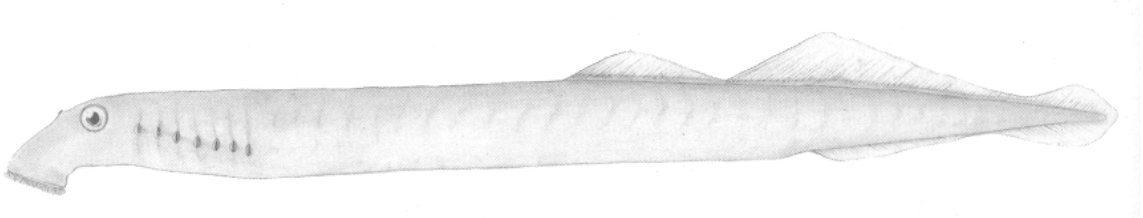
COSEWIC
Assessment and Status Report

on the

Western Brook Lamprey
Lampetra richardsoni

Morrison Creek Population

in Canada



ENDANGERED
2010

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

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

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Previous report(s):

COSEWIC. 2000. COSEWIC assessment and update status report on the Morrison Creek Lamprey *Lampetra richardsoni* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 14 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

Beamish, R.J., J.H. Youson and L.A. Chapman. 1999. COSEWIC status report on the Morrison Creek Lamprey *Lampetra richardsoni* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-14 pp.

Production note:
COSEWIC acknowledges Mike Pearson for writing the updated status report on the Western Brook Lamprey, *Lampetra richardsoni*, prepared under contract with Environment Canada. The contractor's involvement with the writing of the status report ended with the acceptance of the provisional report. Any modifications to the status report during the subsequent preparation of the 6-month interim and 2-month interim status reports were overseen by Eric Taylor, Freshwater Fishes Specialist Subcommittee Co-chair.

Please note: The Western Brook Lamprey *Lampetra richardsoni,* Morrison Creek Population is also referred to as the Morrison Creek Lamprey.

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Western Brook Lamprey — drawing by D.L McPhail adapted from McPhail 2007 by permission.

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COSEWIC
Assessment Summary

Assessment Summary – April 2010

Common name
Western Brook Lamprey - Morrison Creek Population

Scientific name
Lampetra richardsoni

Status
Endangered

Reason for designation
This dimorphic population of lamprey is a small freshwater fish endemic to a small stream on eastern Vancouver Island. It is susceptible to habitat loss and degradation owing to its close proximity to a major highway and increasing urbanization in the watershed.

Occurrence
British Columbia

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

COSEWIC
Executive Summary

Western Brook Lamprey
Lampetra richardsoni

Morrison Creek Population

Wildlife species information

Adult Western Brook Lamprey are small (~ 10 cm), elongate, jawless fish that live exclusively in freshwater. They have seven near-circular gill pores on either side of the branchial region, a single nostril atop the head, and a round, disc-like mouth. Paired fins are lacking. The skeleton is formed of cartilage and the blunt teeth of keratin. Typically, adult Western Brook Lamprey do not feed. Larvae (ammocoetes) are 10 to 15 cm long, and worm-like in shape, with a scoop-like oral hood covering a toothless mouth and translucent skin covering developing eyes. A population of Western Brook Lamprey found in Morrison Creek is a dimorphic population and is distinguished from the Western Brook Lamprey by the presence of a unique "*marifuga*" form as well as "typical" form. The *marifuga* form can be recognized as distinct from the typical form during a short period of its life cycle by its silver colour, larger size (15 to 18 cm), and tooth counts on the tongue. While both forms feed as larvae, only the *marifuga* form is able to feed following metamorphosis. The forms are, however, morphologically indistinguishable as ammocoetes. The degree of reproductive isolation between them is uncertain, but genetic data suggest that both forms are part of a single population. The Western Brook Lamprey (Morrison Creek Population) has no commercial value, but ammocoetes may play a major role in stream nutrient cycling. The *marifuga* form is of scientific interest for its extreme endemism and as a highly unusual example of evolution in lampreys. It has intrinsic value as a unique part of Canada's biodiversity and for biological education.

Distribution

Western Brook Lamprey occur in coastal streams from northern California to the Skeena River and Queen Charlotte Islands in British Columbia. The Western Brook Lamprey (Morrison Creek Population) is endemic to Morrison Creek, a small tributary (890 ha watershed) of the Puntledge River, on the central east coast of Vancouver Island.

Habitat

Little information is available concerning the biology and habitat of the Western Brook Lamprey (Morrison Creek Population). More generally, Western Brook Lamprey nests are typically constructed in shallow, flowing water over sand and gravel substrate. Young ammocoetes are found in mud and silt substrates in shallow pools but move into deeper pools with sand or leaf substrates when larger. Newly metamorphosed adults are typically found beneath rocks or other cover near stream margins during the winter. Morrison Creek is atypical of streams on eastern Vancouver Island, with its extensive headwater wetlands and springs, which provide stable flows of cool water. Logging, land development and highway construction have impacted the watershed historically, although the habitat remains relatively healthy. Less than 5% of the watershed area is currently protected in conservation areas, but the City of Courtenay controls most streamside lands in the lower watershed.

Biology

The Western Brook Lamprey (Morrison Creek Population) spawns in April and May. Both sexes participate in excavating a small depression. Adults usually spawn in pairs, although group spawning with multiple males and females is also common and different groups may use the same site. All lampreys die after spawning. In other populations of Western Brook Lamprey, eggs hatch within 30 days at 10^{o}C and larvae remain in the gravel for an additional two to three weeks, before emerging at night to be swept downstream, where they burrow into the mud to filter feed on detritus. This ammocoete stage probably lasts from three to seven years. Metamorphosis from ammocoetes to adults begins in July and finishes by October of the same year. Adults usually show the first external signs of sexual maturation in April and complete the process by early May. They spawn and die by June. In Morrison Creek, some ammocoetes metamorphose into the *marifuga* form, in which sexual maturity is delayed, and a characteristic silver colour with pronounced counter shading is acquired. The new teeth remain sharp and the intestine remains functional, unlike in the typical form. They feed readily on live and dead fishes when held in aquaria, but feeding has never been observed in the wild. The *marifuga* form is approximately 80% male. In the creek, the *marifuga* form first appears in traps in late March and the last are caught in mid-August. Both forms are unable to acclimate to sea water and are believed to remain in Morrison Creek for their entire lives.

Population sizes and trends

No population estimates exist for either the *marifuga* or typical form of the Western Brook Lamprey (Morrison Creek Population), but there appear to have been no major fluctuations. The *marifuga* form appears to have been caught less frequently than the typical form.

Limiting factors and threats

Forest harvest is declining in the watershed but urban development pressure is increasing. Both may impact Morrison Creek through changes to its flow regime, riparian vegetation loss, sediment deposition and other effects. Assuming the *marifuga* form does feed within Morrison Creek, declines in Pacific salmon abundance may limit food availability. Although no impacts have been detected to date, a leaking landfill site in the headwaters is a concern. The extremely restricted distribution of Western Brook Lamprey (Morrison Creek Population) exacerbates its vulnerability to all threats.

Existing protection

As an aquatic species listed as “Endangered” under Schedule 1 of the federal *Species at Risk Act*, the Western Brook Lamprey (Morrison Creek Population) is protected from harm or capture. The habitat is provided some protection under the federal *Fisheries Act*.

