COSEWIC
Assessment and Update Status Report

on the

Vancouver Lamprey
Lampetra macrostoma

in Canada

THREATENED
2008

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 reports:

COSEWIC. 2000. COSEWIC assessment and update status report on the Cowichan Lake Lamprey *Lampetra macrostoma* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 9 pp.

Beamish, R.J. 1998. Update COSEWIC status report on the Cowichan Lake Lamprey *Lampetra macrostoma* in Canada, *in* COSEWIC assessment and update status report on the Cowichan Lake Lamprey *Lampetra macrostoma* in Canada. Ottawa. 1-9 pp.

Beamish, R.J. 1986. COSEWIC status report on the Lake Lamprey *Lampetra macrostoma* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 14 pp.

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COSEWIC acknowledges Margaret F. Docker for writing the provisional update status report on the Vancouver Lamprey, *Lampetra macrostoma.* Modifications to the status report during the subsequent preparation of the 6-month interim and 2-month interim status reports were overseen by R. Campbell, and C. Renaud, COSEWIC Freshwater Fishes Specialist Subcommittee Co-chairs.

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COSEWIC
Assessment Summary

Assessment Summary – November 2008

Common name
Vancouver Lamprey

Scientific name
Lampetra macrostoma

Status
Threatened

Reason for designation
This endemic parasitic species, known only from one location in British Columbia, is dependent on the availability of salmonids. Given that its primary prey is juvenile Coho Salmon in Cowichan Lake, the recent and ongoing decline of Coho adults observed returning to the lake is expected to have a significant negative impact on lamprey numbers.

Occurrence
British Columbia

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 and in November 2008. Last assessment based on an update status report.

COSEWIC
Executive Summary

Vancouver Lamprey
Lampetra macrostoma

Species Information

The Vancouver Lamprey is a parasitic eel-shaped fish, with a round, sucker-like mouth which it uses to attach to the side of prey fishes. Adults range in size from 18 to 27 cm. The larger mouth and eye, and its ability to remain in fresh water throughout its feeding phase, distinguish the Vancouver Lamprey from the closely related Pacific lamprey.

Distribution

The Vancouver Lamprey is endemic to Canada, and is known to occur only in Cowichan and Mesachie lakes on southern Vancouver Island, British Columbia, and the lower part of tributaries flowing into these lakes.

Habitat

Adult Vancouver Lampreys spawn on shallow gravel bars in nearshore lake habitat. After hatching, the larval lampreys (ammocoetes) burrow into soft fine sediments or sand. The juvenile lampreys likely seek prey in the open lake.

Biology

The life cycle of the Vancouver Lamprey consists of two distinct stages: a blind, filter-feeding larval stage (which lasts approximately 6 years) and a parasitic phase (probably less than 2 years). Metamorphosis into the juvenile stage (i.e. post-metamorphosis but prior to full sexual maturity) occurs from July to October. After overwintering in the gravel, the juvenile likely begins feeding on young salmonids (especially coho salmon) in the open waters of Cowichan and Mesachie lakes. It is believed that feeding continues for one year and that reproduction occurs the following year from May to August. Lampreys are considered to be semelparous, i.e., reproducing only once before dying.

Population sizes and trends

No population estimates have been made for the Vancouver Lamprey. The number of adults (i.e. sexually mature individuals) in the two lakes has been estimated to be between 1000 and 2000, but quantitative estimates of population size are required. Changes in salmonid scarring rates provide an index of the number of adult lampreys that suggests that there have been fluctuations in population abundance. The magnitude and frequency of such fluctuations have not been sufficiently quantified, but they suggest that the number of Vancouver Lampreys in 1987-1996 (in Mesachie Lake, at least) are lower than they were prior to 1982.

Limiting factors and threats

Vancouver Lamprey, given its restricted distribution, is vulnerable to localized changes in habitat or other localized threats. A thorough threats assessment is difficult given the lack of information available on the general biology, habitat use, and abundance of this species, but a decline in the abundance of their most commonly observed prey (coho salmon) is believed to directly affect abundance of this species. In addition, deliberate destruction of Vancouver Lamprey adults when caught by recreational anglers may be having adverse effects on the adult population. However, the threat from this mortality source is unquantified.

Special significance of the species

The Vancouver Lamprey is endemic to Canada and is known to occur in only two lakes on Vancouver Island. Although there is no commercial value to this species and it preys upon commercially-valuable salmonid species, it contributes to biodiversity and plays an important role in the ecosystem. It is especially important for its scientific value. Lampreys are ancient fish providing insights into the origin and evolution of vertebrates, and the Vancouver Lamprey represents an example of evolutionary divergence.

Existing protection or other status designations

The Vancouver Lamprey was designated by COSEWIC as Special Concern in 1986. The species was re-examined by COSEWIC in November 2000 and designated Threatened. The Vancouver Lamprey is red-listed (i.e. extirpated, endangered, or threatened in British Columbia) by the BC government. It is protected under the federal *Species at Risk Act* (SARA) as a Schedule 1 Species.

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
(2008)

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.

Update
COSEWIC Status Report

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SPECIES INFORMATION

Name and classification

Kingdom:	Animalia
Phylum:	Chordata
Class:	Cephalaspidomorphi
Order:	Petromyzontiformes
Family:	Petromyzontidae
Scientific name:	*Lampetra macrostoma* Beamish 1982
Synonym:	*Entosphenus macrostomus* Beamish 1982. Whereas, some authors (e.g., Hubbs and Potter 1971) considered *Entosphenus* as a subgenus within the genus *Lampetra*, others (e.g., Vladykov and Kott 1979) classified it as a distinct genus. Recent morphological (Gill *et al.* 2003), and genetic (Beamish and Withler 1986; Docker *et al.* 1999) evidence, suggest that *Entosphenus* is sufficiently distinct to be considered a separate genus. This status report will conform to the terminology adopted by the American Fisheries Society Common and Scientific Names of Fishes and use the genus name *Lampetra* (Nelson *et al.* 2004). However, Nelson (2006) recognized *Entosphenus* as a valid genus, making *Entosphenus macrostomus* the scientific name of this species, and the Committee on Names of Fishes is currently reviewing their 2004 decision (Nelson pers. comm. 2007).
Common name:	English: Vancouver Lamprey (Nelson *et al.* 2004) Other: Lake Lamprey, Cowichan Lake Lamprey, Cowichan Lamprey French: Lamproie de Vancouver (Coad 1995) Other: Lamproie de lac, Lamproie du lac Cowichan

The Vancouver Lamprey was initially believed to be a dwarf race of Pacific lamprey (*Lampetra (Entosphenus) tridentata*) that either spent one year in fresh water prior to going to sea or was landlocked (see Beamish 1985). It was described as a distinct species (Beamish 1982) on the basis of morphological and physiological differences (*see* "Morphological Description," below) and differences in spawning time and location that would likely lead to reproductive isolation (*see* "Habitat Requirements" and "Life Cycle and Reproduction." below).

The Vancouver Lamprey is probably one of several independently derived freshwater derivatives of the Pacific lamprey, including others on Quadra and Nelson islands (Beamish 1982) and on the Sechelt Peninsula (Baillie pers. comm. 2007; Taylor pers. comm. 2007) (*see* "Canadian Range," below). The phylogenetic identity of such recently and independently derived forms is complex (i.e. whether each independently derived freshwater form merits species status). Freshwater-resident populations are known in other anadromous lamprey species (e.g., sea lamprey, *Petromyzon marinus*; Arctic lamprey, *Lethenteron camtschaticum*; European river lamprey, *Lampetra* *fluviatilis*; Hardisty 2006), without being accorded species status (but see morphological description of *Lampetra macrostoma*, below). Likewise, freshwater and anadromous forms of other postglacial fish species are common in British Columbia (e.g., rainbow trout and steelhead, *Oncorhynchus mykiss*; kokanee and sockeye salmon, *O. nerka*; freshwater and anadromous threespine stickleback, *Gasterosteus aculeatus*; see Taylor 1999). Other freshwater lampreys that are presumably derivatives of the Pacific lamprey (e.g., Klamath River lamprey, *L. similis*, and Miller Lake lamprey, *L. minima*) have been recognized in Oregon and California (Vladykov and Kott 1976; Bond and Kan 1973; Gill *et al.* 2003), but they are genetically distinct from the Pacific lamprey (*see* "Genetic Description," below). As other freshwater derivatives of the Pacific lamprey and their relationship to the Vancouver Lamprey are studied in more detail, the taxonomic status of the Vancouver Lamprey may be revised.

Morphological description

The Vancouver Lamprey has a cylindrical, eel-like, scaleless body with no paired fins. It has seven pairs of gill openings, and its skeleton is cartilaginous. It has a small caudal fin, and two distinct dorsal fins (Figure 1).

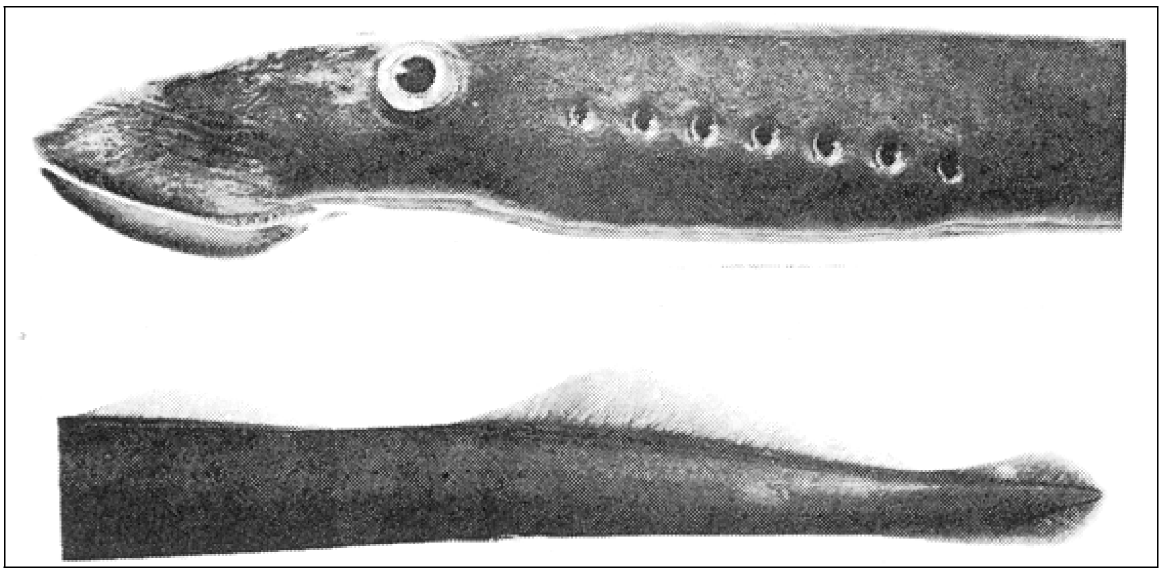

Figure 1. Head and tail regions of a 22.8 cm Vancouver Lamprey *Lampetra macrostoma* photographed live and captured in Cowichan Lake, November 1980. Photograph by R.J. Beamish (with permission).

