PROPOSED

Species at Risk Act
Recovery Strategy Series

Recovery Strategy for Vancouver Lamprey *(Lampetra macrostoma)* in Canada

Vancouver Lamprey

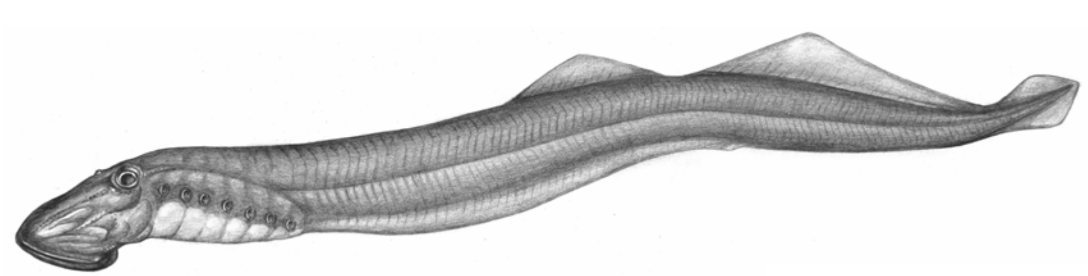

Illustration: Loucas Raptis

June 2007

Fisheries and Oceans Canada Pêches et Océans Canada

Canada

About the *Species at Risk Act* Recovery Strategy Series

What is the *Species at Risk Act* (SARA)?

SARA is the Act developed by the federal government as a key contribution to the common national effort to protect and conserve species at risk in Canada. SARA came into force in 2003 and one of its purposes is *"to provide for the recovery of wildlife species that are extirpated, endangered or threatened as a result of human activity."*

What is recovery?

In the context of species at risk conservation, **recovery** is the process by which the decline of an endangered, threatened, or extirpated species is arrested or reversed and threats are removed or reduced to improve the likelihood of the species' persistence in the wild. A species will be considered **recovered** when its long-term persistence in the wild has been secured.

What is a recovery strategy?

A recovery strategy is a planning document that identifies what needs to be done to arrest or reverse the decline of a species. It sets goals and objectives and identifies the main areas of activities to be undertaken. Detailed planning is done at the action plan stage.

Recovery strategy development is a commitment of all provinces and territories and of three federal agencies — Environment Canada, Parks Canada Agency, and Fisheries and Oceans Canada — under the Accord for the Protection of Species at Risk. Sections 37–46 of SARA (http://www.sararegistry.gc.ca/the_act/) outline both the required content and the process for developing recovery strategies published in this series.

Depending on the status of the species and when it was assessed, a recovery strategy has to be developed within one to two years after the species is added to the List of Wildlife Species at Risk. Three to four years is allowed for those species that were automatically listed when SARA came into force.

What's next?

In most cases, one or more action plans will be developed to define and guide implementation of the recovery strategy. Nevertheless, directions set in the recovery strategy are sufficient to begin involving communities, land users, and conservationists in recovery implementation. Cost-effective measures to prevent the reduction or loss of the species should not be postponed for lack of full scientific certainty.

The series

This series presents the recovery strategies prepared or adopted by the federal government under SARA. New documents will be added regularly as species get listed and as strategies are updated.

To learn more

To learn more about the *Species at Risk Act* and recovery initiatives, please consult the SARA Public Registry (http://www.sararegistry.gc.ca/) and the Web site of the Recovery Secretariat (http://www.speciesatrisk.gc.ca/recovery/).

Recovery Strategy for the Vancouver Lamprey (*Lampetra macrostoma*) in Canada (PROPOSED)

June 2007

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Additional copies:

Additional copies can be downloaded from the SARA Public Registry (http://www.sararegistry.gc.ca/)

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DECLARATION

This proposed recovery strategy for Vancouver lamprey has been prepared by Fisheries and Oceans Canada and the British Columbia Ministry of Environment. Fisheries and Oceans Canada has reviewed and accepts this document as its recovery strategy for Vancouver lamprey as required by the *Species at Risk Act*. The British Columbia Ministry of Environment has reviewed and accepts this document as scientific advice.

This document identifies the recovery strategies that are deemed necessary, based on the best available scientific and biological information, to recovery Vancouver lamprey populations in Canada. Success in the recovery of this species depends on the commitment and cooperation of many different constituencies that will be involved in implementing the directions set out in this strategy and will not be achieved by Fisheries and Oceans Canada or any other jurisdiction alone. In the spirit of the National Accord for the Protection of Species at Risk, the Minister of Fisheries and Oceans invites all Canadians to join Fisheries and Oceans Canada in supporting and implementing this strategy for the benefit of Vancouver lamprey and Canadian society as a whole. Fisheries and Oceans Canada and the BC Ministry of Environment will support implementation of this strategy to the extent possible, given available resources and its overall responsibility for species at risk conservation. The Minister will report on progress within five years.

This strategy will be complemented by one or more action plans that will provide details on specific recovery measures to be taken to support conservation of the species. The Minister will take steps to ensure that, to the extent possible, Canadians interested in or affected by these measures will be consulted.

RESPONSIBLE JURISDICTIONS

The responsible jurisdiction for Vancouver lamprey under the *Species at Risk Act* is Fisheries and Oceans Canada. The Province of British Columbia co-led the development of this recovery strategy.

AUTHORS

DFO and the Province of British Columbia cooperated in the development of this recovery strategy. A recovery team was assembled to provide science-based recommendations to government with respect to the recovery of Vancouver lamprey. Members of the Vancouver Lamprey Recovery Team are listed below:

Jordan Rosenfeld, MoE, (co-chair)
Dan Sneep, DFO, (co-chair)
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ACKNOWLEDGMENTS

Fisheries and Oceans Canada and the Province of BC are grateful to the technical experts involved in drafting this strategy, for their time and effort in attending meetings and reviewing the document. Development of this strategy was partially funded by the Habitat Conservation Trust Fund of British Columbia.

STRATEGIC ENVIRONMENTAL ASSESSMENT STATEMENT

A strategic environmental assessment (SEA) is conducted on all SARA recovery planning documents, in accordance with the *Cabinet Directive on the Environmental Assessment of Policy, Plan and Program Proposals*. The purpose of a SEA is to incorporate environmental considerations into the development of public policies, plans, and program proposals to support environmentally-sound decision making.

Recovery planning is intended to benefit species at risk and biodiversity in general. However, it is recognized that strategies may also inadvertently lead to environmental effects beyond the intended benefits. The recovery planning process based on national guidelines directly incorporates consideration of all environmental effects, with a particular focus on possible impacts on non-target species or habitats. The results of the SEA are incorporated directly in the strategy itself, but are also summarized below.

This recovery strategy will clearly benefit the environment by promoting the recovery of the Vancouver lamprey. The potential for the strategy to inadvertently lead to adverse effects on other species was considered. The SEA concluded that this strategy will clearly benefit the environment and will not entail any significant adverse effects. Refer to the following sections of the document in particular: Description of the Species – General Biology, Ecological Role and Limiting Factors; Potential Management Impacts for Other Species; and Recommended Approach/Scale for Recovery.

