmission can disrupt vision and make it harder to choose mates; the severity of the effect depends on how closely the lake and stream pairs share breeding habitat; the degree to which is highly uncertain. Light transmission is affected by suspended solids and the amount of DOC (already relatively high in tannin-rich Misty Lake). Habitat impacts that alter the balance between zooplankton (eaten by the lake form) and macroinvertebrates (eaten by the stream form) could reduce reproductive isolation and increase the likelihood of hybridization. Because of the importance of habitat in maintaining reproductive isolation of each form, potential critical habitat includes the entire lake and inlet stream, a portion of the outlet stream, and appropriate riparian buffers.

Threats to habitat that have reduced habitat quantity and quality

There are no known threats that have measurably reduced habitat quantity and quality. It is important to note that data quality in this regard is poor.

Phase III: Scenarios for mitigation and alternatives to activities

Inventory of feasible measures and alternative activities to minimize/mitigate threats

Alien species

There are few easy access points to Misty Lake, so the accepted strategy of minimizing the risk of species introductions, namely aggressive signage and other means of raising public awareness, may be an effective deterrent. Relocating the rest stop on Highway 19 would help reduce access.

Rest stop runoff

The paved parking area on the margin of the lake likely poses a conservation risk. While the risk of highway runoff is not limited to the rest area (Highway 19 runs close to Misty Lake along its entire southern border), it could be greatly reduced by moving the rest stop to another part of Highway 19.

Forestry

The current plan for harvesting forest to the north and west of Misty Lake and along its inlet and outlet streams was not available at the time of writing this RPA. The likelihood of harm from forestry is greatest near the inlet stream, which contains the most genetically divergent forms. Sedimentation and reduction of stream canopy can be minimized or eliminated by application of the B.C. Riparian Area Regulations. However, these regulations do not apply on privately

owned lands. There are presently three areas subject to a cutting permit in the area of the upper and lower inlet. Two of these areas are mainly Crown land; the third, eastern most area is at least partly private. An on-site survey would be required to refine these boundaries. The likelihood of harm from forestry in the inlet area depends on activities of the tenure holder and applicability of riparian area regulations. Severity is not possible to predict.

Particular attention should be paid to the wetland area where the inlet enters the lake, to avoid the known effects of logging on DOC inputs. A further measure of protection would come from extending the ecological reserve along the length of the inlet and outlet streams.

Managing water levels

The improved culvert on the inlet stream approximately 1 km above the lake removes a barrier to stickleback that existed during low water periods. Despite this improvement, maintaining the current low level of water extraction in the Misty Lake watershed is advisable.

Enlargement of the Ecological Reserve

The Misty Lake Ecological Reserve provides some protection to the Lake population. Parts of the inlet and outlet streams are not included in the reserve. For these areas, the only protection is through standard riparian management practices. Threats to habitat could thus be further reduced by expanding the ecological reserve to include the full length of the inlet stream.

CONCLUSION AND ADVICE

Long-term persistence of the stream-lake pair depends on protecting stream and lake habitats to insure reproductive isolation of the different population forms. Any loss of the stream and lake habitat could result in a high probability of hybridization and hence the collapse of the species pair. This includes the lake, the full length of the inlet stream, 2.3 km of the outlet stream and all ephemeral streams. Estimates of allowable harm are themselves highly uncertain but annual removals of 5% are likely sustainable based on limited life history information borrowed from other species.

There remains high uncertainty in the amount of riparian habitat needed to protect the pair populations and, in particular, to protect the lake habitat. The Misty Lake Ecological Reserve provides a degree of protection mainly for the lake habitat. Parts of the inlet and outlet streams are not included in the reserve. For these areas, the only protection is through riparian management practices. The need for suitable aquatic habitat for stickleback pair survival was is acknowledged, along with the recognition that an intact riparian zone can contribute to protecting water quality. However, the importance of other riparian vegetation contributions to aquatic environments such as supplying woody debris, leaf litter, insect drop and shade to the survival of this species pair was not accepted by all meeting participants. Given this uncertainty, riparian buffer widths of 15-30 m around the lake and the inlet and outlet streams, based the on riparian needs of salmonids, is recommended. Additional study of the relationship between stickleback pair survival needs and riparian functions may help to confirm the identified critical habitat in the future.

Introduction of alien species is considered the most serious threat to the pair populations. There are few easy access points to Misty Lake, so the accepted strategy of minimizing the risk of species introductions, namely aggressive signage and other means of raising public awareness, may help prevent species introductions. Relocating the rest stop on Highway 19 would reduce

access to the lake. Threats to habitat could be further reduced by expanding the ecological reserve to include the full length of the inlet stream and at least 2.3 km of the outlet stream.

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