The adult is blue-black or dark brown on its dorsal surface, with a lighter ventral surface. It has a round suctorial mouth with many sharp, horny teeth, and the tongue also has many sharp teeth. The eyes are large and located high on the head. Vancouver Lamprey adults range in size from 18 to 27 cm (average 20.6 cm), with females being slightly smaller than males (Beamish 1982). It can be morphologically distinguished from the closely related Pacific lamprey mostly by the relatively larger size of its oral disc. When a Vancouver Lamprey adult is viewed from above, the diameter of the mouth is noticeably wider than its head, whereas the diameter of the mouth of a Pacific lamprey adult is not wider than its head or body (McPhail and Carveth 1993). The disc of the Vancouver Lamprey has approximately two-thirds more surface area than that of a similar sized Pacific lamprey and there are some differences in dentition (Beamish 1982). In addition, the Vancouver Lamprey is generally smaller than the Pacific lamprey; mature Pacific lampreys range in length from 13 to at least 72 cm (Beamish 1980) and average approximately 54 cm in length (Scott and Crossman 1973). Other morphological differences include a relatively larger eye, longer prebranchial length and, possibly, a shorter trunk length in the Vancouver Lamprey compared to the Pacific lamprey (Beamish 1982). Internally, the velar tentacles in *L. macrostoma* are very weakly pigmented relative to the darkly pigmented base and lower portion of the velar tentacles of *L. tridentata* (Beamish 1982). These differences in body proportion are consistent with those found between other recognized lamprey species. For example, the European and North American river lampreys (*Lampetra fluviatilis* and *L. ayresii*, respectively) can be distinguished based on relatively small differences in body proportions (Vladykov and Follett 1958), yet they are genetically very distinct (Docker *et al.* 1999). Physiologically, the Vancouver Lamprey also differs from the Pacific lamprey in its ability to osmoregulate in fresh water throughout its entire life cycle; feeding-phase Pacific lampreys, in contrast, are incapable of surviving in fresh water (Beamish 1982; Clarke and Beamish 1988).

As adults, the Vancouver Lamprey can be distinguished from the other lampreys found in British Columbia (the river and western brook lampreys, *Lampetra (Lampetra) ayresii* and *Lampetra (Lampetra) richardsoni*, respectively) largely by differences in tooth patterns. The supraoral lamina (the tooth bar immediately above the mouth) has three teeth in Vancouver and Pacific lampreys, but only two teeth in the river and western brook lampreys (see McPhail and Carveth 1993).

The larvae, known as ammocoetes, lack teeth and true eyes (possessing instead an “eye spot,” in which the developing eye is encased under a transparent patch of skin), and possess an oral hood rather than the sucking disc characteristic of adult lampreys. Ammocoetes may be as large as 17 cm in length (Beamish 1982). No reliable characters have been found to distinguish larval Vancouver and Pacific lampreys (Richards *et al.* 1982), but they can be distinguished from river and western brook lampreys by differences in pigmentation. In Vancouver and Pacific lamprey ammocoetes, the caudal ridge (a thickening in the tail region formed by the end of the notochord and its overlying tissues) is lightly pigmented and the body and head are extensively pigmented, whereas the tail is darkly pigmented in the caudal ridge area in western brook lamprey ammocoetes; in the river lamprey, both the tail and head regions are lightly pigmented (Richards *et al.* 1982; *see also* McPhail and Carveth 1993).

Genetic description

The only genetic study published to date (Docker *et al.* 1999) compared 735 base pairs of mitochondrial DNA sequence in Vancouver and Pacific lampreys, and found the two species to be genetically indistinguishable at these two genes (cytochrome b and ND3 genes). This suggests recent divergence between these two species, i.e. that the Vancouver Lamprey is a recent freshwater derivative of the anadromous Pacific lamprey. Docker *et al.* (1999) approximated that divergences more recent than 70,000 years could not be detected with the sequence data they examined, and Beamish (1982) suggested that Cowichan Lake drainage patterns changed about 10,000 years ago, resulting in reproductive isolation of the *L. macrostoma* lineage from sea-run *L. tridentata* in the Strait of Georgia. Although the other presumptive *L. tridentata* derivatives, the Klamath River and Miller Lake lampreys were genetically distinct from anadromous *L. tridentata* (Docker *et al.* 1999), the Pit-Klamath brook lamprey (*L. lethophaga*) from California was also genetically indistinguishable from *L. tridentata* (Docker *et al.* 1999) and a lack of fixed sequence differences between closely related lamprey species is common (e.g., Schreiber and Engelhorn 1998; Docker *et al.* 1999; Lorion *et al.* 2000). Further work using higher-resolution genetic markers (e.g., microsatellite loci) is required to better determine the level of genetic differentiation between *L. macrostoma* and *L. tridentata*. Molecular genetic assessments to consider population structure within the Cowichan Lake system-particularly looking at differentiation between Cowichan River ammocoetes (presumably *L. tridentata*) and lake specimens (presumably *L. macrostoma*)-are to be carried out at the University of British Columbia (Taylor pers. comm. 2007).

Designatable units

The Vancouver Lamprey is known to occur only in Cowichan and Mesachie lakes on southern Vancouver Island, British Columbia (Beamish 1982). Juveniles (i.e. post-metamorphosis but prior to full sexual maturity) and adults (sexually mature individuals; *see* “Life Cycle and Reproduction,” below) have also been caught in the creek connecting these lakes (Mesachie Creek), largely in the downstream traps of an enumeration fence, but at least five lampreys have also been caught in the upstream trap (data from Baillie pers. comm. 2007; *see* “Distribution,” below). This suggests gene flow between the lakes. There is, therefore, no evidence to suggest the existence of more than one designatable unit under the COSEWIC Guidelines for Recognizing Designatable Units Below the Species Level (COSEWIC 2005).

Eligibility

The Vancouver Lamprey is a recognized species (Nelson *et al.* 2004). It is a Canadian endemic with reproducing populations in two small lakes on Vancouver Island.

DISTRIBUTION

Global range

This species is found only in Canada (*see* "Canadian range," below).

Canadian range

The Vancouver Lamprey is endemic to Canada, and is found only in Cowichan and Mesachie lakes on southern Vancouver Island, British Columbia (Figure 2), and the lower part of tributaries flowing into these lakes (Beamish 1982). The Vancouver Lamprey has not been observed below the lake outlets (Beamish 1982), even though there are no physical barriers in these lakes that prevent access to the sea.

Cowichan and Mesachie lakes are adjacent and connected via Bear Lake (which is an embayment of Cowichan Lake and connected to Cowichan Lake by a slow-moving channel) and Mesachie Creek (which connects Bear and Mesachie lakes; Figure 2). The Robertson River flows into Bear Lake (Baillie pers. comm. 2007), and Mesachie Lake has one tributary steam on the east side of the lake (Harris pers. comm. 2007). Since the Mesachie Lake outlet stream dries up or has only reduced intermittent flow during the summer (Beamish pers. comm. 2008), it does not provide suitable habitat for lamprey ammocoetes. Beamish (2001) reported that no lampreys have been found in Mesachie Creek, and L.N. Harris and E.B. Taylor found only a single ammocoete in 2007, despite electrofishing the entire length of the creek from Bear Lake to Mesachie Lake (Harris pers. comm. 2007). An enumeration fence that was operated on Mesachie Creek between 1986 and 1995, immediately downstream of the Forestry Road bridge, likewise captured a single ammocoete. However, this enumeration fence caught up to 60 lamprey juveniles or adults per year (data from Baillie pers. comm. 2007; Figure 3a, 4; *see* "Population Sizes and Trends," below). Numerous ammocoetes have been captured in Bear Lake, at the mouth of the Robertson River (Harris pers. comm. 2007). No ammocoetes were collected in the channel that connects Bear Lake to Cowichan Lake, but very few sites were electrofished in this channel given the depth and method of collection (Harris pers. comm. 2007; *see* "Habitat," below).

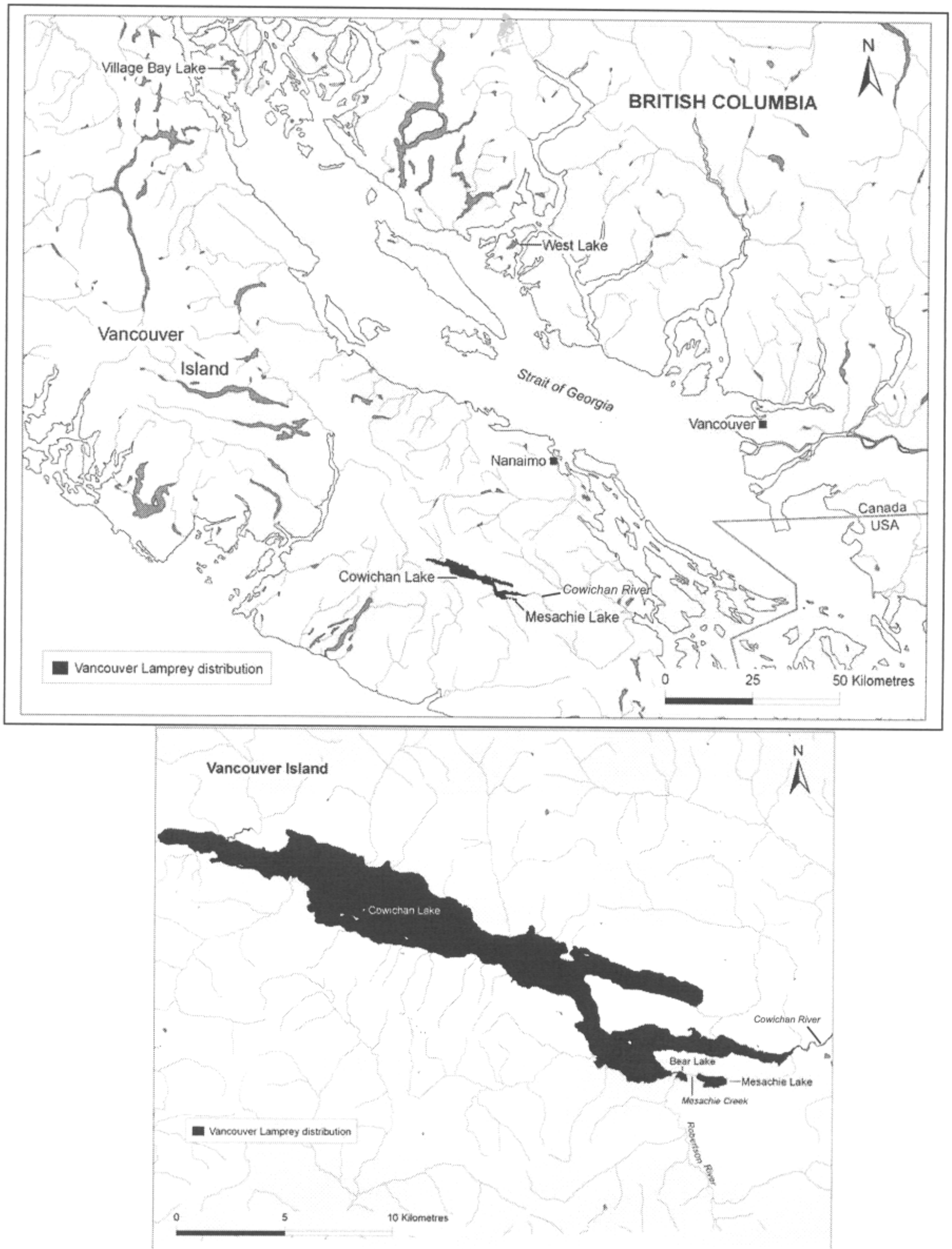

Figure 2. Distribution of the Vancouver Lamprey, *Lampetra macrostoma*, in Cowichan and Mesachie lakes. Other freshwater *Lampetra tridentata*-like lampreys have been reported in Village Bay Lake, West Lake, and Sakinaw Lake (see text, “Distribution”).