RESIDENCE

SARA defines 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*" **[SARA S2(1)]**.

Residence descriptions, or the rationale for why the residence concept does not apply to a given species, are posted on the SARA public registry: http://www.sararegistry.gc.ca/plans/residence_e.cfm

PREFACE

The Vancouver lamprey is a freshwater fish and was listed as Threatened under SARA in June 2003. The *Species at Risk Act* (SARA, Section 37) requires the competent minister to prepare recovery strategies for listed extirpated, endangered or threatened species. Fisheries and

Oceans Canada – Pacific Region co-led the development of this recovery strategy with the British Columbia Ministry of Environment. The proposed strategy meets SARA requirements in terms of content and process (Sections 39-41).

EXECUTIVE SUMMARY

Vancouver lamprey (*Lampetra macrostoma*) is a species derived from the Pacific lamprey (*L. tridentata*) and is reported only in Cowichan and Mesachie lakes on Vancouver Island, British Columbia. *L. macrostoma* was deemed a separate species based on its unique morphological and physiological traits, primarily its large oral disk and physiological adaptation to freshwater. Some phylogenetic uncertainty remains and requires additional investigation. There has been little or no research done on this species since the 1980s, and no firm conclusions can be drawn with the current data regarding population status and trends. Its extreme endemic distribution is the principal factor in its designation as Threatened, and suggests that the species will always remain at some risk.

A variety of factors threaten the Vancouver lamprey and its associated habitat, though the extent and severity of threats are unknown. This recovery strategy focuses on ensuring the long-term viability of Vancouver lamprey, and offers a variety of approaches to attain this goal. The priority actions are to fill data gaps that inhibit conservation of the species, and to collect information to allow delineation of critical habitat in the wild. Activities aimed at protecting and enhancing other species of fish and wildlife are likely to also benefit Vancouver lamprey, and vice versa.

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SPECIES INFORMATION

Common Names: Vancouver lamprey, Cowichan Lake lamprey, Lake lamprey
Scientific Name: *Lampetra macrostoma*
Canadian Occurrence: British Columbia
COSEWIC Status: Threatened, November 2000
SARA Status: Threatened, June 2003
COSEWIC Reason for Designation: This landlocked parasitic species is endemic to British Columbia and occurs in a very restricted area. It is at risk due to intensive human activity.

Status History: Designated Special Concern in April 1986. Status re-examined and confirmed in April 1998. Status re-examined and designated Threatened in November 2000. Last assessment based on an existing status report (Beamish 1998).

1. DESCRIPTION OF THE SPECIES

1.1 General Biology

Lampreys are members of the Superclass Agnatha, jawless fishes. Lampreys are distinguished by a cylindrical, eel-like, scale-less body and a round suctorial mouth armed with a series of sharp, horny teeth. They have a small caudal fin, and long dorsal fin, often with two distinct parts; they have no paired fins (Figure 1). The skeleton is cartilaginous, a trait that has contributed to a poor fossil record. Lampreys have seven pairs of gills in the form of gill pouches, each with an individual opening to the outside (Scott and Crossman 1973). There are about 40-45 species of lamprey within 9 genera, depending on the current interpretations of experts (ITIS 2005).

Lampreys are generally distributed in temperate marine and freshwaters; the worldwide distribution is predominantly in the Northern Hemisphere (Scott and Crossman 1973). About 1/3 of lamprey species are anadromous. As adults, lamprey species are either externally parasitic of other fish species, or do not feed at all. All lamprey are semelparous and die soon after spawning (Larson 1980).

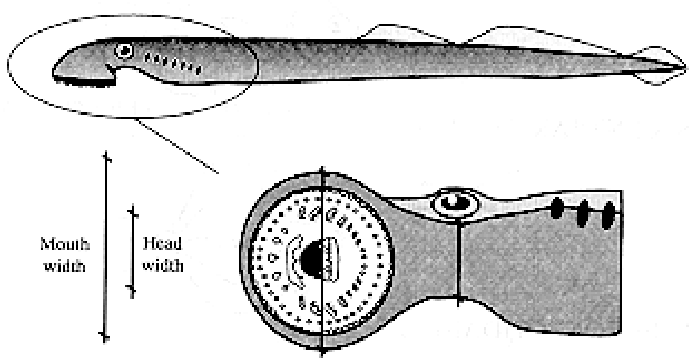

Figure 1. Drawing of Vancouver lamprey (from McPhail and Carveth 1993).

Lampreys are difficult to age reliably (Beamish and Medland 1988; Kostow 2002). They have a distinct larval phase followed by metamorphosis (Scott and Crossman 1973), but time to metamorphosis (sometimes called transformation) varies among species. Larvae, called ammocoetes (Figure 2), live in burrows in stream and lake sediments (Scott and Crossman 1973). Ammocoetes have sightless eyes; teeth and oral disk are absent, and the mouth is covered with an oral hood. Ammocoetes feed by filtering microscopic plant and animal material and organic detritus through the oral hood (e.g., Manion 1967; Moore 1973, 1980; Sutton et al. 1994; Mundahl et al. 2005).

In British Columbia there are four described species of lamprey[1] (Beamish 1985). The Western brook lamprey, *Lampetra richardsoni*, is a non-anadromous, non-parasitic, freshwater-resident species commonly found in streams. The Pacific lamprey, *L. tridentata*, is anadromous and parasitic; it is commonly found in coastal streams and marine coastal areas. The river lamprey, *L. ayresi*, is anadromous and parasitic. It can be very abundant in the Fraser River, and is common in the Strait of Georgia during its parasitic phase. Little research has been done on this species outside the Georgia Basin. *L. macrostoma*, originally described by Beamish (1982), is parasitic and assumed to be derived from *L. tridentata*. It has been reported only in Cowichan and Mesachie lakes on Vancouver Island (Beamish 1998). Common names of *L. macrostoma* are Vancouver lamprey, Cowichan Lake lamprey, or lake lamprey. In this recovery strategy we refer to the species as Vancouver lamprey, the name with which it was listed under SARA.

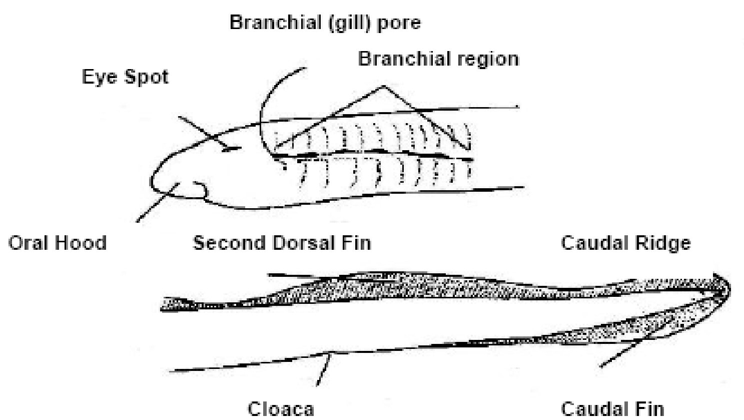

Figure 2. External features of lamprey ammocoete (from McDermott 2003).