TECHNICAL SUMMARY

Lampetra richardsoni
Western Brook Lamprey - (Morrison Creek population) lamproie de l'ouest (population du ruisseau Morrison)
Endemic to Morrison Creek, Vancouver Island, British Columbia

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines (2008) is being used)	4 to 9 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Unknown
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown
Are the causes of the decline clearly reversible and understood and ceased?	NA, no evidence of decline
Are there extreme fluctuations in number of mature individuals?	Unknown

Extent and Occupancy Information

Estimated extent of occurrence	~ 9 km²
Index of area of occupancy (IAO) AO = 19 km channel x 2 m width + 96 ha wetlands = 0.998 km²	AO < 1 km² IAO (2x2) = 11.7 km² IAO (1x1) = 7.4 km²
Is the total population severely fragmented?	No
Number of "locations*"	1
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	Unknown, appears stable
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	Unknown
Is there an [observed, inferred, or projected] continuing decline in number of populations?	No
Is there an [observed, inferred, or projected] continuing decline in number of locations?	No
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat? Inferred from continuing urbanization throughout the watershed	Yes
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

* See definition of location in O&P manual.

Number of Mature Individuals (in each population)

Population	N Mature Individuals
Total	Unknown

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or five generations, or 10% within 100 years].	Not conducted

Threats (actual or imminent, to populations or habitats)

Actual

- Declines in habitat area and quality from urbanization, landfill leachate, forest harvest

Potential

- Spills from road crossings of the Island Highway

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? NA, endemic to Morrison Creek	
Is immigration known or possible?	NA, endemic
Would immigrants be adapted to survive in Canada?	NA, endemic
Is there sufficient habitat for immigrants in Canada?	NA, endemic
Is rescue from outside populations likely?	No

Current Status

COSEWIC: Endangered (2010); SARA Endangered, Schedule 1
WildSpecies Canada (2005): Not listed. *L. richardsoni* is ranked as "4" = "Secure"
BC: Red-listed (S1, 2004)
NatureServe (2005); Ranked as G4G5T1Q , S1 (BC)

Status and Reasons for Designation

Status:	**Alpha-numeric code:**
Endangered	B1ab(iii)+2ab(iii)

Reasons for designation:
This dimorphic population of lamprey is a small freshwater fish endemic to a small stream on eastern Vancouver Island. It is susceptible to habitat loss and degradation owing to its close proximity to a major highway and increasing urbanization in the watershed.

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals):
Not applicable. No quantitative data on trends in population sizes.

Criterion B (Small Distribution Range and Decline or Fluctuation):
Meets Endangered B1ab(iii)+2ab(iii). EO is << 5,000 km², IAO is << 500 km², the species is found at fewer than 5 locations, and some habitat loss and degradation has occurred and is projected to continue because of urban expansion and proximity to a major highway.

Criterion C (Small and Declining Number of Mature Individuals):
Not applicable. No estimates of past or present population sizes are available.

Criterion D (Very Small Population or Restricted Distribution)
Meets Threatened D2. IAO is < 20 km² and the species is found at a single location that is susceptible to habitat degradation in the headwaters because of urbanization.

Criterion E (Quantitative Analysis) :
Not available.

PREFACE

The Western Brook Lamprey (Morrison Creek Population) is a population of Western Brook Lamprey (*Lampetra richardsoni*) found in a small stream on the east central coast of Vancouver Island, British Columbia. The Western Brook Lamprey (Morrison Creek Population) was first assessed as endangered by COSEWIC in 2000 based on its restriction to a single, small locality, inferred small population size, and threats of habitat degradation owing to increased urbanization and highway construction within the headwaters of Morrison Creek. Since the completion of the first status report on the Western Brook Lamprey (Morrison Creek Population) in 2000, it was listed as endangered under *SARA* in 2003. A recovery strategy development was led by Fisheries and Oceans Canada – Pacific Region and the British Columbia Ministry of the Environment, and was completed in 2007. The recovery strategy listed a series of threats to the lamprey, the greatest being increased urbanization of the headwater area. Much of the land surrounding Morrison Creek is privately owned. In addition, a series of biological studies was proposed, the most important being the identification of critical habitat, studies on the genetic relationships of lamprey within Morrison Creek, and basic inventory data on abundance and distribution. Several local groups have initiated action on the study and recovery of the Western Brook Lamprey (Morrison Creek Population). For instance, in 2000, the Comox Valley Project Watershed Society and the Morrison Creek Streamkeepers (http://www.morrisoncreek.org/) conducted a streamside landowner contact program. In 2005, landowners were provided with updated maps of Morrison Creek, information about the Western Brook Lamprey (Morrison Creek Population) and a copy of *On the Living Edge: Your Handbook for Waterfront Living*, which provided suggestions on how to protect waterfront habitat.

Several habitat restoration projects have been conducted by the Morrison Creek Streamkeepers to restore native vegetation to the streamside, reduce soil erosion into the river and restore a natural diversity of water flows (e.g., pools, riffles, slow and fast-flowing water). These restoration projects are targeted largely towards salmon and trout that reside in Morrison Creek, but also probably benefit lamprey.

COSEWIC HISTORY

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

COSEWIC MANDATE

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

COSEWIC MEMBERSHIP

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

DEFINITIONS (2010)

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

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

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

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

Environment Canada / Environnement Canada
Canadian Wildlife Service / Service canadien de la faune
Canada

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

COSEWIC Status Report

on the

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2010

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WILDLIFE SPECIES INFORMATION

Name and classification

Kingdom:	Animalia
Phylum:	Chordata
Class:	Cephalaspidomorphi
Order:	Petromyzontiformes
Family:	Petromyzontidae
Genus:	*Lampetra*
Species:	*richardsoni*

Common Names:

English	Western Brook Lamprey (Morrison Creek Population)
French	Lamproie de l'ouest (population du ruisseau Morrison)

The Western Brook Lamprey *(Lampetra richardsoni)* is a small lamprey that completes its life cycle entirely in freshwater. It was formerly known as *Lampetra planeri* (Bloch), a European species, until described as distinct by Vladykov and Follett (1965). The taxon is widespread in coastal streams of western North America and uncertainties remain regarding its taxonomic status and relationships to other lampreys. One population of the Western Brook Lamprey found in Morrison Creek, Vancouver Island produces two feeding types of lampreys: non-parasitic individuals that mature, spawn and die, six to eight months following metamorphosis from the larval (ammocoete) stage, as is typical of *L. richardsoni* populations, and the so-called *marifuga* variety of *L. richardsoni* described by Beamish (1985) (Figure 1). The two forms of *L. richardsoni* in Morrison Creek differ morphologically in traits typically used in lamprey systematics (Potter 1980b) and, to some extent, anatomically in traits important to feeding biology. In addition, the *marifuga* form can feed as a parasite or scavenger and is able to sustain itself for an additional year of life and growth before spawning (Table 1). The degree of reproductive isolation between these forms, if any, is uncertain although the available genetic evidence suggests they are part of a single population (Beamish and Withler 1986 and see below).

Figure 1. The *marifuga* (feeding) form of the Morrison Creek population of *Lampetra richardsoni*. This individual is believed to be three to four months post-metamorphosis and ~ 12 cm long. Photo by Jim Palmer.

Table 1. Summary of differences in morphology and life history between forms of lamprey, *Lampetra richarsoni* and *L. richardsoni* var. *marifuga*, from Morrison Creek following metamorphosis. CLLL = number of cusps on the longitudinal lingual lamina, CTLL = number of cusps on the transverse lingual lamina, TL = Total length, BL/TL = ratio of branchial length to total length, ED/TL = ratio of eye diameter to total length, POL/TL = ratio of postorbital length to total length. Values for counts are means (SD, N). All comparisons except that for CLLL were significantly different from one another (post hoc tests following ANOVA, P < 0.05). Note that cusp characters were compared between *marifuga* and *L. richardsoni* from five localities outside Morrison Creek, while length and body proportions were compared between *marifuga* and *L. richardsoni* from Morrison Creek (Beamish unpublished data and personal communication, 2010).