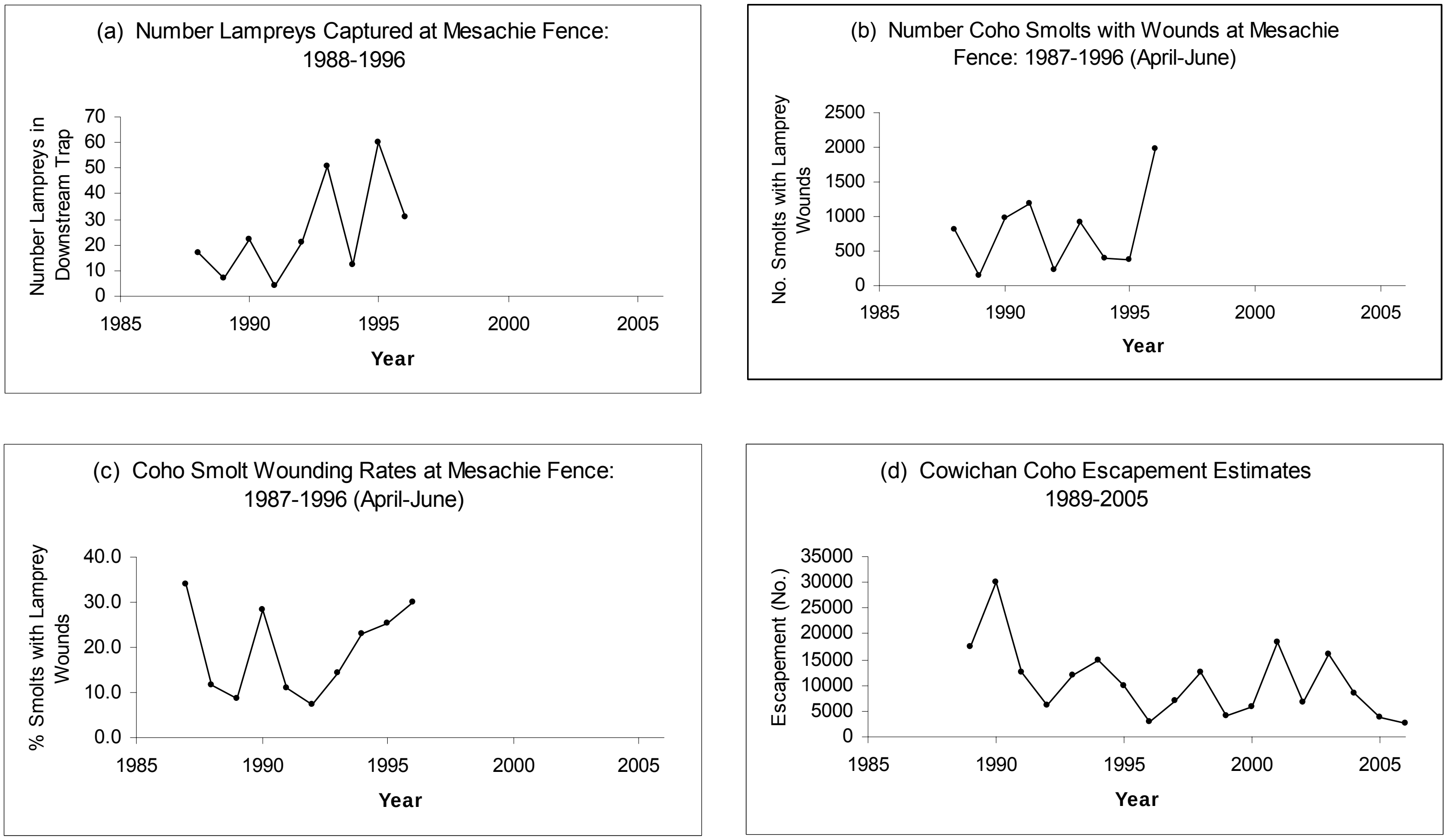

Figure 3. Fluctuations in lamprey numbers, number and percentage of downstream-migrating coho salmon smolts with lamprey wounds, and coho salmon escapement estimates (all data from Baillie pers. comm. 2007).

(a) Total number of lampreys captured in the downstream trap at the Mesachie Creek enumeration fence from 1988 to 1996.

(b) Number of coho salmon smolts with lamprey wounds captured in the downstream trap at the Mesachie Creek enumeration fence from April to June in 1988-1996; 1987 was excluded because data were available only from May 30 to June 2 (see Table 1).

(c) Percentage of coho salmon smolts with lamprey wounds captured in the downstream trap at the Mesachie Creek enumeration fence from 1987 to 1996 (April to June).

(d) Coho salmon escapement estimates for the Cowichan Lake system (including Mesachie Lake) from 1989 to 2006, calculated according to the escapement estimate model used by the Georgia Basin Salmon Stock Assessment unit, Fisheries and Oceans Canada. Escapement prior to 1989 was estimated using less precise methods but, for a general comparison, returns from 1953 to 1988 ranged from 5,000 to 75,000 and averaged 37,900 per year (see text, “Limiting Factors and Threats”).

The known distribution of the Vancouver Lamprey is very limited. Cowichan Lake is approximately 34 km long with a surface area of 6204 ha (62 km^2) (BC Lake Stewardship Society 2005), and Mesachie Lake, the much smaller of the two lakes, is only 2.7 km long with a surface area of 59 ha (0.6 km^2) (Beamish 2001). Although ammocoetes have also been found in the streams that flow into Cowichan Lake, few have been found at distances greater than 100 m from the lake (Beamish 1982). The known distribution of this species, therefore, is restricted to approximately 63 km^2. Its extent of occurrence (EO) according to the COSEWIC guidelines (i.e. using the minimum convex polygon method) is approximately 121 km^2. NatureServe (2006) estimates its range to be approximately 100-250 km^2.

Using 2 x 2 km grid cells intersecting the lakes, an index of area of occupancy (IAO) for the Vancouver Lamprey was estimated at 180 km^2. However, its actual AO would be approximately equal to the surface area of the two lakes (i.e. approximately 65 km^2) since it appears that a large part of each lake-at least in terms of surface area-is utilized when all stages are included *(see* "Habitat Requirements," below). Given the relatively small area of the restricted distribution the use of a 1 X 1 km grid is more appropriate and application of a 1 X 1 km overlaid grid yields an IAO of 125 km^2. The species is only found in the two lakes, and the entire length of the shoreline plus 100 m of the streams have been included in the calculation, this is a clear case where a 1 X 1 km grid is suitable.

There is no information to suggest that there have been changes in the distribution of this species (i.e. any expansions or contractions of its range) since its description in 1982. Little research has been done on this species since the 1980s, but recent surveys by L.N. Harris and E.B. Taylor focusing on the distribution of *L. macrostoma* in the Cowichan Lake system suggest that ammocoetes are widely distributed in the system. Ammocoetes were collected from 16 geographically distinct areas in Cowichan, Mesachie, and Bear lakes (Harris pers. comm. 2007; *see* "Habitat," below). Caudal fin pigmentation of these ammocoetes was consistent with either *L. macrostoma* or *L. tridentata* (Harris pers. comm. 2008; *see* "Morphological description," above), but adult *L. tridentata* have not been found in these lakes (see below). There is no evidence that the extent of its total population or if the population in either lake has changed.

Three additional populations of freshwater *Lampetra tridentata*-like lampreys have been reported in British Columbia (Figure 2): 1) from Village Bay Lake, Quadra Island (Beamish 2001); 2) West Lake, Nelson Island (Beamish 2001); and, 3) Sakinaw Lake, at the north end of the Sechelt Peninsula (Baillie pers. comm. 2007; Taylor pers. comm. 2007). Anadromous *L. tridentata* are found in the Sakinaw Lake system, but a freshwater form which is morphologically different from *L. macrostoma* (Beamish pers. comm. 2008) is also present. Sakinaw Lake supports a COSEWIC-listed sockeye salmon (*Oncorhynchus nerka*) stock, and enumerations of sockeye and coho (*O. kisutch*) salmon smolts leaving the lake show that 5 and 20% of the smolts, respectively, have been attacked by a freshwater-resident lamprey (Baillie pers. comm. 2007). However, the relationship between these additional populations and the Vancouver Lamprey has not yet been studied (Beamish 1982; Taylor pers.

comm. 2007). In addition, Vladykov and Kott (1979) described a landlocked lamprey from Cultus Lake, which is located on the mainland approximately 90 km from Vancouver, but its disc size was smaller (Beamish 1982), and its relationship to the Vancouver Lamprey is also not known. It is possible, if not likely, that these other populations are independently derived freshwater-resident lampreys and do not form a monophyletic taxon with *L. macrostoma* (see Hubbs and Potter 1971 re: independentlyderived nonparasitic lamprey populations). More morphological, physiological, and genetic data would be required before considering these possible populations of *L. macrostoma*. As such the Vancouver Lamprey is considered a distinct species until such time when other populations have been adequately described.

It is believed that the Vancouver Lamprey does not occur sympatrically with the Pacific lamprey but this has not yet been demonstrated conclusively, especially since these two species cannot be distinguished in the larval stage. R.J. Beamish (pers. comm. 2007; Beamish 1982) has never found Pacific lampreys in Mesachie or Cowichan lakes, although Pacific lampreys are common downstream of the outlet to Cowichan Lake (i.e. Cowichan River). However, Beamish (pers. comm. 2007) has stated that he cannot be certain that they do not occur in Cowichan Lake, and earlier records are difficult to interpret given that the lampreys in these lakes were originally identified as *L. tridentata* (e.g., Carl 1953). Many of the lampreys collected at the enumeration fence on Mesachie Creek were identified simply as “lamprey,” but most were recorded as *L. macrostoma* and S. Baillie (pers. comm. 2007) remembers looking for and finding the large oral disc characteristic of this species on most specimens. Two specimens from May 1993 (one in the downstream trap and one in the upstream trap) were recorded as *L. tridentata*, although K. Simpson (pers. comm. 2007) states that this likely was not a positive identification. Further surveys are required to determine whether all lampreys occurring in Cowichan and Mesachie lakes are indeed Vancouver Lamprey.