L. macrostoma has been deemed a separate species based on its unique morphological and physiological traits. There are numerous differences between *L. tridentata* and *L. macrostoma*, including some unreported characters (R. Beamish, unpublished data), but the biggest differences are the size of the oral disk and physiological adaptation to fresh and marine waters (Beamish 1982). The oral disk is the key character used to define and differentiate species of parasitic lamprey (Vladykov and Kott 1979); the disk of a Vancouver lamprey has approximately two-thirds more surface area than that of a similar size *L. tridentata* and there are some differences in dentition (Beamish 1982). Physiologically, Vancouver lamprey are better adapted to life in freshwater (although they can survive in salt water), whereas Pacific lamprey are better adapted to life in sea water (Beamish 1982). In fact, there is no evidence that *L. tridentata* can survive in freshwater after metamorphosis, except as a returning spawner (Beamish 1982, Clarke and Beamish 1988). *L. macrostoma* also has a smaller total size, larger eye, longer prebranchial length, and possibly a shorter trunk length than *L. tridentata* (Beamish 1982).

[1] A fifth distinct taxon occurs in Morrison Creek, Vancouver Island, but has not been formally designated as a distinct species.

Beamish (1982) indicated that *L. macrostoma* warrants status as a distinct species, since the magnitude of trait difference is equivalent to or greater than other species derived from *L. tridentata*. However, the taxonomic status of Vancouver lamprey remains somewhat uncertain. The only genetic study involving this species to date (Docker et al. 1999) found that *L. macrostoma* was genetically indistinguishable from *L. tridentata* (and from a second *L. tridentata* derivative, the Pit-Klamath brook lamprey, *L. lethophaga*, from California). These results suggest that both species are recent derivatives of *L. tridentata*, but more extensive genetic analysis is required to better resolve the phylogenetic relationships among these closely-related species.

Vancouver lamprey range in size from 18 to 27 cm, with females slightly smaller than males (Beamish 1985). The average size of recently metamorphosed lamprey is 11.7 cm (Beamish 1985). The considerable growth that occurs from recently metamorphosed individuals to adult size indicates that the species is an obligate parasite (Beamish 1985). It is possible to collect ammocoetes from lake and stream sediments, but adults are easily captured only during the spawning period (Beamish 1998). Thus, very little is known about the young adult phase.

Like all lampreys, the Vancouver lamprey spawns once and dies shortly thereafter (Beamish 1998). The spawning season is May to August. Duration of larval and adult life is not known, but Vancouver lamprey are thought to spend about six years as larvae and two years post-metamorphosis (Beamish 1998). Metamorphosis occurs from July to October; young adults likely remain in the substrate until the following spring (Beamish 1998). Active feeding in adults is thought to commence during the spring after metamorphosis and continue until just before spawning, the following spring or summer (Beamish 1982). Feeding adults readily prey upon live fish (Beamish 1982), and many fish collected in Cowichan Lake show scarring and wounds from lamprey (Carl 1953 cited in Beamish 1982; Beamish 1982).

1.2 Distribution

The Vancouver lamprey is an extreme endemic. It has been reported only in Cowichan and Mesachie lakes, on southern Vancouver Island, British Columbia, and the lower part of tributaries to these lakes (Figure 3). The two lakes are adjacent and connected via the Robertson River, Bear Lake and an unnamed watercourse, sometimes referred to as Mesachie Creek. There are no complete barriers to fish downstream of Cowichan Lake, as evidenced yearly by anadromous salmonids that use the lake and its tributaries for spawning and rearing. Pacific lamprey are common downstream of the lake outlet, but have not been observed upstream of this point (Beamish 1982). Likewise, Vancouver lamprey have not been observed downstream of the lake outlet (Beamish 1982).

1.3 Abundance

There has been little or no research done on this species since the 1980s, and at no time have estimates been made of total population or habitat-specific abundance. The incidence of lamprey-induced scarring and wounding on salmonids implies that abundance fluctuates (Beamish 1998), but the magnitude and frequency of fluctuations is unknown. It is expected that lamprey populations fluctuate in response to prey availability (Beamish 1998). There is no evidence that the species is especially rare or in decline; however, no firm conclusions can be drawn with the current data. Beamish (1998) provides a guess at abundance of 1,000 to 2,000 adults throughout both lakes.

1.4 Importance to People

The special significance of the Vancouver lamprey is primarily its scientific value. There is no commercial value to the species. As a parasitic species feeding predominantly on salmonids (a set of highly-valued species), lamprey are generally not well-regarded. The fact that introduced lamprey have caused considerable harm in other systems (Fuller et al. 2005) likely adds to the lamprey's poor reputation. Conversely, others view Vancouver lamprey as a member of the native fauna, with its own intrinsic value, ecological role and contribution to biodiversity, and its special value to education and science. As a scientific subject, the Vancouver lamprey is of considerable interest for its extreme endemism and as a newly-evolved species. It is the only reported example of a freshwater parasitic derivative of *L. tridentata* in Canada, and is valued scientifically because it is an example of the resiliency in life history strategy that is a key to the evolutionary success of lamprey. There may also be cultural value of Vancouver lamprey to First Nations, though consultations with First Nations by Fisheries and Oceans Canada in May 2006 did not yield information on the species' cultural value. It should be noted that Pacific lamprey has significant cultural value for First Nations people in some regions (Close et al. 2002).

