COSEWIC
Assessment and Update Status Report

on the

Pacific Water Shrew
Sorex bendirii

in Canada

ENDANGERED
2006

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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For additional copies contact:

COSEWIC Secretariat
c/o Canadian Wildlife Service
Environment Canada
Ottawa, ON
K1A 0H3

Tel.: (819) 997-4991 / (819) 953-3215
Fax: (819) 994-3684
E-mail: COSEWIC/COSEPAC@ec.gc.ca
http://www.cosewic.gc.ca

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Pacific water shrew – by Ron Altig.

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COSEWIC
Assessment Summary

Assessment Summary – April 2006

Common name
Pacific water shrew

Scientific name
Sorex bendirii

Status
Endangered

Reason for designation
The habitat of this rare species, confined to the lower Fraser valley region of British Columbia, continues to decline and fragment as a result of development.There is little chance of rescue. It is extremely rare throughout its range.

Occurrence
British Columbia

Status history
Designated Threatened in April 1994 and in May 2000. Status re-examined and designated Endangered in April 2006. Last assessment based on an update status report.

COSEWIC
Executive Summary

Pacific Water Shrew
Sorex bendirii

Species information

The Pacific water shrew is the largest North American species of *Sorex* with a total length of 154 mm and a body mass of 10.6 g. The dorsal pelage ranges from dark brown to black; the undersides are dark brown. The tail is a unicoloured dark brown. The large hind feet have a stiff fringe of hairs up to 1 mm in length.

Distribution

The Pacific water shrew ranges from northern California through western Oregon and Washington to southwestern British Columbia in Canada. In Canada, the Pacific water shrew is confined to the lower Fraser River valley region in extreme southwestern British Columbia, where it ranges as far east as the Chilliwack River and Harrison Lake. Northern limits of the range are lower elevations (below 800 m) in the Coast Mountains on the north side of the Fraser River. The 142 known occurrence records represent about 44 distinct locations or sites. The extent of occurrence based on historical and recent occurrences is about 3,350 km^2.

Habitat

The Pacific water shrew is associated with skunk cabbage marshes, red alder riparian and stream habitats, and dense wet forests of western redcedar. Most captures are in riparian habitats in close proximity to water. But individuals have been captured 25-350 m away from streams in forest. Although forested habitats are important, it has been found in non-forested grassy habitats bordering ditches and sloughs in British Columbia. There are no specific data on habitat trends and no quantitative data exist for the rate of habitat loss in the past 10 years. But wetlands and forested habitats have declined over the past 100 years. Protected areas are limited to 26 provincial and regional parks. Federal lands within the known range include 4 Department of National Defence properties and about 62 Indian Reserve lands. The amount of habitat on provincial Crown land is small, probably less than 20%.

Biology

The basic biology of this species has been little studied. It is primarily insectivorous eating insect larvae, slugs, snails, mayfly naiads, and earthworms. At least 25% of the prey

is aquatic. The Pacific water shrew is semi-aquatic and capable of swimming and diving in water. It can swim continuously for up to 3.5 minutes and dive for up to 60 seconds. The breeding season extends from February to August with females producing two to three litters of five to seven young. The generation time is about one year.

Population sizes and trends

No estimates of population density exist for this species from any part of its range and the total number of individuals and the number of mature animals in Canada is unknown. The Pacific water shrew appears to be rare throughout its range. Nothing is known about yearly population fluctuations. Long-term population trends can only be inferred from anecdotal accounts and evidence from historical captures.

Limiting factors and threats

In Canada, the Pacific water shrew's distribution coincides with a heavily urbanized area undergoing rapid development and habitat change. Rarity, coupled with its restriction to riparian and wetland habitats, make this species susceptible to habitat loss, fragmentation, and degradation from development. Housing, commercial, recreational (such as golf courses), and industrial development reduces forested areas and riparian habitats that border streams or wetlands and degrade habitat from run-off and storm water management.

Special significance of the species

The Pacific water shrew is a member of the Pacific Coastal faunal element, a group of coastal mammals that range from northern California to British Columbia and southeast Alaska.