HABITAT

Habitat requirements

Cowichan and Mesachie lakes are both oligotrophic, a nutrient status typical of coastal lakes in British Columbia (Vancouver Lamprey Recovery Team 2007). The Cowichan Valley experiences a variable climate that is generally warm and dry in summer and mild and wet in winter (Vancouver Lamprey Recovery Team 2007), and these two lakes have temperatures that do not fall below 4ºC. Maximum surface temperature in the North Arm of Cowichan Lake was 24 and 23.5 ºC in 2004 and 2005, respectively, and minimum surface temperatures were 17.5 and 12.5 ºC (BC Lake Stewardship Society 2005).

Adult Vancouver Lampreys have been observed spawning on shallow gravel bars in near shore lake habitat (e.g., at the mouth of several creeks) rather than the riffle areas of streams usually used by other lamprey species. However, since ammocoetes have been found in the lower portions of some lake tributaries, some spawning apparently occurs in tributaries as well (Beamish 1987), although their occurrence in these creeks could also be due to larval dispersal (Harris pers. comm. 2007). Spawning aggregations have been observed at depths ranging from 20 cm to more than 2 m, and actual spawning was observed at the shallower of these depths. However, it could not be determined if spawning occurred in the deeper waters (Beamish 1987).

After hatching, ammocoetes drift a short distance from the nest, where they burrow into soft fine sediments or sand. Beamish (1982) found them to be most plentiful along the edge of Cowichan and Mesachie lakes, most often in close proximity to lake tributaries, although ammocoetes have also been collected quite a distance from the mouths of creeks (Harris pers. comm. 2007). This again suggests that spawning generally occurs in the lake and the ammocoetes remain in the lake (Beamish 1987). Consistent with this suggestion, ammocoetes have been found in Bear Lake, including at the mouth of the Robertson River (Harris pers. comm. 2007), but were not found in the Robertson River itself (Harris pers. comm. 2007) and only two ammocoetes have been found in Mesachie Creek (see “Distribution,” above).

However, spawning in this lamprey species generally occurs in the lake and the ammocoetes remain in the lake. Habitat for Vancouver Lamprey ammocoetes appears very similar to that used by lamprey species from riverine habitats (e.g., Beamish and Jebbink 1994; Beamish and Lowartz 1996; Mundahl *et al.* 2006). Recent electrofishing surveys by L.N. Harris and E.B. Taylor found ammocoetes predominantly where the sediments were composed of medium-fine or fine substrates where there was a layer of organic debris; they found that organic substrates such as decaying leaves or aquatic vegetation were preferable to larger organics that had not yet decomposed (Harris pers. comm. 2007). Ammocoetes were rarely captured in areas where small particle substrates (e.g., silts and clays) dominated or in coarse substrates such as gravels and cobble (Harris pers. comm. 2007). As for their depth distribution, however, relatively little is known as ammocoetes have only been captured using an electroshocker at shallow depths. L.N. Harris and E.B. Taylor were limited to electrofishing at depths of no more than 120 cm, but ammocoetes were found up to this maximum depth (Harris pers. comm. 2007). Habitat that appeared suitable for ammocoetes was found beyond this depth, but dredging would be required to determine the maximum depth distribution of Vancouver Lamprey ammocoetes (Harris pers. comm. 2007).

Relatively little is known about the Vancouver Lamprey during its feeding (juvenile) phase, i.e. between the time of metamorphosis and spawning. The Vancouver Lamprey metamorphoses into a juvenile from July to October, and likely remains in the substrate until the spring of the following year. In the spring, juveniles begin feeding and attack large numbers of young salmonids (Beamish 1987; *see* “Biology,” below). It is assumed that during this time, Vancouver Lamprey seek prey in a variety of locations, including the water column, but the habitat requirements of this life stage are not known (Vancouver Lamprey Recovery Team 2007).

Habitat trends

Recent and ongoing studies are examining the quantity and quality of Vancouver Lamprey habitat (Beamish pers. comm. 2007; Harris pers. comm. 2007); but, at present, habitat trends are not known. The Vancouver Lamprey Recovery Team (2007) reported that there is no indication that substantial habitat loss is occurring, but a recent unpublished study by R.J. Beamish and J. Wade on the critical habitat of the Vancouver Lamprey in Mesachie Lake suggests a decrease in habitat in this lake over the past 20 years (Beamish pers. comm. 2007). Beamish (2001) suggested that increasing siltation of lakes and rivers may be increasing habitat for larval Vancouver Lampreys, but a concomitant loss of shallow water gravel areas for spawning would presumably have an adverse effect. It appears that Mesachie Lake, in particular, has been affected by increasing siltation. Mesachie Lake was used as a log storage area for a local mill during the early 20th century and many logs sunk during this time. During the 1980s, there was a log salvage operation on the lake that resulted in a redistribution of the bottom sediments throughout the lake; sediments would have settled on the lamprey spawning areas (Baillie pers. comm. 2007). Cowichan Lake would have had similar problems due to runoff from logged areas, but likely not to the same extent (Baillie pers. comm. 2007).

Habitat protection/ownership

There are no specific habitat provisions for the Vancouver Lamprey, but there are provisions that protect fish habitat in general. In Canada, all publicly owned waters and associated fish habitat within these waters are protected by the federal *Fisheries Act.* Existing legislation in BC (e.g., the *Fish Protection Act* and riparian protection under the *Forest and Range Practices Act*) will also offer some limited habitat protection. The Vancouver Lamprey will likely also benefit from habitat protection and enhancement efforts aimed at other fish species.

BIOLOGY

Until recently, virtually all the known information about the biology of the Vancouver Lamprey had come from research published by R.J. Beamish (1982), and little research had been done on this species since the mid-1980s. Additional research has recently been conducted by R.J. Beamish and J. Wade (Fisheries and Oceans

Canada) and L.H. Harris and E.B. Taylor (University of British Columbia), and some of their preliminary findings are included in this report. In addition, data from the Mesachie Creek enumeration fence regarding lamprey occurrence records and wounding rates on coho salmon smolts (from 1987 to 1996) have been provided by S. Baillie (Fisheries and Oceans Canada) and were analyzed for this report. The Vancouver Lamprey Recovery Team identified some of the key information gaps that inhibit conservation of this species (Vancouver Lamprey Recovery Team 2007), and many of these information gaps are identified below.

Life cycle and reproduction

Like all lampreys, the Vancouver Lamprey is semelparous, that is, they reproduce only once during their lifetime and die following reproduction; although it should be noted that repeat spawning has been suggested in a few marked Pacific lamprey individuals (Michael 1980, 1984). Beamish (2001) estimated generation time (the average age of parents at the time of reproduction) to be approximately 8 years.

The life cycle of the Vancouver Lamprey consists of two distinct life history stages: a blind, filter-feeding larval stage and the juvenile or adult phase. Beamish (2001) estimated that the larval phase lasts approximately 6 years, and the juvenile or adult phase probably 2 years. However, age estimates from length-frequency curves and statolith banding patterns in other lamprey species (e.g., Medland & Beamish 1987) show that length of the larval stage can vary considerably among individuals, and Beamish (2001) acknowledged that his estimate of life span is an "educated guess."

In the Vancouver Lamprey, reproduction occurs from May to August. Starting the description of the life cycle with the larval phase, hatching would occur approximately 2-3 weeks after fertilization (Piavis 1961; Smith *et al.* 1968). Unlike most other lamprey species where ammocoetes rear in rivers and streams, it appears that Vancouver Lamprey larvae remain in the lake in the vicinity of creeks (Beamish 1982), although ammocoetes have also been collected quite far from tributaries (Harris pers. comm. 2007). Some ammocoetes have been found in the lower portions of some lake tributaries, but few at distances greater than 100 m from the lake (Beamish 1982) and virtually no ammocoetes have been found in Mesachie Creek and Robertson River (Harris pers. comm. 2007; *see* "Distribution," above). Although the biology of the Vancouver Lamprey has not been well studied, it appears that other aspects of the larval phase are similar to other lamprey species. After hatching, lamprey prolarvae burrow into sand, silt and detritus (*see* "Habitat requirements," above) where they feed by filtering microscopic plant and animal material and detritus through the oral hood (e.g., Mundahl *et al.* 2005). Vancouver Lamprey ammocoetes may grow as large as 17 cm, but metamorphosis generally begins at lengths of approximately 12-14 cm (Beamish 1982).

The Vancouver Lamprey metamorphoses into a young adult (juvenile) from July to October (Beamish 1982). Metamorphosing lampreys have been collected in Cowichan and Mesachie lakes from mid-September to mid-November, but the stage of metamorphosis was not as advanced as that of Pacific lamprey collected from the same time period from other areas (Beamish 1982). Following metamorphosis, the juvenile probably over winters in the substrate, and begins feeding in the open waters of Cowichan and Mesachie lakes the following spring (Beamish 2001). Data from the Mesachie Creek enumeration fence show that over 20% of coho salmon smolts captured in the downstream trap in early April bore lamprey wounds (Figure 5); many of these wounds were severe (i.e. open wounds that exposed flesh or viscera) and appeared not to have been made the previous year (data from Baillie pers. comm. 2007; Table 1). Juvenile Vancouver Lampreys readily attack large numbers of young salmonids, especially age 1 and 2 coho salmon (Table 1; Figures 3, 5), coastal cutthroat trout (*O. clarkii clarkii*), and Dolly Varden (*Salvelinus malma*); lamprey wounds were reported at the Mesachie Creek enumeration fence on a small number of these latter two species (data from Baillie pers. comm. 2007). Other species that are present in the lakes and that may be prey for the Vancouver Lamprey include kokanee salmon (*O. nerka*), steelhead and rainbow trout (*O. mykiss*). The Vancouver Lamprey Recovery Team (2007) reported that stocked Atlantic salmon (*Salmo salar*) and brook trout (*Salvelinus fontinalis*) are also present in these lakes and that chinook salmon (*O. tshawytscha*) occur in Cowichan Lake, but S. Baillie has indicated that Atlantic salmon are not present, brook trout have not been seen for several decades, and Chinook salmon are seldom present in Cowichan Lake; Chinook salmon are only present in the Cowichan River and only for a maximum of three months post-emergence (Baillie pers. comm. 2007). Lamprey feeding continues throughout the summer and fall and into the winter (Beamish 1987).

It is believed that reproduction in the Vancouver Lamprey occurs the following spring/summer, i.e. two years after metamorphosis (Beamish 1987). This species appears to experience a relatively short non-feeding period prior to spawning compared to the Pacific lamprey (R.J. Beamish 1980) and many other migratory lamprey species (e.g., F.W.H. Beamish 1980; Larsen 1980; Hardisty 2006), but similar to that of other freshwater-resident parasitic lampreys (e.g., Bergstedt and Swink 1995). The largest sexually immature Vancouver Lamprey reported was 27.3 cm and the largest mature specimen was 25.6 cm (Beamish 1982), implying only a small amount of shrinkage during maturation. In contrast, Pacific lampreys from the Skeena River system may enter fresh water up to one year before spawning and, during this time, decrease approximately 20% in length (Beamish 1980).