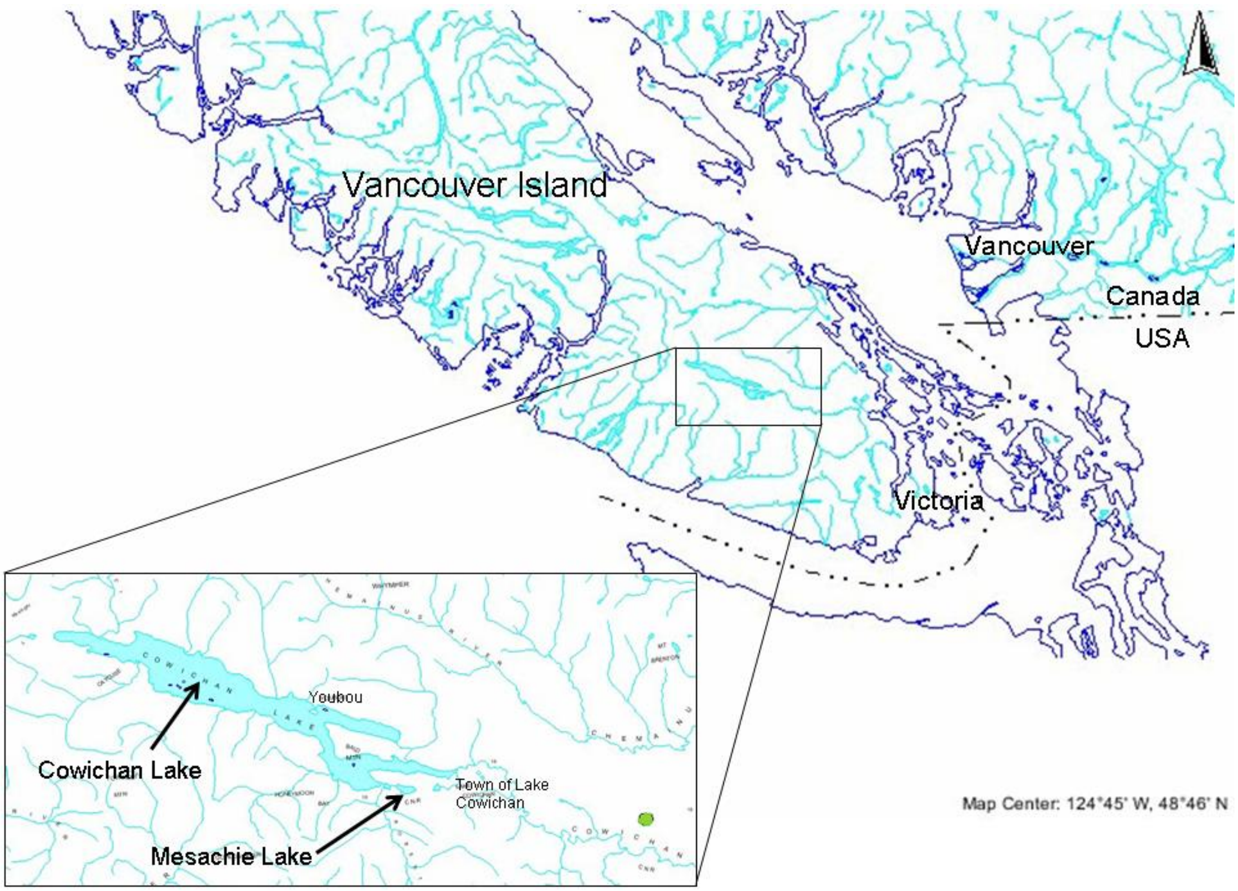

Figure 3. Distribution of Vancouver lamprey. (Map base obtained from Ministry of Energy, Mines and Petroleum Resources, http://www.em.gov.bc.ca/mining/Geolsurv/MapPlace/themeMaps.htm).

2. DESCRIPTION OF NEEDS OF THE SPECIES

2.1 Biological Needs, Ecological Role and Limiting Factors

Ecological Role.— After metamorphosis, Vancouver lamprey are external parasites of other fish species, and as such play a role in limiting abundance of those species. They feed primarily on coho salmon (*Oncorhynchus kisutch*) and coastal cutthroat trout (*O. clarki clarki*), although other salmonids such as Dolly Varden char (*Salvelinus malma*) are also preyed upon (Beamish 1998). Lamprey are also preyed upon by fishes and other wildlife and thereby form part of the food base of those species. Ammocoetes are most vulnerable to predation immediately after emerging from their burrows (Close et al. 2002). Both live and spawned out adults of Pacific lamprey are a significant component of some fish and wildlife diets (Close et al. 2002), though the extent of predation on Vancouver lamprey is not known.

Limiting Factors.— The environmental factors that limit Vancouver lamprey have not been well-studied. We assume that populations are affected by competition, predation, habitat quantity and quality, and food availability, though the relative effect of each is not known. It is evident that to persist over the long term, all species require sufficient rearing and spawning habitat and a healthy food base.

2.2 Habitat Needs

Vancouver lamprey have been reported only in Cowichan and Mesachie lakes on Vancouver Island. Cowichan Lake is 30 km long, 6204.3 ha in area, 152 m maximum depth, 50.1 m average depth, and has an elevation of 164 m (Province of BC 2005). It is the second largest lake on Vancouver Island, and drains eastward into the Cowichan River. Mesachie Lake is considerably smaller: 59.3 ha in area, 32 m maximum depth, and with an elevation of 167 m (Province of BC 2005). It is entirely within the Cowichan Lake watershed and drains into the southwestern corner of Cowichan Lake. Both lakes are oligotrophic, a nutrient status typical of coastal lakes in the area. The Cowichan Valley experiences a variable climate that is generally warm and dry in summer and mild and wet in winter.

A variety of other fish species have been reported from the lakes, including chinook (*O. tschawytscha*; Cowichan Lake only), coho salmon, cutthroat trout, Dolly Varden, kokanee (*O. nerka*), prickly sculpin (*Cottus asper*), rainbow and steelhead trout (*O. mykiss*), threespine stickleback (*Gasterosteus aculeatus*), plus three non-native species – Atlantic salmon (*Salmo salar*; likely not self-sustaining), brook trout (*Salvelinus fontinalis*) and smallmouth bass (*Micropterus dolomieui*; Cowichan Lake only) (Province of BC 2005).

The spawning habitat requirements of Vancouver lamprey are not known in detail. Beamish (1985, 1998) indicated that they use nearshore lake habitat for spawning, rather than the stream habitats typically used by Pacific lamprey. However, ammocoetes have been found in the lower portions of some lake tributaries (Beamish 1982), indicating that some spawning does occur in these tributaries. Beamish (1998) describes spawning aggregations on shallow gravel deltas near the mouth of tributary creeks, in water depths of 0.2 to 2 m. Spawning behaviour in the lab is similar to that of Pacific lamprey (Beamish 1998), which construct nests in areas of gravel, where eggs are deposited and fertilized, and subsequently rear. Hatching generally occurs a short time after fertilization. Other lamprey species require clean gravels with interstitial flow or groundwater upwelling for spawning and incubation. We assume that Vancouver lamprey have similar requirements. Distribution into deeper habitats has not been investigated.

After hatching, ammocoetes drift a short distance from the nest, where they burrow into soft fine sediments or sand (Scott and Crossman 1973). Vancouver lamprey ammocoetes are usually found within the lake in close proximity to tributary creeks (Beamish 1998). Larval habitat is thus generally defined as fine sediment areas in close proximity to lake tributaries, but the depth and spatial distribution of larval habitat remains poorly understood.

Little is known about Vancouver lamprey biology between the time of metamorphosis and spawning. Active feeding occurs in the warmer months, and considerable growth occurs from metamorphosis to time at spawning (Beamish 1982). We assume that during this time, the lamprey seek prey in a variety of locations within the water column. The habitat requirements of this life stage are not known.

3. THREATS

Given their extremely restricted distribution, Vancouver lamprey can be considered especially susceptible to a variety of local threats. Much information is lacking on the general biology and habitat use of the species, which makes a thorough threats assessment difficult. Nevertheless, it is possible to identify general threats, and these are discussed below.

Water Use.— There are a number of active water licences on Cowichan Lake and its tributaries, and many more downstream on the Cowichan River and its tributaries. Water licences on the lake and its tributaries may affect Vancouver lamprey. Active water licences are summarized in Table 1.

Table 1. Summary of active water licences for Cowichan Lake, summarized from Land and Water BC database query (http://www.elp.gov.bc.ca:8000/pls/wtrwhse/water_licences.input).