Characteristic	*L. richardsoni*	*L. richardsoni* (*marifuga* form)
CLLL	10.5 (0.88, 32)	9.8 (1.43, 79)
CTLL	8.6 (1.77, 26)	7.9 (1.23, 79)
TL	92.6 (0.96, 16)	128.2 (17.5, 91)
BL/TL	0.106 (0.012, 16)	0.101 (0.006, 91)
ED/TL	0.031 (0.003, 16)	0.026 (0.003, 91)
POL/TL	0.031 (0.004, 16)	0.028 (0.003, 91)
Typical Spawning Time	April to mid-June same year as metamorphosis	April to mid-June up to 1 year after metamorphosis
Colouration	Dark pigmentation	Silvery sides, white bottom
Feeding	Does not feed	Actively feeds under laboratory conditions
Sex ratio (m:f)	~1:1	~1.8:1

The evolution of similar closely related pairs of parasitic and non-parasitic forms is a common phenomenon within the Petromyzontidae (Zanandrea 1959; Vladykov and Kott 1979; Potter 1980b). Given their close evolutionary relationship to one another (Beamish and Withler 1986; Docker *et al*. 1999), the freshwater, non-parasitic *L. richardsoni* probably evolved from the parasitic and anadromous *L. ayresii* (which does not occur in Morrison Creek). An allozyme study of Beamish and Withler (1986) indicated that there were no detectable differences between *L. richardsoni* and *L. richardsoni* var. *marifuga* (genetic distance of 0.000). The possibility that the *marifuga* form is the result of hybridization between *L. richardsoni* and *L. ayresii* has been raised, but is considered unlikely; laboratory crosses produced hybrid ammocoetes of intermediate colouration, unlike any observed in Morrison Creek (Beamish and Neville 1992), *L. ayresii* are not known from Morrison Creek (Beamish 1987; Province of BC 2008), and the *marifuga* form is apparently absent in numerous other watersheds known to contain both *L. ayresii* and *L. richardsoni* (Beamish 1985).

The Morrison Creek population of *L. richardsoni* is highly unusual by virtue of a dimorphic life history and, in particular, the presence of both parasitic freshwater and non-parasitic freshwater forms. Such a dimorphic life-history appears to be unique among *L. richardsoni* populations (Beamish and Withler 1986; Beamish 1987) and is highly unusual among lampreys (Potter 1980b; Espanhol *et al*. 2007; Docker 2009, but see Kucheryavyi *et al*. 2007). Given, however, the lack of evidence for reproductive isolation between *L. richardsoni* and *L. richardsoni* var. *marifuga*, and the lack of detailed demographic or ecological information for the latter, the *marifuga* form is considered a component of the *L. richardsoni* complex inhabiting Morrison Creek in this report.

Morphological description

Adults of the “typical” form in Morrison Creek appear similar to those of other populations of *L. richardsoni,* although they are somewhat smaller in total length (8-12 cm total length, Beamish and Withler 1986) compared to the maximum reported size for the species (16 cm, McPhail 2007). They are eel-like in shape, lack scales and jaws and have seven near-circular gill pores on either side of the branchial region, a single nostril on top of the head, and a round, suctorial mouth. The eyes are prominent and set relatively high on the head. The body is nearly cylindrical in cross-section ahead of the two dorsal fins, and then becomes laterally compressed towards the caudal fin. The caudal fin is small and paired fins are lacking. The skull and un-segmented rod that functions like a backbone are formed of cartilage (Scott and Crossman 1973; McPhail 2007). The teeth are composed of keratin and become blunt and peg-like midway through maturation (October) and their arrangement is characteristic of the species (Figure 2). Sexes are difficult to distinguish except during the spawning season, when males develop a slender urogenital papilla that protrudes up to 6 mm from the body and females develop a “pseudoanal fin”, a swelling posterior to the vent (Scott and Crossman 1973; McPhail 2007).

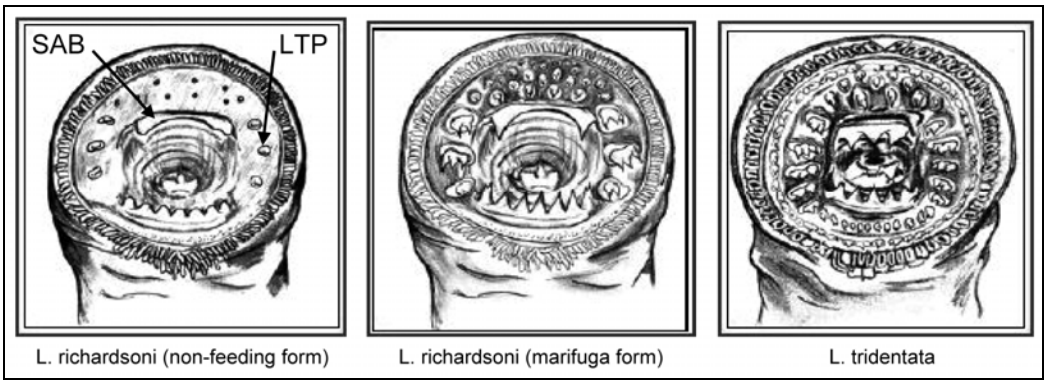

Figure 2. Dentition of lampreys found in Morrison Creek. Typical, non-feeding *L. richardsoni* (left) show blunt teeth. The *marifuga* form (centre) has sharp, well developed teeth. *L. tridentata* (right), an anadromous parasitic species known from Morrison Creek, also has sharp, well developed teeth, but differs from the others in having three (rather than two) cusps on the supraoral bar (SAB) and four (rather than two or three) lateral tooth plates (LTP) on each side. Adapted from McDermott (2003).

The adult *marifuga* form (Figure 1) is identified by its silver colour, more prominent counter-shading, larger size (15 to 18 cm), and sharper, more prominent teeth (Beamish 1985). They can be distinguished from typical *L. richardsoni* in colour by March through the end of September, when they become uniformly dark, like the typical form (Beamish 1985, 1987). Gonad development in *marifuga* is delayed after metamorphosis, particularly in females (Youson and Beamish 1991), and the cranial pancreas is usually absent (Youson *et al*. 1988). Body size is larger than in the typical morph, up to 18 cm in captive individuals, but shrinks during sexual maturation, so that the morphs are difficult to distinguish at the spawning stage (Beamish and Withler 1986). Both forms are smaller than adult Pacific Lamprey*, L. tridentata*, which typically reach 20-30 cm in Morrison Creek (McDermott 2003).

As ammocoetes (larvae), the *marifuga* and typical forms are indistinguishable. Both forms are 10 to 15 cm long (Beamish 1987) and worm-like in shape and general appearance, with a scoop-like oral hood covering the mouth and translucent skin covering the developing eyes. They lack teeth, have relatively undeveloped fins and, if similar to other *L richardsoni* populations, have 57-65 myomeres compared to the adult's 60-67 (Scott and Crossman 1973). The walls of the pharynx produce mucus, which is directed back into the esophagus by cilia, to carry entrapped food particles into the gut. This system is common to ammocoetes of all sizes and species (Moore and Mallatt 1980). *Lampetra richardsoni* ammocoetes may be mistaken for those of Pacific Lamprey, which also occur in Morrison Creek, but are not part of the same species complex. *L. richardsoni* show a patch or streaks of darker pigmentation on the caudal ridge of the tail (Richards *et al*. 1982; McPhail and Carveth 1994).