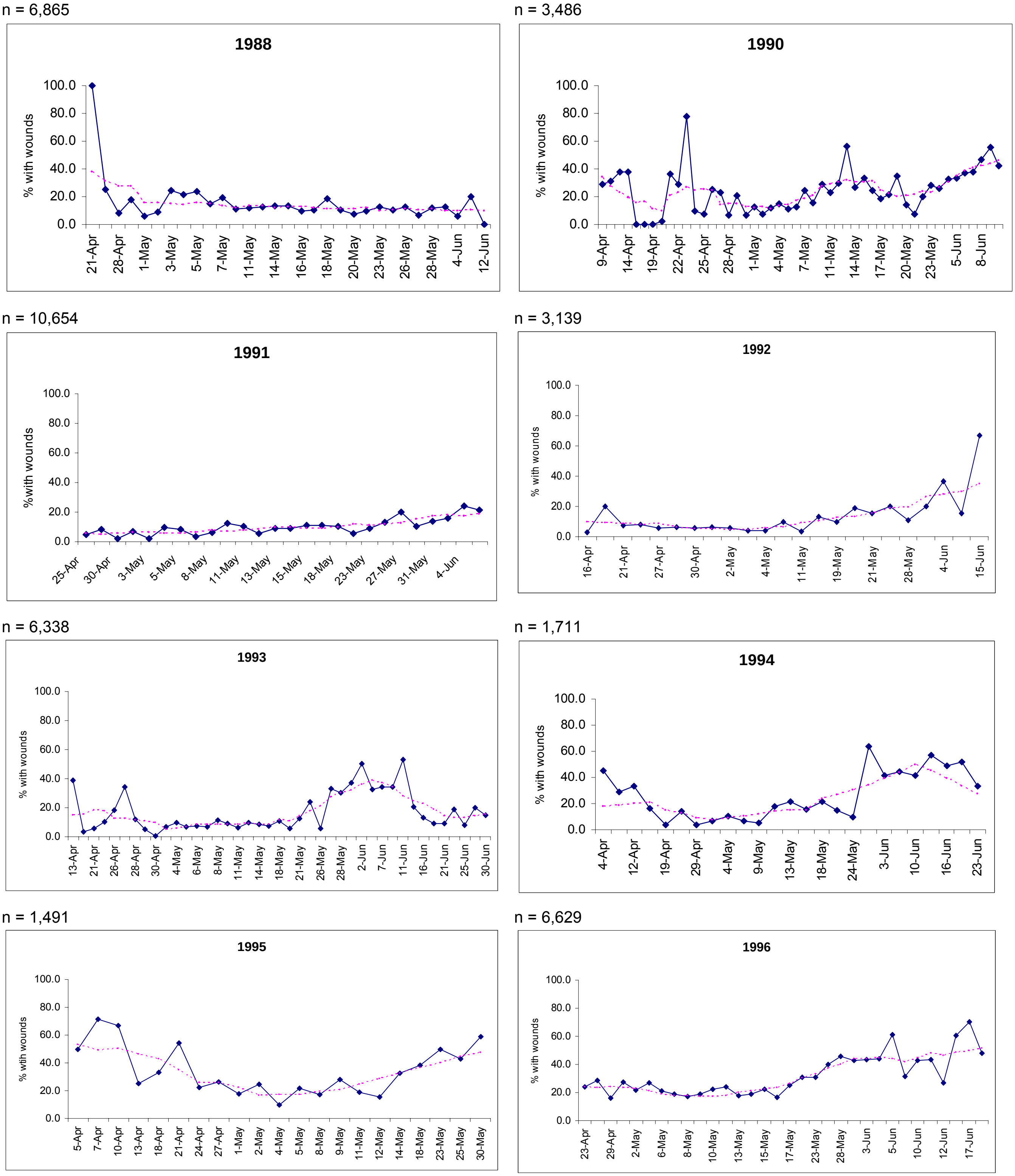

Figure 4. Percentage of coho salmon smolts with lamprey wounds captured in the downstream trap at the Mesachie Creek enumeration fence from April to June in 1988 and 1990-1996 (data from Baillie pers. comm. 2007). Solid line and diamonds are actual values; dotted line shows moving average of 7. Number of smolts on which these calculations are based is indicated on each graph.

Table 1. Wounding rates of coho salmon smolts collected in the downstream trap of the Mesachie Creek enumeration fence from 1987 to 1996, percentage of smolts with multiple wounds (2-6 per fish), and percentage with light, moderate, and severe wounds (light = small wounds that are largely healed; moderate = larger wounds that are mostly healed; severe = open wounds that expose flesh or viscera) (data from S. Baillie pers. comm. 2007).

Year	Dates	Number Smolts Checked for Wounds	Smolts with Lamprey Wounds		Number Smolts Checked for Wound Number, Severity	% Multiple Wounds (2-6 per Fish)	% Light	% Moderate	% Severe
			N	%					
1987	May 30 – June 2	1,845	629	34.1	629	20.3			
1988	Apr 20 – June 27	6,865	810	11.8	391	22.3	33.0	30.1	36.8
1989	Apr 7 – June 7	1,580	139	8.8	121	16.5	23.9	32.1	44.0
1990	Apr 9 – June 13	3,486	987	28.3	266	34.3	38.0	23.0	39.0
1991	Apr 25 – June 5	10,654	1183	11.1	188	21.8			
1992	Apr 16 – June 15	3,139	229	7.3					
1993	Apr 13 – June 30	6,338	919	14.5					
1994	Apr 4 – June 23	1,711	392	22.9					
1995	Apr 5 – May 30	1,491	376	25.2					
1996	Apr 23 – June 19	6,629	1982	29.9					

Spawning aggregations of male and female Vancouver Lampreys have been observed from May to August in Cowichan and Mesachie lakes. Spawning mostly occurs on shallow gravel bars in nearshore lake habitat, although some spawning apparently occurs in tributaries as well (Beamish 1987; *see* "Habitat Requirements," above). Since other lamprey species require clean gravel with interstitial flow or groundwater upwelling for spawning and incubation, it is assumed that the Vancouver Lamprey has similar requirements (Vancouver Lamprey Recovery Team 2007).
Other requirements for spawning are not well known. For example, there are no reports of the water temperature at which Vancouver Lampreys spawn. Pacific lampreys in Washington State spawn at water temperatures ranging from 10.1 to 17.3ºC (from the first week of May to the end of July) (Stone 2006). Beamish (1980) observed spawning in Pacific lamprey in the Stamp and Englishman rivers (Vancouver Island) in April and June, respectively, and Pletcher (1963) reported that April to May was the main spawning period for Pacific lamprey. In general, spawning in the Vancouver Lamprey occurs later than in the Pacific lamprey, but whether this is because of different lake temperatures or different temperature preferences has not been reported.

NatureServe (2006) described the Vancouver Lamprey as a communal spawner. Spawning behaviour has been observed in the laboratory and is reported by Beamish (2001) to be similar to behaviours described by Pletcher (1963) for Pacific and western brook lampreys. In the western brook lamprey, a single nest may contain as many as 12 spawning lampreys, and Pacific lamprey males may mate with more than one female in different nests (Pletcher 1963; *see* Scott and Crossman 1973). There have been no reports of sex ratios in spawning Vancouver Lampreys. The sex ratio of upstream migrating Pacific lamprey was approximately equal in four of five streams studied by Beamish (1980). However, it is not uncommon to have skewed sex ratios at spawning in other lamprey species, and male-biased sex ratios are frequently reported (e.g., Hardisty 1954, 1961). Beamish (1987) suggested that population size may influence sex ratio in the Vancouver Lamprey. It may be possible to determine sex ratios non-invasively in the Vancouver Lamprey as males are readily identifiable by the presence of an external genital papilla (Beamish 1982).

There are no known reports on the fecundity of the Vancouver Lamprey, but since fecundity is generally correlated with adult size (Vladykov 1951), it should be possible to extrapolate from other parasitic lamprey species. Fecundity in populations of the silver lamprey (*Ichthyomyzon unicuspis*) where total length at maturity was approximately the same as that observed in Vancouver Lampreys (i.e. 20-25 cm) averaged 14,310-15,470 eggs per female. No estimates of survival rates are available for Vancouver Lamprey, but lampreys appear to be able to increase in abundance relatively rapidly, indicating a relatively high rate of larval and juvenile survival at low population levels (Beamish 1987). The wide range of survival rates estimated for various stages of the sea lamprey (*Petromyzon marinus*) under different conditions (Howe *et al.* 2004) supports this.

Predation

Nothing has been reported specifically about predation on the Vancouver Lamprey, but salmonids and other fishes are known to prey on the eggs of other lamprey species at spawning time (Scott and Crossman 1973). Predation on the ammocoetes is thought to be minimal since they are buried in the substrate, and it appears that some fish species have an aversion to the taste of large ammocoetes, perhaps as the result of skin secretions (Pfeiffer and Pletcher 1964; *see* Scott and Crossman 1973). Nevertheless, since ammocoetes are used successfully as bait (Close *et al.* 2002), it is assumed that some fish will feed on ammocoetes if given the opportunity. In river habitats, ammocoetes may be vulnerable to predation during scouring events that dislodge them from their burrows (Close *et al.* 2002), but the extent to which this might be important in Cowichan and Mesachie lakes is unknown.

Likewise, nothing has been reported about predation on juvenile and adult Vancouver Lamprey. However, other lamprey species (e.g., downstream migrating Pacific lamprey) are found in the diets of piscivorous fish (Close *et al.* 2002) and adult lampreys spawning in shallow water may be vulnerable to predation by birds [e.g., predation on northern brook lamprey by ravens (Scott and Crossman 1973), or silver lamprey by gulls (Cochran *et al.* 1992)], or other animals [e.g., predation on spawning adult Pacific lamprey by mink (Beamish 1980)].

Physiology

The most notable aspect of the physiology of the Vancouver Lamprey is its ability to osmoregulate in fresh water throughout its entire life cycle (Beamish 1982); feeding-phase Pacific lampreys, in contrast, are incapable of surviving in fresh water due to lack of an osmoregulatory ability in fresh water (Beamish 1980, 1982; Clarke and Beamish 1988). The Vancouver Lamprey can also live and feed in salt water, although it appears to be not as well adapted to sea water as the Pacific lamprey. Beamish (1982) found that *L. macrostoma* in the earlier stages of metamorphosis died when subjected to increasing concentrations of salt water, but was able to survive in full-strength salt water a few months later.

Other than this, little has been reported regarding the physiology of the Vancouver Lamprey. For example, nothing has been reported regarding its thermal tolerance and preference. Survival and development of other lamprey species is known to be sensitive to temperature. The optimal temperature for survival of early life stage sea lampreys (Piavis 1961; Rodríguez-Muñoz *et al.* 2001) and western brook and Pacific lampreys (Meeuwig *et al.* 2005) is 18-19ºC. At higher temperatures (22ºC), survival was significantly reduced (Piavis 1961; Meeuwig *et al.* 2005) and developmental abnormalities increased (Meeuwig *et al.* 2005). At lower temperatures, the response varied among species: no sea lamprey embryos survived at temperatures below 15.6ºC (Piavis 1961); whereas Meeuwig *et al.* (2005) found survival in western brook and Pacific lampreys at 14 and 10ºC to be similar to that at 18ºC.