Licensed Volume (m^3 / yr)	Purpose
61,304,950.0	storage (lake)
4,071.0	storage (tributary)
2,467,250.2	diversion (lake)
1,761,084.5	diversion (tributary)

There are two storage licences and 60 diversion licences on Cowichan Lake, plus two storage licences and 173 diversion licences on tributaries. The largest licences by far are the two storage licences owned by Norske Canada (now Catalyst Paper), which together sum to 61,304,950 $m^3 \cdot year^{-1}$, and are used to provide flow into Cowichan River for diversion to the pulp mill in Crofton and a minimum flow to the river for ecological purposes. Storage is provided by a low weir (0.96 m of storage) at the outlet of Cowichan Lake. In the winter wet period lake level is typically higher than the top of the weir, so maximum lake elevation has not been significantly altered from the pre-weir state. The weir has a series of four gates that control flow in the river from April 1 to September 30. During this period, lake level and river discharge are controlled according to the MoE storage rule curve and the release schedule, which ration water stored in the spring season for release into the river during the summer (M. Vessey, Catalyst Paper, personal communication). In essence, the weir and its operation simply release Cowichan Lake water more uniformly through the dry season than would occur naturally. Before construction of the weir, river flows would often fall to 1 $m^3 \cdot sec^{-1}$ or less, but can now be maintained at 7 $m^3 \cdot sec^{-1}$ during a normal summer (M. Vessey, Catalyst Paper, personal communication).

Dam construction and water storage has the capacity to alter lake levels and thereby affect aquatic habitat. Impacts may occur if lake levels are raised or lowered, or if fluctuations differ from normal. To help assess whether lake levels have been markedly altered we examined lake level data since records began being collected in 1913. We compared lake level data from before and after the weir was constructed in 1957. Results are summarized in Table 2.

Table 2. Cowichan Lake surface elevation summaries before and after weir construction (i.e., pre- and post-1957). Minimum, maximum and difference between minimum and maximum are shown for the full calendar year, and for the May to August spawning season of Vancouver lamprey. All elevations are in metres (data from Environment Canada Hydat database).

Year	Span	Average min	Average max	Average difference
1913 to 1956	all year	0.264	2.899	2.635
1957 to 2000	all year	0.579	3.052	2.473
1913 to 1956	May to Aug	0.338	1.358	1.020
1957 to 2000	May to Aug	0.864	1.649	0.785

Annual fluctuations are approximately the same in both periods, and have been somewhat more stable during the lamprey spawning period after the weir construction. Diversion amounts are only approximately 6% of the storage amounts. Both storage and diversion appear to pose at most a minor threat to Vancouver lamprey. It should be noted, however, that this assessment is subjective, and has not been ground-truthed.

There are two water licences on Mesachie Lake, one a consumptive license for 8,018 m^3 $year^{-1}$, the other for the purpose of constructing and operating a fish counting fence. The consumptive licence equates to approximately 1.4 cm of lake depth, an amount that seems unlikely to cause substantial impacts to Vancouver lamprey.

In addition to licensed users there are likely unlicensed water users in the Cowichan and Mesachie watersheds. The threats to Vancouver lamprey posed by unlicensed water users is not known, but seem unlikely to exceed the threats posed by licensed users. Taken together, licensed and unlicensed water use does not seem to be a substantial threat at this time.

Increased development in the Cowichan Valley has and will continue to put pressure on the ecosystem. The Cowichan Valley Regional District is currently leading the development of a water management plan that attempts to balance the requirements of fish and wildlife with human needs. Success of the water management plan in protecting the conservation requirements of Vancouver lamprey will need to be assessed in the future, perhaps through monitoring lamprey populations and habitats. The needs of Vancouver lamprey should be considered in water use decisions, at present and in the future. To ensure that long-term changes in water use do not adversely affect lamprey recruitment, it would be particularly useful to assess potential impacts of drawdowns, and set bounds for water level fluctuations that would protect eggs and ammocoetes.

Land Use.— Some land-based activities have the capacity to alter aquatic habitat directly (e.g., impacts to riparian habitat, alteration of run-off rates) or indirectly (e.g., changes to water quality through introduction of pollutants). These activities include forestry, mining, and land development for residential or industrial uses.

Forest harvesting is a prominent industry in the Cowichan watershed. The primary potential threats to aquatic habitat from forestry practises include deposition of sediments and fine woody debris, riparian habitat destruction, and changes in hydrology and water quality. There is substantial literature demonstrating the negative effects of suspended sediments on fish and egg survival. Moderate increases in fine sediment inputs associated with logging may be a benefit for lamprey ammocoetes in sediment-poor drainages, because ammocoetes rear in depositional habitats with fine sediments, conditions that are often lacking in high gradient coastal watersheds (Beamish 1998). Excessive sediment inputs, however, may negatively impact spawning areas and perhaps other lamprey habitats. Given the long history of forest harvesting in the Cowichan watershed, and the apparently stable status of Vancouver lamprey, the risk of extinction from this potential threat is not believed to be substantial.

A review of information on mineral extraction indicated no mining activity at present or in the recent past in the Cowichan Lake watershed (Ministry of Energy, Mines and Petroleum Resources 2005 http://webmap.em.gov.bc.ca/mapplace/minpot/minEconomy.cfm#).

Development pressures exist in the Cowichan Valley and specifically around Cowichan Lake. This pressure comes in the form of increased demand for water, alteration of nearshore and surrounding lands through construction of buildings, roads, and docks, as well as recreation in and around Cowichan Lake. Of particular concern is impact to littoral spawning areas. Assessing this threat will require additional information on the distribution and utilization of spawning habitat for Vancouver lamprey.

Water Quality.— There are no known water quality issues within Cowichan or Mesachie lakes. Chemical spills associated with industrial or residential development have the capacity to negatively impact Vancouver lamprey, however this risk does not seem extreme. The recent closing and dismantling of the Youbou Mill has likely lessened the inputs of industrial pollutants. There has been a steady increase in recreation and residential property development in the Cowichan Valley, but the density of this development is still fairly low. High winter rainfall in the area likely leads to a reasonably high flushing rate of both Cowichan and Mesachie lakes. This threat may require additional assessment in the future as related information becomes available.

Recreation.— Cowichan Lake is a popular recreation site for tourists and local residents. Fishing, boating, swimming and hiking all take place frequently in the watershed. The primary potential threats from recreation activities are competition for prey species through fishing, negative effects on water quality via pollution from power boats, and disturbance or destruction of shallow littoral areas. Given the large perimeter of Cowichan Lake and the fairly localized areas of recreation use, these threats do not appear to be substantial. However, a proper assessment of these threats will require a greater understanding of lamprey habitat use and distribution of suitable habitats within the lake. The extent of these threats on Mesachie Lake is not known.

A direct source of mortality for Vancouver lamprey is their destruction when incidentally caught by recreational anglers targeting salmonids. Anglers are known to destroy lamprey that are parasitizing their catch. The threat from this mortality source is unquantified, but thought to have an impact on the adult population.

Prey Base.— Adult Vancouver lamprey are obligate external parasites of resident fish of Cowichan and Mesachie lakes. It appears that salmonids, in particular young coho, are preferred over other species (Beamish 1982). Human impacts on salmonid species (e.g., recreational and commercial fishing, habitat destruction) are therefore expected to affect abundance of Vancouver lamprey. Ammocoetes are filter feeders, feeding on detritus and suspended organic matter while living in burrows in soft sediments. Activities that alter the productivity of this food base are expected to also affect abundance of Vancouver lamprey. There have been no formal assessments of the threats to the prey base of Vancouver lamprey.