Spatial population structure and variability

Beamish and Withler's (1986) allozyme work showed that the average pairwise Nei's (1978) genetic distance among five *L. richardsoni* populations was 0.025 with up to 14% of the total variation attributable to differences among populations. In addition, the typical *L. richardsoni* and *marifuga* forms in Morrison Creek had indistinguishable allele frequencies at each of 21 loci and enzyme polymorphism and heterozygosity levels in the combined Morrison Creek population (33.3% and 0.14) were similar to those of other populations of *L. richardsoni* (31.4% and 0.12), but lower than in *L. ayresii* populations (43.5% and 0.14). The Western Brook Lamprey (Morrison Creek Population) (*L. richardsoni* and *L. richardsoni* var. *marifuga*) itself showed a Nei's (1978) genetic distance of about 0.022 from five other populations of *L. richardsoni* in BC although the differentiation appeared to be driven strongly by a single locus, Gapdh, (Glyceraldehyde-phosphate dehydrogenase, Beamish and Withler 1986). The frequency of the most common (100) allele at Gapdh ranged between 0.58-0.94 in the other *L. richardsoni* populations (total N = 251 lampreys) whereas this allele was found at a frequency of only 0.19 in the Western Brook Lamprey (Morrison Creek Population) (N = 57, $P < 0.001$, chi-square test).

Designatable units

The Western Brook Lamprey (Morrison Creek Population) satisfies the "discrete" and "significance" criteria for recognition as a designatable unit within *Lampetra richardsoni*. It is discrete in that it is highly divergent at a single allozyme locus (as discussed above under **Spatial population structure and variability**) and exhibits an extremely unusual dimorphic life history (it produces both parasitic and non-parasitic varieties) with associated differences in morphology, anatomy, and physiology (Table 1). The significance of the discreteness of the Western Brook Lamprey (Morrison Creek Population) lies in its occupying an unusual ecological setting (the ability to produce freshwater-resident parasitic and non-parasitic forms) that is of importance to the understanding of the evolution of lampreys and of alternative life histories in general (see below).

Special significance

In streams where they are abundant, ammocoetes may constitute a large portion of total biomass and, as detritivores, play a major role in nutrient processing, storage and cycling (Close *et al*. 2002). The Western Brook Lamprey (Morrison Creek Population) has no real commercial value although ammocoetes of *L. richardsoni* are occasionally used elsewhere as fish bait, particularly in recreational fisheries for White Sturgeon, *Acipenser transmontanus* (Scott and Crossman 1973). The *marifuga* form is of considerable scientific interest for its endemism and as a highly unusual example of evolution and life history plasticity among lampreys. Beamish (1985) has suggested that it may represent a transition between parasitic and non-parasitic forms, a transition that is the basis of much of lamprey taxonomy and systematics. Understanding the processes involved in lamprey life history evolution and speciation is an active area of

research in evolutionary biology (Salewski 2003; Docker 2009). The Western Brook Lamprey (Morrison Creek Population), therefore, has intrinsic value as a unique component of Canada's native biodiversity and for biological education.

Searches of the UBC library catalogue and a number of zoological, First Nations, and anthropological databases yielded no reports of Aboriginal use or traditional knowledge of *L. richardsoni*.

DISTRIBUTION

Global range

Lampetra richardsoni is documented from coastal streams from the Skeena River and Queen Charlotte Islands in British Columbia south to Oregon and possibly northern California (Scott and Crossman 1973; McPhail 2007). The Western Brook Lamprey (Morrison Creek Population) is endemic to Morrison Creek, an eight km long tributary to the Puntledge River, which flows into the Strait of Georgia, midway up the eastern coast of Vancouver (Figure 3).

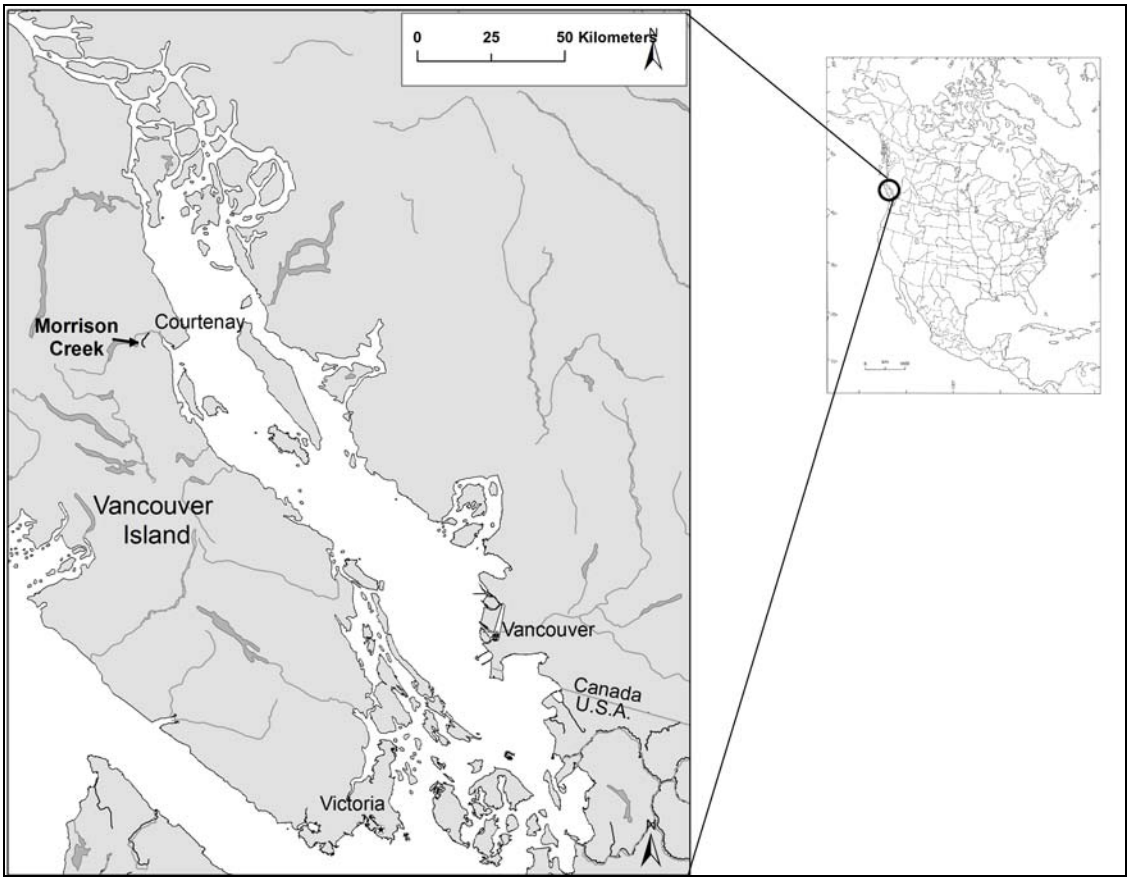

Figure 3. The global range of the Western Brook Lamprey (Morrison Creek Population) is restricted to Morrison Creek, located on the east coast of Vancouver Island, British Columbia.

Canadian range

Lampetra richardsoni is common in small streams throughout the Fraser Valley and north along the British Columbia (BC) coast to at least the Skeena River. It occurs along both coasts of Vancouver Island, on King, Princess and Royal Islands, and on the Queen Charlotte Islands (McPhail 2007).

Morrison Creek originates approximately eight km south of the town of Courtenay, BC, where it enters the Puntledge River, which flows into the Strait of Georgia, a few kilometres to the east (Figure 4). It is within the coastal Douglas-fir (*Pseudotsuga menziesii*) biogeoclimatic zone and the Pacific National Freshwater Biogeographic Zone (COSEWIC 2008). The distribution of the Western Brook Lamprey (Morrison Creek Population) within Morrison Creek is poorly known, particularly in the extensive headwater wetlands, where sampling is difficult. The presence of Coho Salmon, *Oncorhynchus kisutch,* in the headwaters of Morrison Creek suggests that there are no barriers to lamprey movement within the stream. The *marifuga* form has not been found in the mainstem or other tributaries of the Puntledge River system or other nearby watersheds (National Recovery Team for Western Brook Lamprey (Morrison Creek Population) 2007). Additional survey work is required to confirm the absence or potential distribution of other potential occurrences outside the Morrison Creek watershed (McPhail 2007).