Existing protection

This species was designated Threatened by COSEWIC in 1994. The status was re-examined and confirmed in May 2000. British Columbia has designated this species as S1S2 (critically imperiled or imperiled). The Pacific water shrew is protected from killing or collecting under the provincial Wildlife Act; it is listed as an Identified Wildlife Species under the British Columbia Provincial Forest and Range Practices Act. Riparian habitat protection is also provided by the Riparian Areas Regulation of the provincial Fish Protection Act. The Department of Fisheries and Oceans (DFO) also has a set of guidelines for establishing Fisheries Sensitive Zones that protect fish and fish habitat. The provincial Riparian Areas Regulation and the DFO regulations apply only to streams, creeks, ditches, or wetlands with fish or that are connected to fresh-water ecosystems with fish. None of the Pacific water shrew's range is in a national park. Its known distributional area includes 5 provincial parks and 26 regional parks. Protected areas on the south side of the Fraser River are small with no connectivity.

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 5th 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 (2006)

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 it 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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2006

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SPECIES INFORMATION

Name and classification

Sorex bendirii Merriam 1884 belongs to the Order Insectivora, Family Soricidae. Jackson (1928) assigned *S. bendirii* to the subgenus *Atophyrax* (the sole member of this group), but most taxonomists (Findley 1955) now treat this species as a member of the subgenus *Otiosorex*, a group that includes a number of North American shrew species. Based on morphology, Findley (1955) considered *S. bendirii* and the common water shrew (*Sorex palustris*) to be sister species. Allozyme data (George 1988) and mitochondrial DNA (mtDNA) data (Demboski and Cook 2001; O'Neill *et al*. 2005) also support the recognition of *S. bendirii* and *S. palustris* as sister taxa. Although they differ in pelage colour and cranial/dental morphology, genetic divergence (cytochrome *b* gene) between these two species is about 3.1% within the range shown by most shrew species for intraspecific divergence (Fumagalli *et al*. 1999). A cladistic analysis (O'Neill *et al*. 2005) comparing *S. bendirii* with samples of *S. palustris* from Vancouver Island (*S*. *p*. *brooksi*), the Cordillera of Alaska, Yukon, British Columbia, and Utah (*S*. *p*. *navigator*), and northern Alberta (*S*. *p*. *palustris*), revealed that *S. bendirii*, *S*. *p*. *brooksi*, and *S*. *p*. *navigator* share a common ancestry, grouping together into a separate lineage from *S*. *p*. *palustris*. These phylogeographic patterns were attributed to vicariance and isolation in several refugia during the Pleistocene.

Traditionally three subspecies are recognized: *S*. *b*. *albiventer* (Olympic Peninsula of Washington), *S*. *b*. *bendirii* (California, Oregon, Washington, British Columbia), and *S*. *b*. *palmeri* (coastal Oregon and northern California). They demonstrate minor differences in ventral pelage colour and size (Jackson 1928; Hoffmann 1971). Data from mtDNA raise doubts about the validity of these subspecies. The genetic study of O'Neill *et al*. (2005) included samples of *S*. *b*. *bendirii* from British Columbia and *S*. *b*. *palmeri* from Oregon. Three phylogenetic trees calculated by O'Neill *et al*. (2005) showed no evidence of two clades or groups concordant with these taxa.

Other English common names are the Bendire shrew and marsh shrew. The French common name is musaraigne de Bendire.

Morphological description

The Pacific water shrew is the largest North American species of *Sorex*. It has a dorsal pelage that ranges from dark brown to black; the undersides are dark brown (Fig. 1). The tail is a unicoloured dark brown. The large hind feet have a stiff fringe of hairs up to 1 mm in length that is most distinct in younger animals. According to Maser (1975), small fleshy projections are present along the outer edge of each nostril. The skull is robust with a rostrum that is curved ventrally in side view. The dental formula is: incisors 1/1, unicuspids 5/1, premolars 1/1, and molars 3/3. Distinctive dental traits include: a third upper unicuspid smaller in size than the fourth upper unicuspid, a large medial tine on the anterior face of the first upper incisor, and two ridges on the occlusal surface of the fourth lower premolar (Carraway 1995; Nagorsen 1996).

Figure 1. Pacific water shrew (*Sorex bendirii*). Photo by Ronn Altig.

Body measurements (range in parentheses) for Canadian animals are total length 154 mm (137-176) n=95, tail vertebrae 70 mm (61-81) n=94, hind foot 19 mm (17-21) n=93, ear 8 mm (7-9) n=3, and body mass 10.6 g (10.0-17.2) n=13 (Nagorsen 1996).

Its large size (total length >130 mm; hind foot >18 mm; skull length >19.0 mm; palatal length >8.2 mm) and fringe of hairs on the hind feet distinguish *S. bendirii* from all other Canadian shrew species except for the common water shrew (*S*. *palustris*). *S. palustris* can be identified by: grey to black dorsal fur with a silver-grey belly, a bicoloured tail that has a paler underside, and a smaller skull with the rostrum not curved ventrally. Although the two species can be easily distinguished in the hand, reliable identification of live animals observed in the wild is difficult.