Climate Change.— Scientific evidence clearly indicates that climate is changing and animal and plant distributions are responding to these changes (Parmesan and Yohe 2003). Since climate affects precipitation, water flow and temperature in many ways, it may also affect Vancouver lamprey abundance and distribution. This threat is of concern; however, it presents a less immediate risk to the lamprey population than other threats, and at present the topic is considered beyond the scope of this recovery strategy. The threat may be assessed and addressed at future stages of recovery planning for Vancouver lamprey.

4. HABITAT TRENDS

Current and historic data are lacking for quantity and quality of Vancouver lamprey habitat, so trends are unknown. Land use practices, water storage and diversion, and other human activities have likely caused some decline in habitat quantity and quality, and development activities in the watershed are likely to increase into the future. However, the magnitude of these impacts is difficult to determine.

5. HABITAT PROTECTION

There are no habitat protection provisions specifically for Vancouver lamprey, however, the species likely benefits from existing legislation that protects fish habitat generally. The *Fisheries Act* provides legal protection of fish and fish habitat and would apply to much of the Cowichan watershed. Further, the Riparian Area Regulation under the *Fish Protection Act* (BC) requires municipal governments to protect riparian habitats subject to urban development, the *Water Act* (BC) regulates any proposed works 'in and about a stream', and provisions under the provincial *Forest and Range Practices Act* address some habitat protection issues related to forest harvesting on private lands. Finally, the *Species at Risk Act* has legal prohibitions that protect Vancouver lamprey individuals, residences and critical habitats, once defined. Lamprey likely also benefit from habitat protection and enhancement efforts aimed at other fish species.

6. CRITICAL HABITAT

Identification and protection of critical habitat is vital for management of species at risk. While defining critical habitat is one of the most challenging aspects of species management, it is essential to ensuring a species' long-term survival. This rationale is central to endangered species legislation in general, and specifically to the *Species at Risk Act*, where critical habitat is defined as:

> *"…the habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in a recovery strategy or in an action plan for the species."* [s. 2(1)]

The need to designate and protect critical habitat is clearly recognized by scientists, resource managers, and the general public. Despite its complexity, the core issue is the same for all species: to determine the role of habitat in population limitation, and to answer the question, How much habitat is necessary for the survival and recovery of a listed wildlife species?

6.1 Identification of the Species' Critical Habitat

At this point, it is possible to indicate some habitats that are important. For example, it is understood that as an ammocoete, Vancouver lamprey inhabits fine sediments in the littoral zone and in the lower portion of some tributaries. It is also known that during spawning, Vancouver lamprey aggregate over shallow gravel beds at the mouths of creeks and along lake shores. Clearly, these habitats, or portions of them, may feature in the identification of the species' critical habitat. However, due to a number of information gaps, we are unable to provide a defensible demarcation of critical habitat at this time.

6.2 Schedule of Studies

Very little is known about Vancouver lamprey. We therefore propose undertaking a series of tasks to allow delineation of critical habitat for the species. The precise nature of each task will be developed in one or more Action Plans. These studies are projected to be undertaken in the next five years, and reassessed in conjunction with updates to the recovery strategy.

Habitat Use.— The initial task in identifying critical habitat for Vancouver lamprey is to develop a better understanding of habitat used by different life stages. A description of the basic habitat associations for each life stage is a core information need for defining critical habitat (Rosenfeld and Hatfield 2006). The first step in defining habitat use would be to synthesize and report on information collected during previous investigations, such as those by R. Beamish. There is a general understanding of habitat types used by Vancouver lamprey ammocoetes and spawning adults. A more precise definition would be beneficial. Where possible, habitat requirements will be defined in terms of microhabitat components such as water depth and velocity, and substrate type and condition. Observations on spawning locations would be useful for identifying the characteristics of habitat suitable for spawning, and candidate sites for critical habitat. Similarly, sampling of littoral sediment to determine the distribution and density of ammocoetes would contribute to identifying locations and characteristics of habitat likely to be important for larval lamprey.

Habitat Availability.— A related task is to review historic and current habitat availability for Vancouver lamprey. Information on the extent and distribution of different habitat types available to a species is also a key component of critical habitat delineation. Studies are required that describe abundance and distribution of different habitats in the wild. Where possible, historic habitat availability should be explored to help provide context for the present condition, and the final delineation of critical habitat.

Population Abundance.— Another task will be to review historic and current population abundance, as part of the process of setting recovery targets. Both the current and historic population abundance provide meaningful context for the recovery target, though we recognize that historic abundance may be difficult to ascertain with accuracy.

Recovery Targets.— Clearly defined population recovery targets for each life stage are integral to the identification of critical habitat, because the quantity of habitat designated as critical must be related to a population benchmark (Rosenfeld and Hatfield 2006). Setting recovery targets may require several steps and the collection of several pieces of information. Recovery targets may be based on rules of thumb (e.g., Thomas 1990; IUCN 2001; Reed et al. 2003), numeric analyses such as population viability analysis (PVA; Morris and Doak 2002), or a combination of techniques. For species such as Vancouver lamprey, where relatively little information exists and additional information takes a long time to collect, it may be beneficial to use targets based on rules of thumb. However, it is nevertheless valuable to examine such targets by assessing key population parameters (e.g., survival and fecundity) and to undertake specific population modeling (e.g., elasticity analysis, see Gross et al. 2002) to explore which life stages are most limiting to lamprey abundance.

Relationship Between Habitat and Abundance.— Designation of critical habitat requires quantitative relationships between habitat and abundance, to establish the amount of habitat required to achieve a population recovery target (Rosenfeld and Hatfield 2006). Developing such a relationship is not a straightforward task and may need to rely, at least in part, on expert judgement.

Define Critical Habitat.— The final step in delineating critical habitat is to use population targets and relationships between habitat types and abundance to determine how much of the different habitats is required to maintain a viable population of Vancouver lamprey, and to then identify the specific locations of these habitats in the wild.

6.3 Examples of Activities That Are Likely to Result in Destruction of Critical Habitat

Until critical habitat is formally delineated it is not possible to provide specific guidance on which activities are most likely to destroy critical habitat, other than in very general terms. For example, lamprey have habitat requirements similar in many respects to those of salmonids, so activities likely to degrade salmonid habitats can be expected to also have negative impacts on lamprey. The more general threats to some of the important habitat types for Vancouver lamprey are discussed in Section 3. These threats and activities should be assessed for their effects on critical habitat and the steps necessary to mitigate negative effects.

RECOVERY

7. Recovery Goal

The recovery goal for Vancouver lamprey is to ensure its long-term viability within its natural range. It is likely that this species will always remain at some risk due to its extremely limited distribution.