Dispersal/migration

Available evidence suggests that the Vancouver Lamprey has exhibited limited dispersal, i.e. remains within Cowichan and Mesachie lakes. No Vancouver Lampreys have been observed below the lake outlets even though there are no physical barriers that prevent access to the sea (Beamish 1982). The Vancouver Lamprey is not “landlocked”; therefore, it appears to be non-anadromous and does not undergo long-distance migration (NatureServe 2006).

Indirect evidence, however, suggests that the Vancouver Lamprey moves between Cowichan and Mesachie lakes. Although Beamish (2001) reported that no lampreys have been found in Mesachie Creek (which connects the two lakes), juvenile and adult Vancouver Lampreys have been noted in the enumeration fence that was operated on this creek between 1987 and 1996 (Figures 3, 4). Lampreys were caught largely in the downstream traps at this fence (up to 60 per year; Figure 3), but at least five lampreys were caught in the upstream trap (data from Baillie pers. comm. 2007). Although it is possible that the lampreys were not moving between the two lakes and rather were entering the traps for other reasons (e.g., seeking a dark refuge), the number of fish captured in the downstream trap was generally highest in May (Figure 4), which could coincide with their downstream movement.

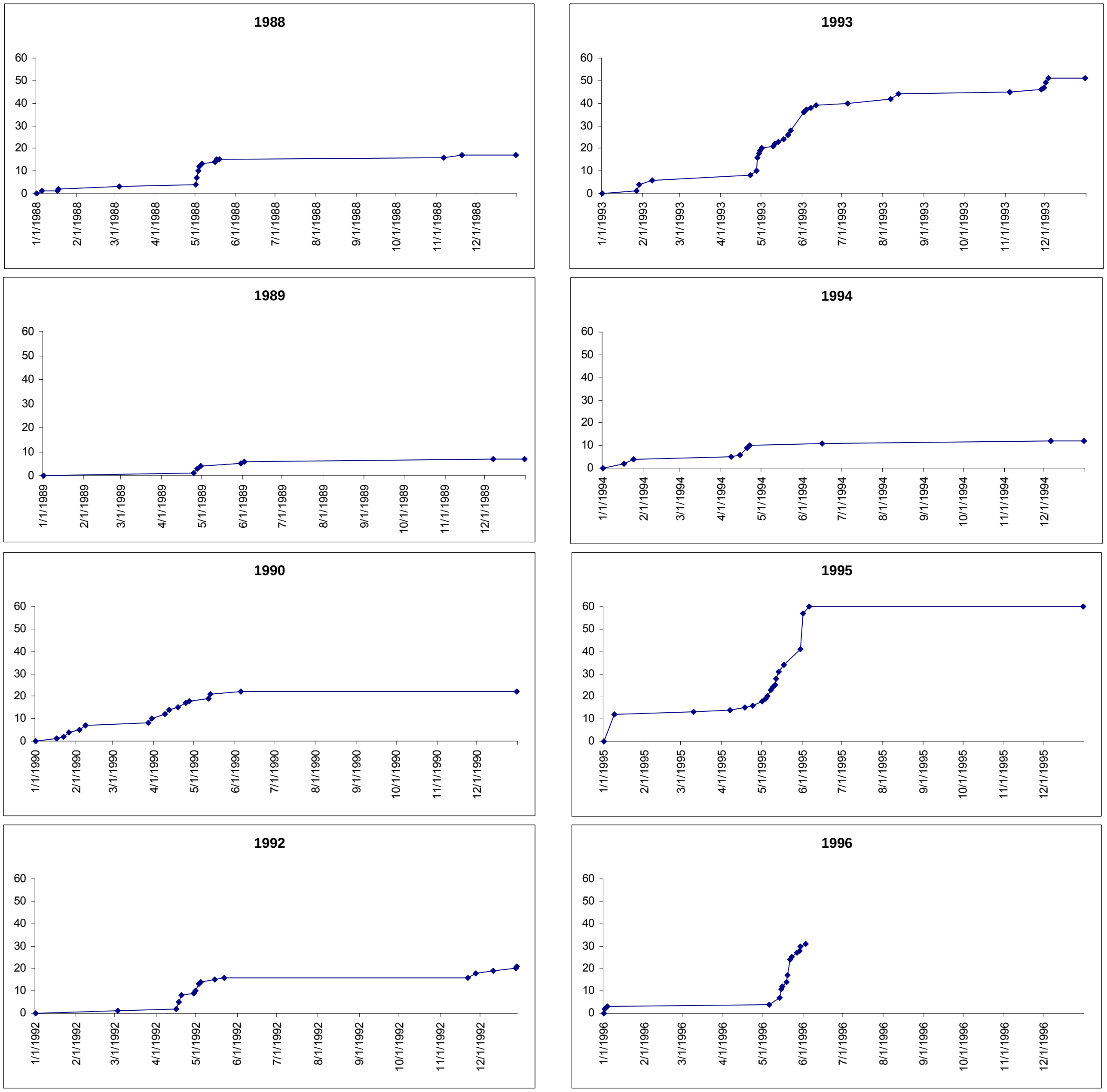

Figure 5. Cumulative number of lampreys collected in the downstream trap at the Mesachie Creek enumeration fence in 1988-1990 and 1992-1996. Only four lampreys were caught in 1991. The fence was not operated from approximately July to September each year, and operation ceased on June 19, 1996 (data from Baillie pers. comm. 2007).

Little is known about dispersal within each lake, but observations in this and other lamprey species suggest that the Vancouver Lamprey would move freely among suitable habitats within each lake. Although larval dispersal is likely more limited than that of river-rearing species which undergo passive downstream dispersal (e.g., Derosier *et al.* 2007), the juvenile Vancouver Lamprey apparently move to open waters to feed and back to nearshore areas to spawn. In other lamprey species, there is no evidence that adults home to their natal spawning sites (Bergstedt and Seelye 1995; Fine *et al.* 2004). NatureServe (2006) based on the primary information from (1987, 2001), considered the Vancouver Lamprey locally migrant, given this apparent tendency to migrate between lakes and spawning sites. Lin *et al.* 2008 suggest that some genetic structuring is evident in Pacific lampreys at a broad geographic scale, although Vancouver Lamprey is not included in their study.

Interspecific interactions

During their feeding phase, Vancouver Lampreys require large numbers of young salmonids, predominantly coho salmon, but also coastal cutthroat trout, and Dolly Varden (Beamish 1982; *see* “Life Cycle and Reproduction,” above). Carl (1953) reported that 80% of the fish examined from Cowichan Lake showed signs of having been attacked by lampreys, and Beamish (1982, 2001) reported that up to 50% of fish collected throughout the years in Mesachie Lake showed evidence of lamprey attacks. Up to 34% of the coho salmon smolts caught in the downstream trap at the Mesachie Creek enumeration fence between 1987 and 1996 (from April to June) bore lamprey wounds, although scarring rates were as low as 7.3% in 1992 (Table 1; *see* “Population Sizes and Trends”). From 1987 to 1991, 16.5-34.3% of these coho salmon smolts had multiple lamprey wounds (2-6 wounds per fish; Table 1).

Although scarring rates provide no information on killing rates, they might provide some indication of the relative abundance of lampreys (at least relative to the abundance of prey). It is by no means a quantitative index, but it’s the best available at this time. Scarring on a large number of these prey fish indicates that the Vancouver Lamprey mostly feeds without killing its host (Beamish 1982; Table 1). However, some mortality of host fish does occur. In 15% of salmonids examined by Beamish (1982), wounds penetrated into the body cavity or deeply into the muscle and likely would have been fatal. In the coho salmon smolts examined from the Mesachie Creek enumeration fence in 1988-1990, over 36% had severe, open wounds that exposed flesh or viscera (Table 1; data from S. Baillie, pers. comm. 2007). Furthermore, coho salmon killed by lamprey have been found on the bottom of the lake and washed up along the shore (Beamish 1982).

Although this endemic lamprey species appears to have historically coexisted with a healthy population of salmonids in its two lakes (NatureServe 2006), there has been a recent decline in wild coho and other salmon in the Cowichan Lake system (Baillie pers. comm. 2007; Yesaki pers. comm. 2007). This decline in its most commonly observed host may affect the abundance of the Vancouver Lamprey. The observed declines were in coho returns in the Cowichan Lake system in general. Mesachie Creek was included in the tributaries evaluated; a similar decline in coho returns was not observed in Mesachie Creek, but the creek is intermittent. Numbers of coho salmon in Mesachie Lake itself is not known *(see* “Limiting Factors and Threats,” below).

Since larval lampreys feed on detritus and suspended organic matter, the productivity of this food base in Cowichan and Mesachie lakes may affect abundance of the Vancouver Lamprey (Vancouver Lamprey Recovery Team 2007). However, in river-rearing species at least, food during the larval phase is not thought to be a limiting factor (Moore and Mallatt 1980).

Interaction between the Vancouver Lamprey and Pacific lamprey is likely minimal. Pacific lamprey is common downstream of the outlet to Cowichan Lake, but they have not been observed upstream of this point (Beamish 1982). They cannot survive entirely in fresh water (Beamish 1982; Clarke and Beamish 1988) and would be expected to migrate to the sea to feed (*see* “Distribution,” above). It is also unlikely that the two species would interbreed, since the Vancouver Lamprey reproduces later in the season than the Pacific lamprey and uses lake habitat rather than river or stream habitat for spawning (Beamish 2001; *see* “Reproduction,” above). Furthermore, size differences between the Vancouver and Pacific lamprey would likely further contribute to reproductive isolation (Beamish 1982).

Adaptability

Little is known specifically about the adaptability of the Vancouver Lamprey, except for the fact that it is able to osmoregulate in fresh water throughout its entire life cycle, as well as in full-strength salt water once it has completed metamorphosis (Beamish 1982; *see* “Physiology,” above).

Lampreys in general, however, appear to be quite adaptable (Hardisty 2006). Lampreys have relatively high rates of larval and juvenile survival at low population levels and are likely able to increase in abundance relatively rapidly at such times (Beamish 1987).

It is possible to artificially spawn and rear other species of lampreys in the laboratory (e.g., Piavis 1961). Although attempts to rear large numbers of parasitic lamprey through the entire life cycle have been largely unsuccessful (Swink 2003), it would likely be feasible to artificially spawn Vancouver Lamprey in the laboratory and reintroduce them into Cowichan and Mesachie lakes as ammocoetes. However, because this species is a potentially serious source of salmonid mortality, fisheries managers would not want to transplant this species to any other lake systems (Beamish 2001).