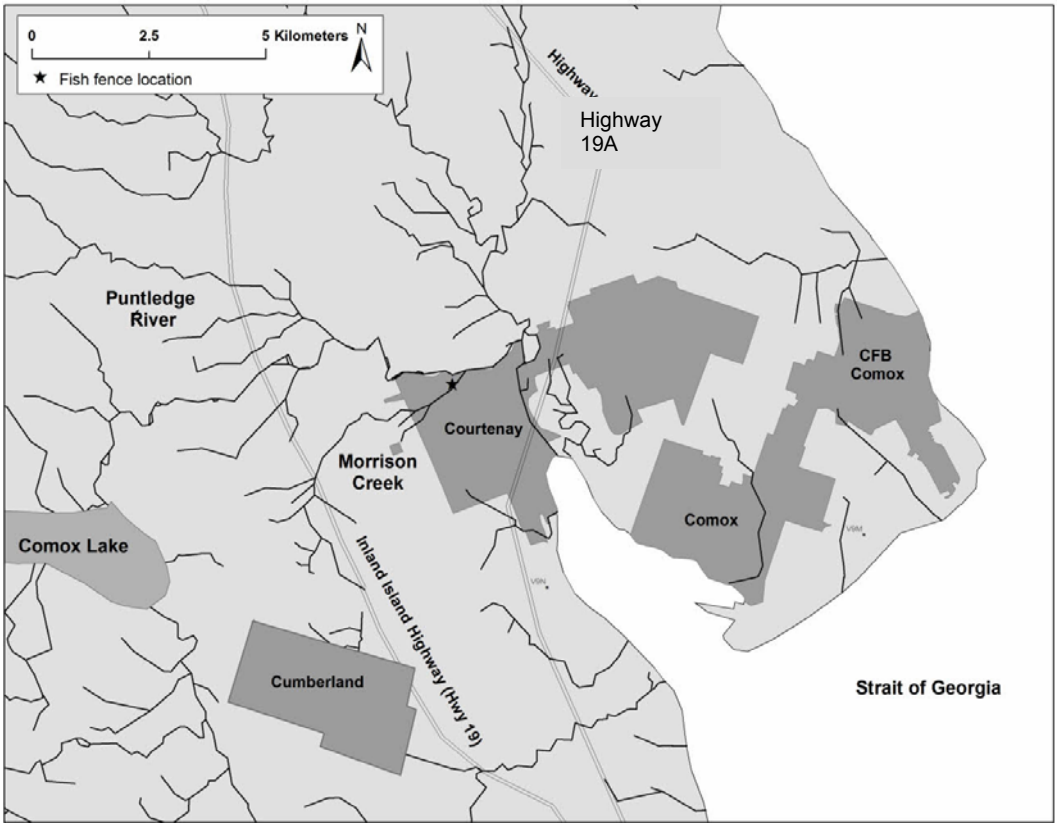

Figure 4. Morrison Creek is a tributary of the Puntledge River located between Comox Lake and the town of Courtenay. Dark-shaded areas represent major urban areas.

The Morrison Creek watershed is less than 8.9 km^2 in area (extent of occurrence (EO) - *see* COSEWIC 2008), and less than 1 km^2 would constitute suitable habitat (19 km of channels x 2 m width + 96 ha wetland =0.998 km^2 = area of occupancy (AO)). The index of area of occupancy (IAO) calculated using a 1 X 1 km overlaid grid is 8 km^2, and 12 km^2 using a 2 X 2 km overlaid grid. Given the very limited distribution of the Western Brook Lamprey (Morrison Creek Population) and the nature of the major threats to it (habitat loss and degradation – see **Threats and limiting factors** section) a single location for the Western Brook Lamprey (Morrison Creek Population) is inferred.

HABITAT

Habitat requirements

In general, there has been little quantitative work completed on the biology of the Western Brook Lamprey (Morrison Creek Population). Consequently, much of the information on the biology and habitat of Western Brook Lamprey (Morrison Creek Population) is inferred from more extensive information on *L. richardsoni* from other watersheds.

Lampetra richardsoni requires suitable habitats for spawning, egg incubation, and ammocoete development, in addition to cover for maturing adults. The *marifuga* form in Morrison Creek may also require suitable foraging habitat. It is also possible that particular habitat features present in the Morrison Creek watershed are required for the development and persistence of the *marifuga* form, but this remains unknown.

Lampetra richardsoni nests are typically constructed in sand and gravel substrate (< 2 cm diameter) near the upstream end of a riffle, in the downstream portions of pools or in runs (Stone 2006; McPhail 2007). Current velocity ranges from 0 to 0.7 m/s, but is typically less than 0.3 m/s and water depth is generally 10 - 25 cm (McIntyre 1969; Stone 2006). McIntyre (1969) reported an apparently preferred spawning site at which several *L. richardsoni* nests were superimposed immediately downstream of a large rock. The lamprey attached themselves to it with their mouths while resting and during courtship. Such features may also reduce current velocity in the nest, lessening egg losses, as has been demonstrated for Sea Lamprey, *Petromyzon marinus* (Moore and Mallatt 1980).

Young-of-the-year and yearling ammocoetes concentrate in mud and silt substrates in shallow areas at the stream margin (Scott and Crossman 1973; McPhail 2007), but are not found in stagnant or highly eutrophic water (Potter 1980a). In the Salmon River (Langley, BC), older ammocoetes were reported to move into deeper pool habitats with sand or leaf substrates (Pletcher 1963 as cited by McPhail 2007). Deep and soft substrates may be important for refuge from disturbances. Ammocoetes of *P. marinus* retreat up to 18 cm below the substrate surface in response to mechanical disturbance (Potter 1980a). Newly transformed adults are typically found beneath rocks or other cover near stream margins during the winter (McDermott 2003).

Morrison Creek is a third-order stream draining an 890 ha watershed below 160 m elevation. Total channel length is approximately 19 km with a width of 1 - 2 m in the headwaters and 3 - 4 m in the lower reaches (Beamish *et al*. 1999). It is atypical of streams on eastern Vancouver Island in being fed by extensive headwater wetlands (96 ha) and springs, which provide relatively stable flows of cool water (Ellefson 2003). Large numbers (3,789 - 15,166) of Coho Salmon smolts were captured annually in a monitoring fence operated between early April and mid-June from 2002 to 2009 (Table 2).

Table 2. Annual catch data from the fish fence near the outlet of Morrison Creek. Under "Lamprey", the first value is the total number of lamprey caught (including ammocoetes) and the value in parentheses indicates the number within the total that were identified as *marifuga* (Jim Palmer, pers. comm. 2009 and www.morrisoncreek.org). Years with no numbers indicate counts for that species are not available or were not taken.