Genetic description

Nothing is known about the population structure of this shrew in Canada. In British Columbia, the only potential geographic barrier is the Fraser River, a major water body that would be expected to limit gene flow among Pacific water shrews inhabiting the north and south sides of the river. The only data on genetic variation are O'Neill's *et al*. (2005) analyses of mtDNA variation (cytochrome *b*) using five individuals from British Columbia. Their genetic divergence values among these five individuals ranged from 0.3 to 1.0% suggesting some genetic variation. However, the variation showed no clear geographic structure and no support for genetic divergence on north and south sides of the Fraser River. Their cladogram revealed two groups of *S. bendirii* — one with individuals from Sumas Mountain, the other with individuals from nearby Aldergrove and the Seymour River on the north side of the Fraser. A genetic study applying other genetic markers such as microsatellite DNA is needed to assess genetic structure and the possible isolating effect of the Fraser River.

DISTRIBUTION

Global range

The Pacific water shrew ranges from northern California through western Oregon and Washington to southwestern British Columbia in Canada (Fig. 2). A Pacific coastal species, this shrew is restricted to coastal lowlands and lower elevations in the coastal mountain ranges.

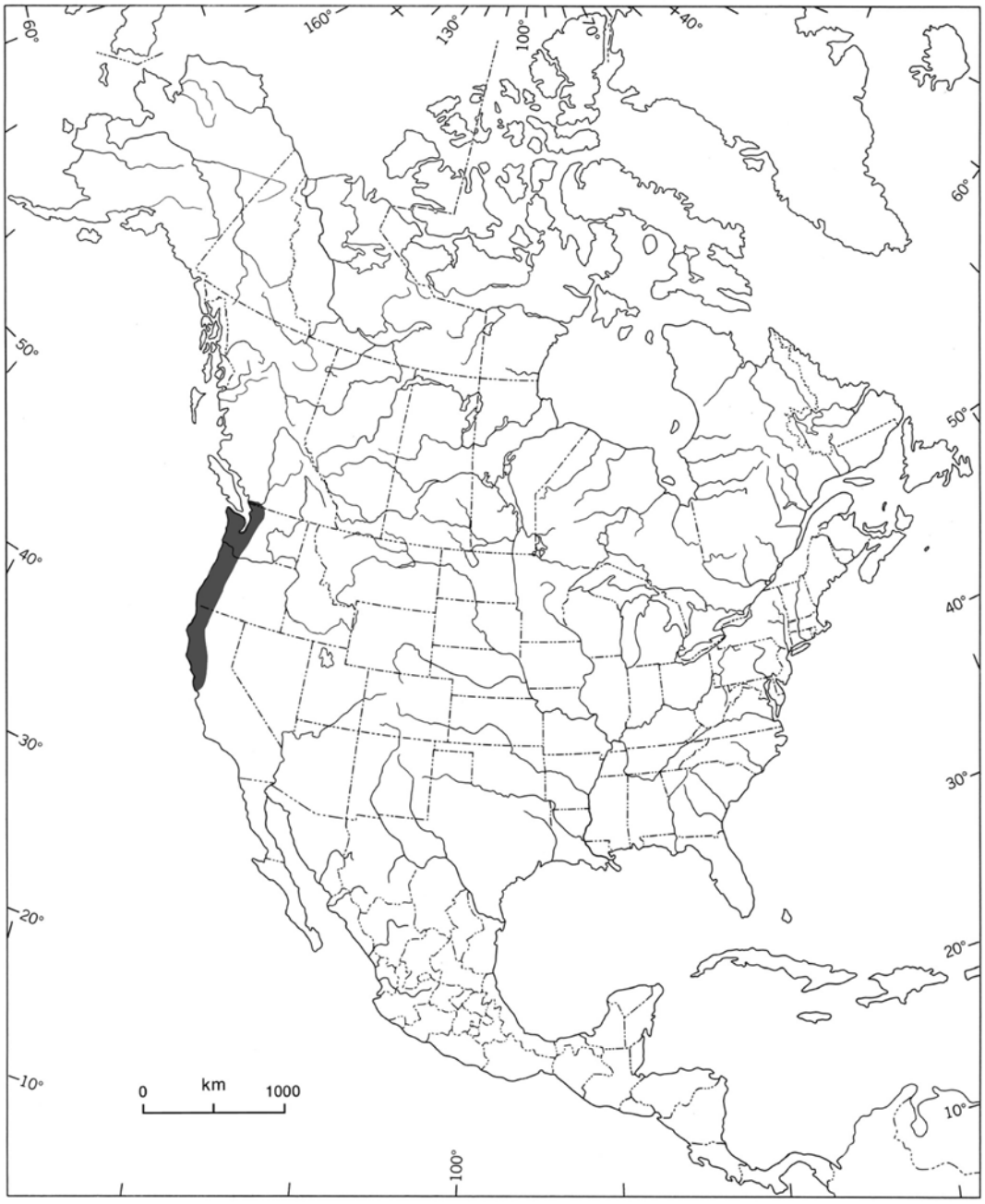

Figure 2. Global range of the Pacific water shrew (*Sorex bendirii*).

Canadian range

In Canada, the Pacific water shrew is confined to the lower Fraser River valley region in extreme southwestern British Columbia. This distributional area is limited to the Lower Mainland Ecoregion of the Pacific Maritime Ecozone. More surveys are required to delimit the precise boundaries of its range. But the known historical and recent occurrence records (Fig. 3) suggest that this species ranges as far east as the Chilliwack River and Harrison Lake. Craig and Vennesland (2004a) reported Pacific water shrew sightings by naturalists further east in the Skagit River valley. However, given that the Skagit River is within the range of the common water shrew (Nagorsen 1996), identifications based on captures are required to verify the presence of the Pacific water shrew in this valley. Northern limits of the range are lower elevations (below 800 m) in the Coast Mountains on the north side of the Fraser River.

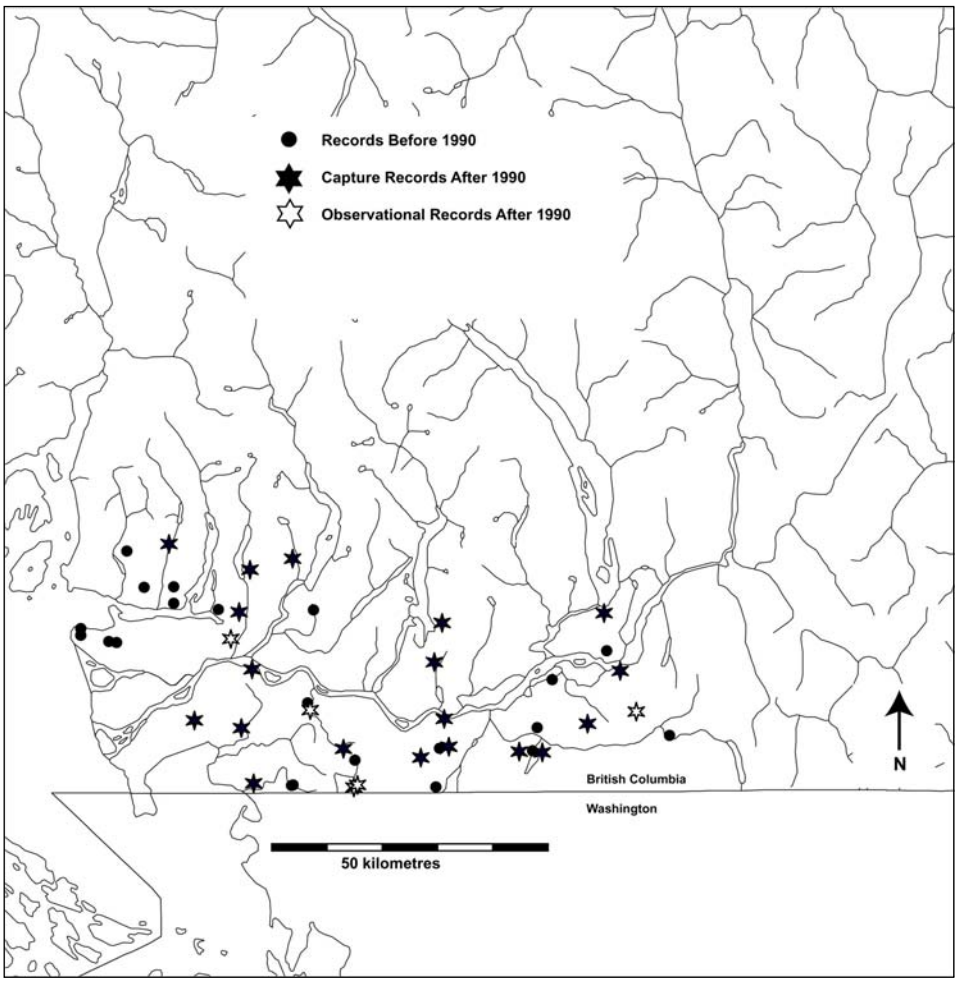

Figure 3. Canadian range of the Pacific water shrew (*Sorex bendirii*) based on all known historical and recent occurrences.