POPULATION SIZES AND TRENDS

Search effort

The search effort used to collect Vancouver Lamprey has not been sufficiently quantitative to measure population sizes or assess population trends. Studies searching for ammocoetes and recently metamorphosed lampreys were conducted using electroshockers along the edge of Cowichan and Mesachie lakes and in outlet and inlet streams, but with a focus on distribution and habitat preference, not abundance (Harris pers. comm. 2007). Postmetamorphic lampreys were sampled using beach seines, purse seines, gill nets, and traps, and were also obtained from sports caught fishes (Beamish 1982), but sampling efforts were not adequately quantified. Changes in abundance have been inferred from changes in the scarring rates of salmonids, as determined from comments from fishermen about the incidence of observed lamprey wounds (Beamish 2001), but these fluctuations likewise have not been sufficiently quantified. However, the number of lampreys and lamprey-scarred coho salmon smolts caught at an enumeration fence on Mesachie Creek between 1987 and 1996 (Baillie pers. comm. 2007) may allow the relative abundance of the Vancouver Lamprey in Mesachie Lake to be roughly estimated for this time period. Search effort each year was consistent in that the fence was operated in both upstream and downstream directions for approximately the same length of time each year, i.e. while there was water present, which was from the first fall storm event (usually in September) until the creek dried up (in July). These raw data were provided by S. Baillie (pers. comm. 2007) and were tallied for this report (Table 1; Figures 3, 4, 5). The number of lampreys collected at the enumeration fence were recorded for this same time period in all years (with the exception of 1996, when operation ceased on June 19). Scarring rates were determined in the spring of each year during a four-day period in 1987 or for 38 to 81 days in the remaining years (Table 1). Due to lack of comparable data, however, comparisons prior to 1987 and after 1996 cannot be made. Likewise, extrapolations to the entire Cowichan Lake system cannot be made. Furthermore, it must be noted that these estimates of relative lamprey abundance are very crude since scarring rates would also be expected to vary with changes in host abundance (which has been inferred from coho salmon return rates, which does not take hatchery releases into account; see below), and type and age of the wounds were not consistently recorded (*see* Ebener *et al.* 2003).

Abundance

At no time have abundance estimates been made for the Vancouver Lamprey (Vancouver Lamprey Recovery Team 2007). Beamish (2001) provided a guess that 1000-2000 adults occur in the two lakes, and NatureServe (2006) uses this estimate and places global abundance at 1000–2500 individuals. This figure, however, may be an underestimate. Up to 60 juvenile or adult Vancouver Lamprey were collected per year in the downstream trap of the Mesachie Creek enumeration fence (Figures 3, 4). It seems likely, therefore, that the number of adults in the entire Cowichan Lake system (given the relatively small size of Mesachie Lake) would exceed 1000-2000. Likewise, in some years (1990, 1996), 1000-2000 coho salmon smolts with lamprey wounds were caught in the downstream trap of the Mesachie Creek enumeration fence; up to 34% of these smolts had multiple wounds (Table 1). Although we have no information regarding the number of smolts a single lamprey juvenile could attack or their survival rate to maturity, it seems likely that the number of adult Vancouver Lampreys in the entire Cowichan Lake system would exceed 1000-2000. However, quantitative estimates of abundance are greatly needed. As mentioned above, these estimates of relative lamprey abundance based on scarring rates are very crude and considerably more effort (e.g., using mark-recapture methods) will be required before quantitative estimates of Vancouver Lamprey abundance are available (see Bergstedt *et al.* 2003; Young *et al.* 2003).

Fluctuations and trends

Observed changes in salmonid scarring rates from fishermen (*see* "Search effort," above) suggest fluctuations in population abundance, although Beamish (2001) stated that no long-term decline is apparent. Based on this statement, NatureServe (2006) considered this species to be stable (i.e. abundance unchanged or within +/- 10% fluctuation in the population, range, area occupied, and/or number or condition of occurrences). However, fluctuations in population abundance in this species need to be better quantified. Between 1987 and 1996, the number of juvenile or adult lampreys caught in the downstream trap at the Mesachie Creek enumeration fence ranged from four (in 1991) to 60 (in 1995), and the number of coho salmon smolts recorded with lamprey wounds ranged from 139 (in 1989) to 1982 (in 1996) (Table 1; Figure 3a, b). In both cases, the numbers varied by more than an order of magnitude, but no decline or increase was evident over this 10-year period (r^2 = 0.3298 and r^2 = 0.0961, respectively). However, comparable pre-1987 values are not available, so that lamprey abundance or number of coho salmon with lamprey wounds from 1987 to 1996 cannot be compared to values observed prior to the suggested decline in the prey base of the lampreys in the 1980s (*see* "Limiting Factors and Threats," below).

Although scarring rates provide only crude estimates of relative abundance, they are the only index currently available. If one sees a decline in scarring rates and the total number of coho salmon has also declined, one can infer that total number of lampreys has declined. The only possible comparison seems to be changes in salmonid scarring rates, as used by Beamish (2001). However, there is also variation in the total number of coho salmon smolts from year to year so it is uncertain if the scarring rate is an accurate indicator of total lamprey numbers. Nevertheless, wounding rates of coho salmon smolts at the Mesachie Creek enumeration fence from 1987 to 1996 ranged from 7.3% (in 1992) to 34.1% (in 1987), with no decline or increase apparent over this time (r^2 = 0.0233; Figure 3c). This is considerably less than the 50% to 80% of salmonids in Mesachie and Cowichan Lake, respectively, showing evidence of lamprey attacks in earlier reports (Beamish 1982 and Carl 1953, respectively). This suggests a decline in the total number of lampreys since the 1980s, especially since it appears that coho salmon numbers have also declined (Figure 3d).

Rescue effect

The Vancouver Lamprey is not known to occur outside of Cowichan and Mesachie lakes and there is, therefore, no possibility of rescue from other lakes (but *see* "Distribution," above).

LIMITING FACTORS AND THREATS

Given the extremely restricted distribution of this species, it could be vulnerable to localized changes in its habitat or other localized threats. Several potential threats to the Vancouver Lamprey and its habitat have been evaluated by the Vancouver Lamprey Recovery Team (2007). They concluded that a variety of factors may threaten the Vancouver Lamprey and its habitat, but caution that a thorough threats assessment is difficult given the lack of information available regarding this species' general biology, habitat use, and population size.

However, two potential threats-a decline in their prey base and destruction of Vancouver Lamprey adults when caught by recreational anglers-were considered current concerns that could cause population-scale impacts (i.e. an impact on the adult population).

With respect to its prey base, the abundance of coho salmon (which is the most commonly observed prey for the Vancouver Lamprey; *see* "Interspecific Interactions," above) has been declining in the Cowichan system. Wild coho salmon stocks were supplemented with hatchery releases into Cowichan Lake and its tributaries from 1982 through 2003, the numbers were fairly low (Figure 6), and compared to historic estimates of juvenile abundance are very low (Pollard pers. comm. 2008). The number of coho salmon juveniles that the lampreys fed upon in the lakes from 1982 to 2003 may not have been directly related to the return rates (Baillie pers. comm. 2008). However, it appears that the years of supplementation did not contribute significantly to availability of juvenile coho as prey for lamprey (Pollard pers. comm. 2008). While adult escapement is not necessarily strongly correlated with smolt numbers emigrating (there is some degree of density-dependent survival for coho fry) total smolt numbers leaving Mesachie and Cowichan lakes have declined significantly in recent years (Table 2), and average adult return numbers for Cowichan Lake are well below historic levels (Yesaki pers. comm. 2007). Returns fluctuate from year to year, but record low returns have been reported recently (Gibson pers. comm. 2007). Annual coho salmon escapement between 1989 and 2006 has been estimated for the Cowichan system by Fisheries and Oceans Canada (Georgia Basin Salmon Stock Assessment; Baillie pers. comm. 2007). During this time period, coho salmon returns ranged from 2,500 to 30,000 to the Cowichan system in general and averaged 11,070 (Figure 3d). Prior to 1989, Cowichan coho salmon escapement was estimated by DFO Fishery Officers using less precise methods (Baillie pers. comm. 2007) and these data are not directly comparable to the above estimates. However, for a general comparison, coho salmon escapement averaged 46,860 in the 1950s; 40,250 in the 1960s; 44,620 in the 1970s, and

20,550 in the 1980s (a decline of ≈ 46% over the last 24 years or 3 lamprey generations, and 73% since the 1950s).

Although there have been no formal assessments of the threats to the prey base of Vancouver Lamprey (e.g., through recreational and commercial fishing for salmonids and destruction of salmonid habitat), such impacts are expected to directly affect abundance of this lamprey species (COSEWIC 2002; Vancouver Lamprey Recovery Team 2007).

Dwindling salmon stocks may lead to increased animosity toward the Vancouver Lamprey by recreational anglers, who are known to kill lampreys that are parasitizing their catch. The threat from this mortality source is unquantified, but the Vancouver Lamprey Recovery Team stated that it may be partially mitigated with better education of anglers (Vancouver Lamprey Recovery Team 2007).

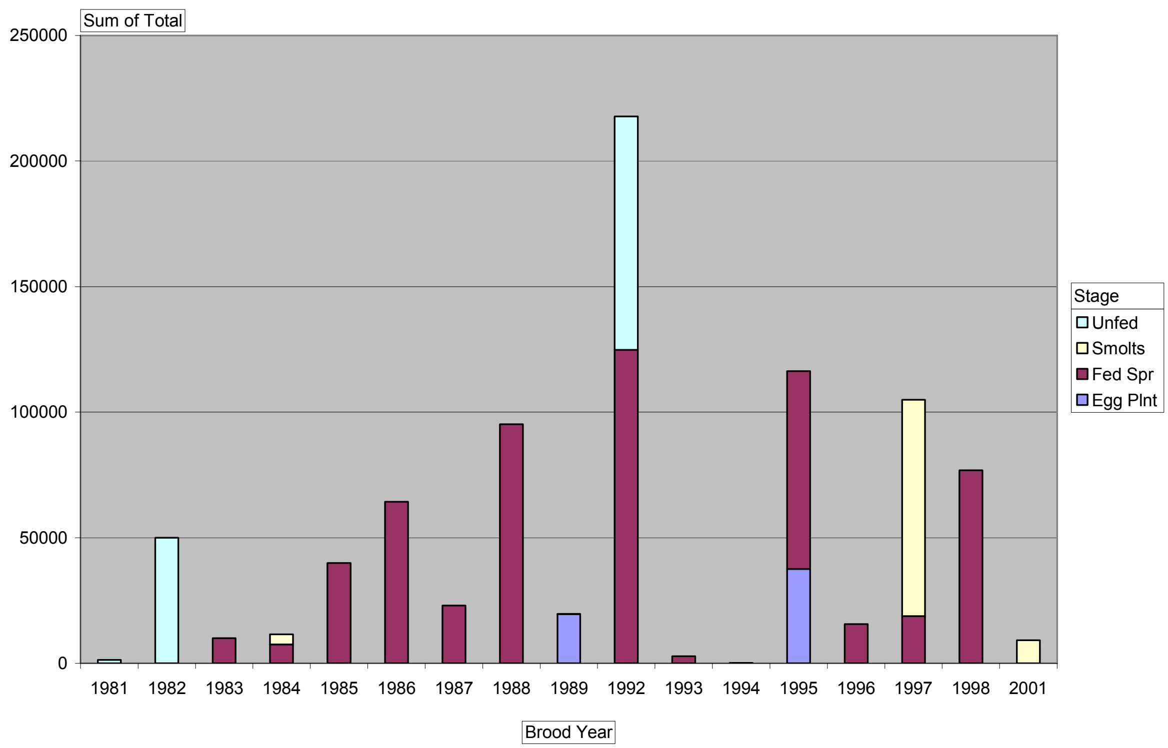

Figure 6. Graph of coho salmon releases into Cowichan and Mesachie lakes 1982-2003 (Baillie unpubl. data).