Year	Coho Salmon	Trout[1]	Pink Salmon	Chum Salmon	Chinook Salmon	Lamprey
2002	15,166	814				36 (3)
2003	9,996	252				17 (3)
2004	4,714	521	1,872	418	14,009	28 (0)
2005	6,698	347	552	76,649	457	53 (12)
2006	3,789	28	0	13,998	468	18 (0)
2007	5,756	214		8,337		21 (0)
2008	7,055	190	6,283	1,398	4,801	24 (1)
2009	11,264	156		172,975		23 (1)
Total	**53,174**	**2,114**	**8,707**	**100,800**	**19,735**	**220 (20)**

[1]Rainbow Trout and Coastal Cutthroat Trout

Habitat trends

Little specific information on aquatic habitat trends within Morrison Creek exists, but some generalizations can be made. Logging has undoubtedly degraded habitat historically, as its impacts on streams are well known (Campbell and Doeg 1989; Chamberlin *et al*. 1991; Whitehead and Robinson 1993), and the entire watershed has been cut at least once. Harvesting continues in private forest lands in the upper watershed, and although rates have declined, localized losses of riparian vegetation have occurred within the City of Courtenay as recently as 2007 (J. Palmer pers. comm. 2008). Land development has been most intense in the lower watershed within the boundaries of Courtenay (population size ~20,000). This has led to a loss of channel complexity and stream bank degradation (Beamish *et al*. 1999), although the habitat remains relatively healthy for an urban stream (Bainbridge and Woodland 1999). Development continues in Courtenay and localized infilling of the floodplain has occurred recently (J. Palmer pers. comm. 2008). The Village of Cumberland (population ~2,800) recently expanded its boundaries to include approximately half of the upper watershed, increasing the likelihood of additional residential and industrial development

in the area (Ellefson 2003). In 2001 the Inland Island Highway bisected the watershed (Highway 19, Figure 4), through a wetland that formerly connected it to neighbouring Piercy Creek and crossing the mainstem via a wide free-span bridge (Ellefson 2003).

Several small-scale habitat complexing, bank stabilization, fish passage and riparian planting projects have been undertaken in the lower watershed by the Morrison Creek Streamkeepers since 2000 (Morrison Creek Streamkeepers 2008). A logging company and the Vancouver Island Highway Project have also completed similar habitat improvements in the headwater areas (Ellefson 2003). Although primarily aimed at salmonids, most of the projects may provide some benefits to lamprey through the reduction of sediment loads, improved water quality, and in the case of the *marifuga* form, a potentially increased prey base.

Habitat protection/Ownership

No federal lands abut Morrison Creek. Provincial lands are limited to three small parcels in the headwaters, none formally protected. The City of Courtenay controls most of the streamside lands in the lower watershed, although residential development backs onto at least one bank for approximately 750 m of channel according to Project Watershed maps (Morrison Creek Streamkeepers 2008). Puntledge Park (City of Courtenay, 4.1 ha) contains the confluence of Morrison Creek and the Puntledge River and approximately 250 m of Morrison Creek mainstem. Morrison Park (City of Courtenay and Nature Trust of BC, 12.8 ha) is forested and immediately upstream of Puntledge Park Elementary School. In total, less than 5% of the watershed area is currently considered protected.

The headwaters are dominated by private forest lands, although two small hobby farms and a small (12 unit) subdivision are also found there. The Linton Environmental Conservation area, a 9.7 ha parcel encompassing wetlands, 500 m of the Morrison Creek mainstem and portions of seven tributaries, was established in 2000 and is monitored by the Nature Trust of British Columbia, as are the habitat mitigation channels constructed by a logging company (2.8 ha).

In-stream habitat is protected from “Harmful alteration, disruption, or destruction” by the federal *Fisheries Act* (Revised Statutes of Canada 1985, c. F-14, s. 35-36), although the Auditor General of Canada (2009) recently found that the *Fisheries Act* is generally failing to protect fish habitat due to inadequate administration and enforcement. The federal *Species at Risk Act* prohibits damage or destruction of a species’ residence or of critical habitat that is identified in a recovery strategy or action plan (Statutes of Canada (SC), 2002, c.29, s.33, 57, 58). Neither has been defined for the Western Brook Lamprey (Morrison Creek Population) (National Recovery Team for Western Brook Lamprey (Morrison Creek Population) 2007).

BIOLOGY

There are few empirical data available on the lampreys of Morrison Creek and most are derived from laboratory studies (Beamish 1985, 1987; Beamish and Withler 1986) where extension to biology in nature can be problematic. Much of the following information is gleaned from studies on populations of *L. richardsoni* in other watersheds (Pletcher 1963 as described by McPhail, 2007; McIntyre 1969; Stone 2006).

Life cycle and reproduction

Lamprey species typically follow one of three life histories. They are anadromous and parasitic, freshwater and non-parasitic, or freshwater and parasitic (Potter 1980b; Beamish 1987; Youson and Beamish 1991). Freshwater life histories are believed to be favoured when the cost of migration exceeds the value of marine food resources (Bell and Andrews 1997). The non-parasitic lampreys appear to have evolved from parasitic species. i.e., *L. richardsoni* probably evolved from *L. ayresii* (Vladykov and Kott 1979). In general, freshwater non-parasitic lampreys are characterized by smaller body size, lower fecundity, a longer ammocoete stage, less well-developed dentition, and accelerated sexual maturation following metamorphosis relative to closely related parasitic species (Potter 1980b). For the Western Brook Lamprey (Morrison Creek Population), there is no evidence that the *marifuga* form spawns separately from the typical form in nature. The presence both of parasitic and non-parasitic varieties within a single taxon of freshwater lampreys is a phenomenon reported, albeit rarely, from a number of other lamprey species (see Docker 2009, for review).

Western Brook Lamprey (Morrison Creek Population) are reported to spawn in April, although the period likely extends into May, as spent, dying adults are found into June (McDermott 2003). More protracted spawning periods, extending into July are reported for other populations (Scott and Crossman 1973; Stone 2006; McPhail 2007). Male *L. richardsoni* begin building nests in response to the presence of a ripe female. Both sexes participate, although males do most of the work. They excavate a small depression (10-12 cm wide, 5 cm deep) by vibrating their bodies and carrying individual stones for short distances using their oral disc. They usually spawn in pairs, although group spawning with multiple males and females is also common (Stone 2006), and different pairs or groups may use the same nest site (McPhail 2007). When nest construction is well advanced, the female attaches to a rock on the upstream edge of the nest, the male glides his oral disc over her body, then attaches himself to her head and coils around her to align their vents and squeeze her body to stimulate the release of small batches of eggs. The spawners pause after each deposition to cover the eggs or to continue nest building before spawning again (McIntyre 1969; Stone 2006; McPhail 2007). This behaviour, with minor variations, is commonly observed in other lamprey species (Manion and Hanson 1980). Fecundity varies with body size from 1,100 to 3,700 eggs (McPhail 2007). All lampreys are semelparous, i.e., they die after spawning (Larsen 1980).

In the laboratory, *L. richardsoni* eggs hatched within 30 days at 10°C and 12 days at 22°C (Meeuwig *et al*. 2005). In the Salmon River (Langley, BC) larvae remain in the gravel for an additional two to three weeks before emerging at night to be swept downstream into calm water, where they burrow into the mud (Pletcher 1963). Although largely sedentary, ammocoetes can and do move to more favourable habitats in response to disturbance or as body size increases (Potter 1980a). Lamprey ammocoetes are efficient digesters of organic detritus, which constitutes the great majority of their diet (> 80% by volume), although phytoplankton and the occasional zooplankter are taken (Moore and Mallatt 1980; Sutton and Bowen 1994; Mundahl *et al*. 2005). The ammocoete stage lasts from three to seven years and is believed to vary considerably among populations (Scott and Crossman 1973; McPhail 2007), although aging ammocoetes is difficult (Beamish and Medland 1988; Meeuwig and Bayer 2005). Non-parasitic forms generally have a longer ammocoete stage (Potter 1980a), but the duration of the ammocoete stage in the Western Brook Lamprey (Morrison Creek Population) is unknown.

Ammocoetes in Morrison Creek begin metamorphosis in July or August and the process is complete by October (Beamish 1987). Non-parasitic lampreys do not feed during metamorphosis and show intestinal atrophy during this process (Larsen 1980). Individuals emerge from the substrate in September. At this stage the typical and *marifuga* forms are very difficult to distinguish, but by November, the newly acquired teeth of the typical form have become blunt and peg-like (McDermott 2003). Metamorphosed individuals showed the first external signs of sexual maturation in April and had completed the process by early May (Beamish 1987). The initiation of the development of secondary sexual characteristics, gonadal maturation and ovulation are not related to day length or temperature, but may depend on a metabolic signal from starvation (Larsen 1980). In Morrison Creek, spawning is complete and all adults are dead by June (McDermott 2003).