8. Recovery Objectives

Recovery objectives are stated as follows:

1. Maintain a self-sustaining population of Vancouver lamprey within Cowichan and Mesachie lakes that is resilient to short-term habitat perturbations.
2. Maintain, and where possible enhance, the ecological integrity of habitat for Vancouver lamprey.
3. Increase scientific understanding of Vancouver lamprey through additional investigation of its taxonomic status, natural history, critical habitat and threats to the species' persistence.
4. Foster awareness of Vancouver lamprey and its conservation status, and encourage active local involvement in stewardship and habitat protection.

9. Approaches to Meeting Recovery Objectives

The general approaches recommended in this recovery strategy are to:

- establish and support stewardship initiatives,
- undertake specific research activities to fill knowledge gaps and clarify threats,
- delineate and protect[2] key habitats,
- minimize impacts from land and water use, and
- design and implement sound monitoring programs.

A description of the recommended strategies and approaches is presented in Table 3. These approaches will be further detailed in one or more Action Plans, to be developed with the participation of a Recovery Implementation Group (RIG). Further plans and decisions may require involvement of various participants including government agencies, First Nations, private land owners, industry and local stewardship groups.

[2] Protection can be achieved through a variety of mechanisms including: voluntary stewardship agreements, conservation covenants, sale by willing vendors on private lands, land use designations and protected areas.

Table 3. Prioritized strategies and recommended approaches for the recovery of Vancouver lamprey.

Priority[3]	Strategy	Approaches	Performance Measure [4]
Necessary	Establish and support a Recovery Implementation Group (RIG) or alternative working group for Vancouver lamprey.	1. Invite stakeholders and interested parties to participate in a RIG. 2. Encourage local governments (e.g., Town of Lake Cowichan, Cowichan Valley Regional District) to have membership or representation on RIGs to facilitate Action Plan communication and implementation. 3. Establish the RIG leadership (chair, facilitator, etc.), develop terms of reference, and obtain necessary funding to support RIG activities. 4. Develop and implement one or more Action Plans, which are to be guided by the Recovery Strategy.	Has a RIG or working group been established? Is the RIG adequately supported with funding and technical expertise? Has an Action Plan been developed? Is the RIG achieving the goals outlined in the Recovery Strategy?
Necessary	Address information gaps that inhibit conservation of Vancouver lamprey.	Address key information gaps including: 1. synthesis and reporting of information from previous studies, 2. phylogenetic studies to clarify taxonomic status, 3. habitat use and requirements, 4. life history information, 5. causes of mortality (e.g., temperature, pollutants, predation, bycatch, etc.), 6. use of tributary habitats throughout the watershed, 7. limiting factors to population growth, 8. levels of parasitism and scarring on prey species, and 9. Aboriginal Traditional Knowledge	Are there key information gaps that inhibit conservation of Vancouver lamprey?

[3] Priority has been assigned based on professional judgement into one of three groups, from highest to lowest: necessary, primary, secondary.
[4] Performance measures plot the progress toward meeting the stated objectives. The performance measures are presented here as questions, the answers to which can be plotted in time to monitor progress.

Priority[3]	Strategy	Approaches	Performance Measure [4]
Primary	Clarify and address threats to Vancouver lamprey.	Undertake appropriate research to clarify threats, including: 1. Quantify relation between abundance of Vancouver lamprey and its prey. 2. Assess effects of land and water use on the productivity of lamprey habitats. 3. Develop guidelines that will mitigate potential threats related to development or water-use.	Have threats been clarified and assessed? Are threats being mitigated?
Primary	Conduct studies to help define critical habitat for Vancouver lamprey.	Undertake necessary research to define critical habitat and to delineate it in the wild. See Section 6.2 for a list of necessary research activities.	Has critical habitat been defined for Vancouver lamprey?
Primary	Develop and implement a long-term monitoring program.	RIG to develop a monitoring program to assess population status and response to management activities or threats. Monitoring may include: • trends in abundance of Vancouver lamprey and its prey species, • trends in habitat quantity and quality, • water quality, • land use, and • water use.	Have monitoring programs been implemented? How long has a monitoring program been in place? Is it effective? Is funding secure for the long term?
Primary	Establish water quality and water use objectives for Cowichan and Mesachie lakes.	1. Assess the need for species-specific water quality or quantity objectives. 2. Work with relevant agencies and stakeholders as required to achieve objectives.	Have water quality and water use objectives been established and communicated to relevant regulators and stakeholders?
Secondary	Develop a comprehensive water management plan for each basin.	RIGs will work with Water Stewardship Division (Ministry of Environment), water licence holders, and stakeholders to: 1. review existing licences, 2. review existing water uses, 3. secure unallocated water for conservation purposes, as needed, and 4. Assess the efficacy of the Cowichan Valley Water Management Plan in relation to conservation of Vancouver lamprey	Does the water management plan adequately address the needs of Vancouver lamprey? Has it been implemented

Priority[3]	Strategy	Approaches	Performance Measure [4]
Secondary	Inform and educate stakeholders and the genral public about the species and general biodiversity values.	RIG to work with government agencies and educators to develop 1. educational material (e.g., an educational brochure, web-based material) to explain the general biology of the species, its biodiversity values and threats to its persistence. Consider developing material for project WILD < http://www.hctf.ca/wild/about.htm>. 2. educational material for use in public schools, particularly schools in the vicinity of Cowichan and Mesachie lakes. 3. educational materials and signage for anglers and other lake users (e.g., at tackle shops, boat ramps, habitat enhancement projects, etc.).	Have educational materials been produced? How many classes have received educational presentations? How many educational signs have been erected? Has public perception and awareness been affected?
Secondary	Work with local governments, land developers, and others to improve and encourage watershed stewardship.	Develop criteria for assessing effects of land developments (including forest harvest) on lamprey habitats, develop guidelines for good stewardship, establish Wildlife Habitat Areas (WHAs) where appropriate, and establish Special Development Areas where appropriate. For private lands, work with land owners to encourage good stewardship. Develop and implement Best Management Practices (BMP), as needed. Develop and employ conservation covenants where useful.	Have forest harvest and land management criteria been developed? Is forest harvest and land development meeting the criteria? Have BMPs been developed and communicated? Is there compliance with BMPs?
Secondary	Develop sound protocols for scientific investigations (e.g., limit number of fish collected each year, etc.)	Recovery Team to work with government agencies to set boundaries for experimental work and collection activities. Note: SARA permits are required to legally collect and undertake research on a listed wildlife species.	Have scientific investigation protocols been set and communicated? Have they been implemented?

10. ANTICIPATED CONFLICTS OR CHALLENGES

Vancouver lamprey are currently of little or no economic value, and this is unlikely to change. By contrast there are other public, private and commercial interests in watersheds in which the species resides. These interests include forestry, water extraction for industrial and residential use, roads, residential and recreational property development, and recreational fishing, boating, and swimming. It is possible that mitigating threats to lampreys will conflict with development pressures. Recovery of the species will therefore benefit from stewardship and specific research over the long-term. It is important to understand that many of the threats to Vancouver lamprey can be reduced but not eliminated.

10.1 Potential Management Impacts for Other Species

Vancouver lamprey are parasitic and have the potential to affect the abundance of other fish species, including salmonids (Beamish 1982). Thus, the introduction of this species into other watersheds is not recommended. No goal of establishing this species in other watersheds has been put forward.