Table 2. Smolt numbers estimated leaving Cowichan Lake based on mark/recapture (Baillie unpubl. data).

Year	1997	1999	2000	2001	2002	2003	2005	2006	2007
Smolt Estimate	97,711	88,500	255,000	233,000	236,000	111,000	126,000	90,000	14,500

No estimates in 1998 and 2004.

Other potential threats evaluated were water use, land use, water quality, recreation, and climate change. With regards to water use, there are a number of active water licences on Cowichan Lake and its tributaries. The largest licences by far (accounting for over 90% of the licenced water volume) are two storage licences. Storage is provided by a low weir at the lake's outlet, built in 1957, but diversion amounts are relatively small, approximately 6% of the storage amounts. The Vancouver Lamprey Recovery Team determined that annual fluctuations in lake level were approximately the same before and after weir construction, and suggested that storage and diversion appear to pose at most a minor threat to the Vancouver Lamprey (Vancouver Lamprey Recovery Team 2007). Likewise, they estimated that consumptive water licences on Mesachie Lake amount to approximately 1.4 cm of lake depth, so that the two water licences on this lake are also unlikely to cause substantial harm to this species. The Vancouver Lamprey Recovery Team considered it unlikely that threats posed by unlicensed water users exceed those posed by licensed users, but reiterate that the threat posed by increased water needs in the Cowichan Valley will need to be more fully evaluated in the future (e.g., assessing potential impacts of water level fluctuations on Vancouver Lamprey eggs and ammocoetes) (Vancouver Lamprey Recovery Team 2007)

There has been no mining in the recent past in the Cowichan Lake watershed and, although there is considerable forestry activity, the Vancouver Lamprey Recovery Team (2007) considered its impact on the Vancouver Lamprey to be small, with the possible exception of an impact from log salvage operations on sedimentation in Mesachie Lake in the 1980s (*see* "Habitat Trends," above). There has also been some illegal gravel mining in some lake tributaries over the last few decades, but likely not enough to affect lamprey populations (Baillie pers. comm. 2007). However, the Vancouver Lamprey Recovery Team (2007) was unable to assess the threat to this species from land development for residential or industrial uses (in particular, its potential impact on littoral spawning areas) without additional information on the habitat requirements of spawning Vancouver Lampreys.

Threats due to poor water quality or general recreational use do not appear to be substantial (Vancouver Lamprey Recovery Team 2007). Threats due to climate change were considered beyond the scope of the Vancouver Lamprey Recovery Team.

SPECIAL SIGNIFICANCE OF THE SPECIES

Lampreys are the most ancient group of living vertebrates (about 300 million years old; Janvier and Lund 1983) and, thus, provide insights into the origin and evolution of vertebrates. Lampreys have been used extensively as experimental animals, particularly in neurobiological studies (Rovainen 1979) and developmental biology (e.g., Cohn 2002, Kuratani *et al.* 2002). Such research on lampreys will likely increase in the near future, given the extensive sea lamprey genomic resources currently being generated (e.g., sequencing of the complete sea lamprey genome, which was initiated in 2004 by the National Human Genome Research Institute).

The Vancouver Lamprey is significant for several reasons. It is endemic to Canada and is known to occur in only two lakes on southern Vancouver Island. Regarding the cultural value of the Vancouver Lamprey to Aboriginal Peoples in Canada, elders for the Cowichan Tribes report that there is a word for the lampreys in their language but no stories or legends around them (Elliott pers. comm. 2007); no other information regarding Aboriginal Traditional Knowledge was found. The Vancouver Lamprey Recovery Team (2007) noted, however, that the closely related Pacific lamprey has significant cultural value for Aboriginal Peoples in some regions (Close *et al.* 2002).

The special significance of the Vancouver Lamprey is primarily its scientific value. Like many other fish species of postglacial origin, lampreys show considerable life history variation (i.e. adult lampreys may be parasitic and anadromous, parasitic and freshwater-resident, or nonparasitic and freshwater-resident), and the evolution of life history type is of great scientific interest (e.g., Hardisty 2006). The freshwater parasitic and nonparasitic life history types have arisen repeatedly and independently in most lamprey taxa, and this may represent one of the most dramatic cases of parallel evolution in any vertebrate (Mayden pers. comm. 2006). The Vancouver Lamprey (especially when considered with other freshwater-derivatives of the Pacific lamprey; *see* “Distribution,” above) can provide insights into evolutionary processes in lampreys (e.g., the rate at which the ability to osmoregulate in fresh water throughout the life cycle can evolve in lampreys) and in general (e.g., using molecular genetic dating to estimate the rate at which speciation can occur). The Vancouver Lamprey’s preference for spawning and rearing in lake rather than river habitat is also of scientific interest.

EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

The Vancouver Lamprey was designated by COSEWIC as Special Concern in 1986. The species was re-examined by COSEWIC in November 2000 and designated Threatened. The Vancouver Lamprey is red-listed (i.e. extirpated, endangered, or threatened in British Columbia) by the BC government (BC Conservation Data Centre 2007). As of July 9, 2002, the Conservation Data Centre ranks this species as G1, N1, S1 (i.e. critically imperiled on global, national, and provincial scales, respectively). It is currently on Schedule 1 of the federal *Species at Risk Act* (SARA), making it illegal to kill, harm, harass, capture, or take Vancouver Lamprey. A draft recovery strategy is available for the Vancouver Lamprey (Vancouver Lamprey Recovery Team 2007). There is currently no recovery action plan for this species, but one is due in two years (Vancouver Lamprey Recovery Team 2007).

TECHNICAL SUMMARY

Lampetra macrostoma

Vancouver Lamprey — Lamproie de Vancouver

Range of Occurrence in Canada: BC – Endemic to Vancouver Island

Demographic Information

Generation time (average age of parents in the population)	8 yr
Observed percent reduction in total number of mature individuals over the last 10 years, or 3 generations. "Decreases in preferred prey (coho) and scarring rates suggest a possible decrease since the 1980s, but this has yet to be verified."	Unknown
Projected percent reduction in total number of mature individuals over the next 10 years, or 3 generations.	Unknown
Observed percent reduction in total number of mature individuals over any 10-year, or 3-generation period, over a time period including both the past and the future.	Unknown
Are the causes of the decline clearly reversible? Not Applicable	Unknown
Are the causes of the decline understood? Not Applicable	Unknown
Have the causes of the decline ceased? Not Applicable	Unknown
Observed trend in number of populations	Stable
Are there extreme fluctuations in number of mature individuals? "Fluctuations of greater than one order of magnitude might be inferred from the number of juveniles caught in the downstream trap, and from salmonid wounding and scarring rates, but the use of scarring rates as an index of the number of mature lampreys has yet to be verified (*see* Fluctuations and Trends)."	Unknown
Are there extreme fluctuations in number of populations?	No

Number of Mature Individuals in Each Population

Population	**N Mature Individuals**
"Estimate of at least 1000-2000 mature individuals in both lakes, but this has never been quantified; (*see* Abundance)."	Unknown, but probably < 10000
Grand Total	Unknown

Extent and Area Information

Estimated extent of occurrence	121 km²
Observed trend in extent of occurrence	Stable
Are there extreme fluctuations in extent of occurrence?	No
Estimated area of occupancy (AO) Index of area of occupancy (IOA) 1 X 1 Grid 2 X 2 Grid	65 km² 125 km² 180 km²
Observed trend in area of occupancy	Unknown
Are there extreme fluctuations in area of occupancy?	No
Is the total population severely fragmented?	No

Number of current locations “Aggregations of larvae have been found at 16 "geographically distinct" sites within the rather large (> 30 km long) lake basin. One might argue that it would be hard to envisage all of these sites constituting one "location" from a threat (e.g., chemical spill), perspective. Although there may be 5-10.spawning locations (genetic data will eventfully be able to test this), larvae and young probably disperse throughout the system based on our knowledge of the distribution of other lampreys, and thus there is one population in one location.”	1
Trend in number of locations	Unknown
Are there extreme fluctuations in number of locations?	No
Trend in area and/or quality of habitat	Unknown

Quantitative Analysis

Not Applicable

Threats (actual or imminent threats to populations or habitats)

Actual: Significant decline in the abundance of their most commonly observed prey (coho salmon) Destruction of Vancouver Lamprey adults when caught by recreational anglers Siltation of littoral spawning areas from anthropogenic activities Imminent: Impact of land development for residential and industrial uses on littoral areas Consumptive water uses leading to water level fluctuations

Rescue Effect (immigration from an outside source)

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

Quantitative Analysis

(Insufficient quantitative data available)	Not Applicable

Current Status

COSEWIC: Threatened, November 2008 BC Government: Red-listed Conservation Data Centre: G1, N1, S1 (i.e. critically imperiled on global, national, and provincial scales, respectively) Wild Species 2005 – National – 1, Provincial (BC) – 1 (at risk) Threatened (Schedule 1, Part 3) under SARA

Status and Reasons for Designation

Status: Threatened	**Alpha-numeric code:** D2
Reasons for Designation: This endemic parasitic species, known only from one location in British Columbia, is dependent on the availability of salmonids. Given that its primary prey is juvenile Coho Salmon in Cowichan Lake, the recent and ongoing decline of Coho adults observed returning to the lake is expected to have a significant negative impact on lamprey numbers.	

Applicability of Criteria

Criterion A (Declining Total Population): Not applicable, rate of decline is unknown.
Criterion B (Small Distribution, and Decline or Fluctuation): Not applicable - although the species is known from only a single location in Canada with an EO of < 121 km^2 and an IAO of < 125 km^2 (AO = 65 km^2), continuing decline in the number of mature individuals can only be indirectly inferred from a decline in the prey base, and an index based on scarring rates of salmonids. The validity of this index as an indicator of lamprey numbers has yet to be verified. This index also suggested that the number of individuals and the number of coho salmon with lamprey scars had fluctuated by more than an order of magnitude in the 10-year period 1987-1996, but no population trends were evident.
Criterion C (Small Total Population Size and Decline: Not applicable-the total number of mature individuals is unknown (although it is probably < 10,000, but > 2000). Although there has been a significant decline in the preferred prey (coho salmon), and as a result, most likely in the number of mature individuals as well (*see* Criterion B above), this has yet to be verified.
Criterion D (Very Small Population or Restricted Distribution): Meets Threatened D2-a Canadian endemic known only from 1 location.
Criterion E (Quantitative Analysis): Not applicable-no data.

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COLLECTIONS EXAMINED

No collections were examined in the preparation of this report.