Ammocoetes held in the laboratory by Beamish (1985, 1987) metamorphosed in October and were held over winter. A fraction became the *marifuga* form (2 out of 18 in 1985 and 1 out of 4 in 1987), beginning to turn silver in March. In these individuals, the teeth remain sharp, the intestine did not atrophy, full sexual maturity was delayed for a further year, and a characteristic silver colour with pronounced counter-shading was acquired (Beamish 1987; Youson and Beamish 1991). Beamish (1985) found that they fed readily on live and dead fishes when held in aquaria. They attacked live Coho Salmon by opening a small wound on the flank and remaining attached to feed through it, although this has yet to be observed in the wild (R.J. Beamish pers. comm. 2008). Dead fish were taken in chunks and sometimes dragged into crevices. Feeding began in July, was most active in September (Beamish 1987), and ceased by mid-November (Beamish 1985). They grew an average of 6.3 cm (8.0 g) over the year (Beamish 1987).

The sex ratio of the *marifuga* form is heavily skewed at ~ 80% male. In one survey (Beamish 1985), 19 of 24 lampreys sampled were males and in another (Youson and Beamish 1991), 21 of 26 were males. Sexual maturation is also slowed relative to the typical *L. richardsoni* form, and metamorphosis may be slower and incomplete, especially in females (e.g., the intestine does not atrophy completely). Males were capable of feeding when mature sperm were present in the gonad (Beamish 1987). The concurrent presence of mature sperm and feeding in Western Brook Lamprey (Morrison Creek Population) is unusual; known parasitic species delay gonadal maturation when in the feeding phase and in non-parasitic species, gonadal maturation is coincident with intestinal atrophy (Youson and Beamish 1991). All *marifuga* males examined had mature gonads containing sperm by early July, but displayed no external secondary sexual characteristics. All females were immature or showing the first signs of maturation in July (Beamish 1985; Youson and Beamish 1991). One female and four males survived a full year after metamorphosis and spawned and died in the laboratory during the typical April-June spawning period in nature. The lifespan from the onset of metamorphosis of the *marifuga* form was two years (Figure 5), identical to that of *L. ayresii* (Beamish 1980). In Morrison Creek, the *marifuga* form first appears in traps in late March, but most are caught between June and early August, but not after mid-August (Beamish 1985).

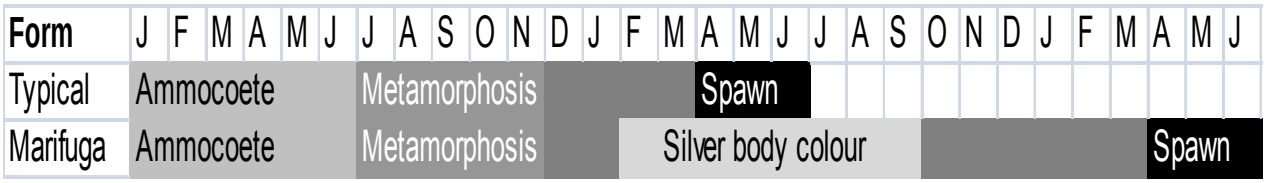

Figure 5. Life history time line for the two forms of *Lampetra richardsoni* found in Morrison Creek. Both spend several years (3-7 in other populations) as ammocoetes prior to the time line's beginning. The *marifuga* time line is derived from laboratory-held individuals, which may differ from those in the wild. They began feeding during July of their silver phase, continuing until October or November.

Predation

Eggs, ammocoetes and adults of *L. richardsoni* are preyed upon by a variety of fishes and other wildlife, although the extent of losses is unknown. *L. richardsoni* are probably most vulnerable as eggs, newly emerged larvae, and as live or spawned out adults as demonstrated for Pacific Lamprey (Close *et al*. 2002). Ammocoete mortality is believed to be relatively low except during emergence (Potter 1980a). Likely predators known to inhabit Morrison Creek or the Puntledge River include Coho Salmon, resident and anadromous Coastal Cutthroat Trout, *O. clarkii clarkii*, and Rainbow Trout/Steelhead, *O. mykiss*, Coastrange Sculpin, *Cottus aleuticus,* Prickly Sculpin*, C. asper*, and Dolly Varden Char, *Salvelinus malma* (McPhail 2007; Province of BC 2008). In the laboratory, juvenile Coho Salmon feed readily on emerging larvae (although larger ammocoetes are reportedly unpalatable) and Ravens (*Corvus corax*) have been observed eating spawning adults (Scott and Crossman 1973).

Physiology

Unlike post-metamorphic *L. ayresii*, neither form of Western Brook Lamprey (Morrison Creek Population) is able to osmoregulate in seawater (Beamish 1985). Egg mortality is temperature-sensitive in *L. richardsoni.* Those incubated above 18^{o}C had significantly more mortalities and abnormalities than those incubated in cooler water. The temperature of zero development is estimated to be at 4.9^{o}C (Meeuwig *et al*. 2005). Lamprey ammocoetes are known to abandon their burrows when dissolved oxygen levels are very low; approximately 1.25 mg/l at 15.5^{o}C (Potter 1980a).

The male-skewed sex ratio seen in the *marifuga* form may be related to pituitary function, which is involved in both sexual maturation and intestinal atrophy in lampreys (Larsen 1980; Docker 2009). In *L. fluviatilis*, hypophysectomy (pituitary removal) prevented gonads from producing the hormones responsible for secondary sex characters, intestinal atrophy, and death following spawning, and particularly extended longevity in males (Larsen 1980). It also interrupted spermatogenesis less than oogenesis, which may explain the asynchronous egg development observed in *marifuga* females (Youson and Beamish 1991). A recently reported polymorphic population of Arctic Lamprey *L. camtschaticum* includes a “praecox” form which is 92% male (Kucheryavyi *et al*. 2007). Previous studies have suggested that divergent feeding types—e.g., praecox (Beamish 1985) and non-parasitic (Hubbs 1971) lampreys—develop more readily in males (see Docker 2009).

Dispersal/Migration

Both the typical and *marifuga* forms are believed to remain in Morrison Creek for their entire life cycle (R.J. Beamish pers. comm. 2008). Adults may migrate upstream before spawning (Renaud 1997). Larvae are typically swept away by the current upon emergence from the nest (June or July), passively dispersing downstream into suitable ammocoete habitats (McPhail 2007). There are no known barriers to movement for lamprey of any life stage within Morrison Creek (Ellefson 2003).

Interspecific interactions

The *marifuga* form is assumed to be an ectoparasite (and/or carcass scavenger) on other fishes in Morrison Creek, based on its behaviour in the laboratory (Beamish 1985). In Morrison Creek, prey/hosts could include Coastal Cutthroat Trout, Rainbow Trout/Steelhead, Coho Salmon, Pink Salmon (*O. gorbuscha*), Chinook Salmon (*O. tshawytscha*), and Chum Salmon (*O. keta).* Cannibalism was also noted in the laboratory (Beamish 1985). There is no evidence, however, of parasitism in the wild. Between 2002 and 2008 over 50,000 juvenile Coho Salmon, Rainbow Trout and Cutthroat Trout were captured in a fish fence at the outlet of Morrison Creek (Morrison Creek Streamkeepers (Table 2). None had attached lamprey or visible scars (Jim Palmer pers. comm. 2008). This suggests that feeding is limited in extent and/or to items other than juvenile salmonids (Beamish 1985, 2008). The fish fence, however, is operated in March and April, which is well outside the reported feeding season for

marifuga held in the laboratory; July to October (Beamish 1985). Competition for spawning sites and as ammocoetes is possible between the two forms of *L. richardsoni*, and with Pacific Lamprey, which also occurs in Morrison Creek (Beamish and Withler 1986). Beverly-Burton and Margolis (1982) described *Ophioxenos lampetrae*, a digenean (flatworm) parasite of *L. richardsoni* ammocoetes from another Vancouver Island river.