It is unlikely that recovery efforts aimed at Vancouver lamprey will have a significant negative effect on other fish or wildlife species indigenous to Cowichan or Mesachie lakes and this could be monitored through the trends in abundance of prey species and parasitic scarring rates. Numeric enhancement of the species is not being recommended, and protection of lamprey habitats will likely benefit other species too.

11. RECOVERY FEASIBILITY

Vancouver lamprey have been reported only in Cowichan and Mesachie lakes and they are unlikely to be purposely transplanted elsewhere in BC. Thus, their population will continue to be limited to a small area. Indeed, it is this extreme endemism that supports its current status as threatened, and which likely will cause the species to continue to be at some risk. Recovery actions will be aimed at maintaining or improving current habitat conditions, monitoring the population, and undertaking specific research tasks. With the support of local governments, local industry and the public, recovery is deemed to be technically and biologically feasible.

As part of the SARA process, the competent minister must determine the feasibility of recovery for each species at risk. To help standardize these determinations, the current Policy on Recovery Feasibility (Government of Canada 2005) poses four questions, which are to be addressed in each recovery strategy. These questions are posed and answered here.

1. Are individuals capable of reproduction currently available to improve the population growth rate or population abundance?

Yes. Vancouver lamprey naturally have a very restricted distribution. The populations are believed to be self-supporting, although population status is not known. Regardless of population abundance and trends, the species will continue to be at risk due to limited geographic range.

2. Is sufficient suitable habitat available to support the species or could it be made available through habitat management or restoration?

Yes. Sufficient suitable habitat exists in Cowichan and Mesachie lakes.

3. Can significant threats to the species or its habitat be avoided or mitigated through recovery actions?

Yes. Controlling threats to Vancouver lamprey is feasible, but rests more on social than technical considerations. For example, the primary threats are water management and land use. Most threats, such as those from excessive water use and land development, can be managed with existing regulations, but will require consultation with stakeholders.

4. Do the necessary recovery techniques exist and are they demonstrated to be effective?

Yes. Special recovery techniques are not required for recovery of Vancouver lamprey. What is required is effective watershed management and mitigation of current and future threats, which is believed to be entirely feasible. It should be stressed, however, that Vancouver lamprey will likely always be very restricted in its distribution. As a result, it will likely always remain at some risk. Recovery efforts are best concentrated on controlling threats. There are no significant technical challenges in this regard.

12. RECOMMENDED APPROACH / SCALE FOR RECOVERY

This recovery strategy recommends the use of a single species approach (rather than an ecosystem approach) because it addresses a single taxonomic unit. There are no apparent opportunities to combine recovery efforts for Vancouver lamprey with recovery efforts for other listed species in the immediate area. There is an opportunity to share information with recovery efforts for the Morrison Creek lamprey, another extreme endemic on Vancouver Island. In addition, every effort should be made to provide input to other management planning initiatives, actions, or policies.

Although very little is known about the Vancouver lamprey, it is likely that there is a significant overlap between the types of habitats used by salmonids, especially with regards to spawning. As such, there may be opportunities to co-ordinate recovery efforts with those of local stewardship groups currently focused on salmonid populations. Efforts to protect salmonid habitats in the Cowichan watershed are likely to help protect lamprey also.

13. KNOWLEDGE GAPS

Basic knowledge exists about the natural history of this species; however, gaps exist with respect to taxonomic status, population demographics, critical habitat, and tolerance to changes in physical habitat. Less is known about the ecology of Vancouver lamprey, the environmental factors that affect abundance and distribution, and the threats to this species. Meeting conservation goals will require addressing several knowledge gaps. The gaps fall into three main categories, as outlined below.

Basic Biology

- Taxonomic status and phylogenetic relationships,
- Habitat use and requirements by life stage (e.g., population distribution within the watershed, differential use of particular tributaries),
- Which habitats are most likely to be limiting,

- Life history information,
- Causes of mortality (e.g., temperature, pollutants, predation, bycatch, etc.), and
- Factors limiting population growth.

Threat Clarification
- Effects of changes in lake elevation and water quality,
- Status of key habitats and potential threats to these habitats
- Trends in prey species abundance and levels of parasitism, and
- Effect of present and future human activities and prioritization of threats.

Population Abundance and Dynamics
- Current population abundance of Vancouver lamprey,
- Natural population fluctuations of Vancouver lamprey,
- Current and historic trends in abundance, and
- Effect of demographics on habitat use.

14. ACTIONS ALREADY COMPLETE AND/OR UNDERWAY

Several recovery actions have been completed or initiated.

1. A variety of scientific investigations have been completed, primarily by R.J. Beamish and co-workers (DFO, Nanaimo):
    a. taxonomic investigations, including some molecular genetics work, and
    b. assessment of the status of Vancouver lamprey.
2. The species has been protected from capture or retention under the *Fisheries Act*, Section 5 of the BC Sport Fishing Regulations, 1996.

15. STATEMENT OF WHEN ACTION PLANS WILL BE COMPLETED

One or more Action Plans will be developed within two years of posting the final Recovery Strategy on the SARA public registry. The plans will include descriptions of programs, plus a timeline of programs with estimated budgets, and will encompass a timeframe of at least five years.

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APPENDIX I - RECORD OF COOPERATION AND CONSULTATION

Vancouver lamprey is listed on Schedule 1 of the *Species at Risk Act* (SARA) and as an aquatic species is under federal jurisdiction and managed by Fisheries and Oceans Canada (DFO): 200 - 401 Burrard Street, Vancouver, BC.

To assist in the development of an initial draft of this Recovery Strategy, as well as those for other listed freshwater fishes in British Columbia, DFO in cooperation with the Province of BC assembled a group of experts from various levels of government, academia, consultants, and non-governmental organizations to form the Pacific Region Non-Game Freshwater Fish Recovery Team. This team, co-chaired by DFO and the Province of BC, is responsible for drafting recovery strategies for Pacific Region freshwater fish species listed under SARA, including Vancouver lamprey.

Public and stakeholder consultation on the draft Recovery Strategy was provided through a Community Dialogue Session. Invitations were sent to nine stakeholder groups related to Cowichan Lake and area, including provincial government, local government, and industry. Notices announcing the session were also placed in six local newspapers. The Community Dialogue Session, consisting of a presentation and discussion on the proposed Recovery Strategy for Vancouver lamprey, was held in Duncan in May 2006, with four attendees. Comments from the session were recorded and archived.

First Nations input on the proposed Recovery Strategy was sought through an information exchange session, to which the Lake Cowichan First Nation, Halalt First Nation, and Cowichan Indian Band were invited. The session, consisting of a presentation and discussion on the proposed Recovery Strategy for Vancouver lamprey, was held in Duncan in May 2006, with three representatives of the Cowichan Tribes. Dialogue from the information exchange was recorded and archived.

Additional input on the draft Recovery Strategy was sought through a discussion guide and feedback form available on the internet (May – June 2006). Two responses were received from area residents. Input from the Province of BC was received through recovery team participation. An external peer review was conducted by Dr. Margaret Docker of the University of Manitoba. All feedback received was considered in the finalization of the Recovery Strategy.

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