Adaptability

Western Brook Lamprey (Morrison Creek Population) are readily kept as ammocoetes in aquaria, but adults of the *marifuga* form are difficult to maintain, frequently dying of fungal infections. In contrast, Beamish (1985) reported little difficulty rearing all other species of British Columbia lampreys in the laboratory. With care, however, Western Brook Lamprey (Morrison Creek Population) can be maintained over winter after metamorphosing, and will spawn in captivity. Survivorship is highest when lampreys are well fed, handled little, and kept in large tanks, singly or in small groups (Beamish 1985).

POPULATION SIZES AND TRENDS

Search effort

Extensive trapping was conducted between 1978 and 1984 during life history studies, but effort, sites, and duration varied among years (Beamish and Withler 1986) and little inventory work has been done since (R.J. Beamish, pers. comm. 2008). The Morrison Creek Streamkeepers, in cooperation with Fisheries and Oceans Canada, have operated a salmonid smolt counting fence at the outlet to Morrison Creek between April and June annually since 2002 (Table 2). Although lamprey are captured and recorded and *marifuga* have been seen in all years for which lamprey are reported, data on the relative abundance of the two forms has not been recorded.

Abundance

No population estimates exist for either *marifuga* or typical *L. richardsoni* in Morrison Creek, and none are possible given existing data. The *marifuga* form has been reported to be caught less frequently than typical spawning stage *L. richardsoni* (Beamish and Withler 1986; J. Palmer pers. comm. 2008). In other streams, ammocoetes of *L. richardsoni* reach densities of up to 170/m^2 (Scott and Crossman 1973).

Fluctuations and trends

The scant available data show no clear indications of major fluctuations in the abundance of Western Brook Lamprey (Morrison Creek Population) (Table 2). Total catches of the *marifuga* form were relatively steady between 1980 and 1984, ranging from 64 to 97 individuals, although effort and protocols varied across years (Beamish

1985). Records from the salmon smolt counting fence show annual catches of *L. richardsoni* ranging from 18 to 53 individuals, but effort varied considerably and it is unclear how many of these were of the *marifuga* form, although some were identified as such based on silver body colouration and the presence of sharp teeth (Table 2, Morrison Creek Streamkeepers 2008; J. Palmer pers. comm. 2008).

THREATS AND LIMITING FACTORS

The lack of information on the general biology of the *marifuga* form limits understanding of the biological limiting factors and some of the threats to the population. A number of general threats have been identified (National Recovery Team for Western Brook Lamprey (Morrison Creek Population) 2007), however, and are discussed below. The threats that have been identified focus on the location of the headwaters of this small stream that is sandwiched between two growing towns and fact that the busiest highway on Vancouver Island (and one of the busiest in BC) runs right through the headwaters. The extremely restricted distribution of Western Brook Lamprey (Morrison Creek Population) exacerbates its vulnerability to all threats.

Land development and forest harvest

Although forest harvest appears to be declining in the Morrison Creek watershed, urban development pressure is clearly increasing, given the expansion of the two towns that border Morrison Creek, and is likely to impact Morrison Creek in the future. The Comox Valley Regional District and the Vancouver Island/Coast Development Region are projected to experience population growth rates of 46% (3rd highest of 29 in BC) and 30% (4th highest of eight in BC) by 2036, respectively (StatsBC 2010). Land use changes and pressures associated with such growth typically alter stream hydrography by increasing peak and reducing base flows (Hollis 1975; Hicks *et al*. 1991). Elevated peak flows can impact fish by incising channels, scouring away gravel containing eggs and displacing individuals (Booth 1990; Bell *et al*. 2001). Reduced base flow can result in elevated water temperatures, reduced dissolved oxygen levels, reduced habitat volume, altered community structure (Grossman *et al*. 1990; Wang *et al*. 2001) and are likely to be exacerbated by climate change in southern British Columbia (Pike *et al*. 2008). Both forest harvest and urban development typically increase sediment delivery to the channel. Deposited sediment inhibits the flow of oxygenated water through gravels to eggs and in extreme cases can infill habitats and destabilize channels (Berkman and Rabeni 1987). Material originating from urban sources may be contaminated with levels of heavy metals exceeding those recommended for aquatic life (Hall *et al*. 1991).

Spills

The Inland Island Highway runs parallel to almost 1 km of the mainstem of Morrison Creek and crosses both the mainstem and a tributary. The risk of a harmful substance entering the creek in an accident is significant over the long term. A severe spill of a toxic substance would probably severely impact the population, although suitable habitat upstream of the highway would provide refuge to a portion of the population.

Landfill leachate

The Pidgeon Lake Landfill (20 ha, established 1964) is the primary waste disposal facility for the Comox Valley Regional District. It is situated atop previously deposited coal mine waste approximately 1,100 m southwest and uphill of Morrison Creek, over an unconfined, highly permeable aquifer. There are no leachate-collection or control provisions and groundwater flows are towards Morrison Creek. Monitoring wells were installed beginning in 1993 and show low pH and elevated levels of sulphate, manganese, and iron relative to drinking water guidelines, but no impacts have been detected in Morrison Creek surface waters (EBA Consulting Engineers 2004).

Declining prey base

The large numbers of Coho Salmon smolts produced in Morrison Creek (see **Habitat** section) may promote the development of feeding lampreys that are usually associated with access to the more productive marine environment (i.e., adequate host availability may be necessary to sustain the existence of feeding and non-feeding types). Pacific salmon and trout (*Oncorhynchus* spp.) abundance, however, is in decline across the British Columbia coast, as it has been for more than a century, due to overfishing and freshwater habitat loss (Schoonmaker *et al*. 2003), exacerbated by recurring periods of low ocean survivorship (Beamish *et al*. 1999; Bradford and Irving 2000). With less than ten years of sampling, and considerable variation between years, the fish fence data (Table 2) show no clear trends specific to Morrison Creek's salmonid populations. Assuming the *marifuga* form does feed within Morrison Creek, these salmonid species are almost certainly its major prey and any decline would be expected to have negative impacts on the *marifuga* form within the population. The presence and ecology of feeding by the *marifuga* form needs to be documented and studied, however, before the potential of this threat can be evaluated.

EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

The conservation status of the Western Brook Lamprey (Morrison Creek Population) (Table 3) includes the *marifuga* and typical forms. As an aquatic species listed as endangered under Schedule 1 of the federal *Species at Risk Act* (*SARA*), the population is protected from harm or capture. *SARA* further prohibits the destruction of a species' critical habitat, but this must be identified in an approved recovery strategy or action plan and the competent minister must make an order before the prohibitions apply (*SARA*, Statutes of Canada 2002, c.29, s. 57-58). Critical habitat has not been defined for the Western Brook Lamprey (Morrison Creek Population), although a schedule of studies to identify the former does appear in the Recovery Strategy (National Recovery Team for Western Brook Lamprey (Morrison Creek Population) 2007). The habitat is provided some protection under the federal *Fisheries Act*.

Table 3. Conservation status of the Western Brook Lamprey (Morrison Creek Population), *Lampetra richardsoni*.

Authority	Status
NatureServe	G4G5T1Q (2005)
B.C. Conservation Data Centre	S1 (2004)
COSEWIC	Endangered (2000)
SARA	Schedule 1, Endangered

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University of British Columbia Fish Museum, Vancouver, BC

Royal British Columbia Museum, Victoria, BC.

University of Washington Fish Collection, Seattle, WA

Canadian Museum of Nature, Ottawa Ont.