There are about 142 occurrence records (historical museum specimens, sightings, recent captures) for this species in Canada. Of the 142 records, 99 (70%) are historical museum specimens taken from 1888-1957. The 142 occurrence records represent about 44 distinct locations or sites.

The extent of occurrence based on historical and recent occurrences is about 3,350 km^2. This represents about 5% of the global range. The area of occupancy is unknown. Based on a comparison of recent (< 20 years ago) and historical records, Craig and Vennesland (2004a) concluded that the extent of occurrence of the Pacific water shrew has declined 16-20%. But there has been no systematic survey of the entire historic range to assess temporal range changes, and the reputed range decline described by Craig and Vennesland (2004a) may be an artifact of recent sampling. For example, no recent surveys have been done in the municipality of Vancouver (compare Fig. 3 and Fig. 5).

HABITAT

Habitat requirements

In Oregon and Washington, the Pacific water shrew is associated with skunk cabbage (*Lysichiton americanum*) marshes, red alder (*Alnus rubra*) riparian and stream habitats, and dense wet forests of western redcedar (*Thuja plicata*) (Maser *et al*. 1984; Johnson and Cassidy 1997; Verts and Carraway 1998). Both McComb *et al*. (1993) and Gomez and Anthony (1998) demonstrated significantly higher capture rates in riparian than upland habitats, and Gomez and Anthony (1998) concluded that this shrew was “an obligate species of riparian habitat”. Anthony *et al*. (1987), who compared small mammal captures in stream edge (~ 1 m from stream edge) and riparian fringe (15-25 m from stream), captured Pacific water shrews only in their stream edge transects. However, other researchers have captured it 25-350 m away from streams in riparian and mature upland forest (McComb *et al*. 1993; Gomez and Anthony 1998). West (1991) reported captures in dry Douglas-fir forests (*Pseudotsuga menziesii*) at considerable distances [no actual distance given] from water. It is unknown if these captures distant from water represent resident or transient animals. Because of the few captures for the Pacific water shrew, small sample sizes in most habitat studies limit statistical analyses. But the capture data strongly suggest that the Pacific water shrew is more abundant in older seral stages of forest than young forests (Aubry *et al*. 1991; McComb *et al*. 1993; Gomez and Anthony 1998). In the Olympic National Forest of Washington, Lomolino and Perault (2001) never detected this species in clear-cut habitats.

In Canada, habitat use is presumably similar to the Oregon and Washington populations, although habitat data are limited to incidental captures or observations. Brooks (1902) reported that it used thick woods and swamps in Chilliwack Valley. Habitat for the three captures taken by Zuleta and Galindo-Leal (1994) were creeks with conifer forest (western redcedar, western hemlock, *Tsuga heterophylla*) or mixed forests (bigleaf maple, *Acer macrophyllum*, Douglas-fir) with canopy covers exceeding 50%.

Based on existing capture records for British Columbia with habitat data, Craig (2003) developed a habitat model for a four-class rating scheme. The model assumes that riparian habitats in mature forest (structural stages 4-7) of western redcedar or western hemlock, and mature (structural stages 4-7) deciduous or coniferous forests associated with marshes or wetlands are the ideal habitat for this species. The model also assumes that the species is usually found within 60 m of streams or wetlands. However, as noted by Craig (2003) more data on habitat are needed to refine the model including the coverage of wetlands and anthropogenic habitats. The model also needs to be tested and verified with actual field surveys. Although forested habitats are important, this shrew has been taken in non-forested grassy habitats bordering ditches and sloughs in British Columbia (Craig and Vennesland 2004a). The most unusual habitat was the capture by Jackson (1951) of nine Pacific water shrews at Point Grey, Vancouver in ocean beach debris near small pools fed by a freshwater spring.

Habitat trends

There are no specific data on habitat trends for the Pacific water shrew and no quantitative data exist for the rate of habitat loss in the past 10 years. However, general trends can be inferred from studies of changes in land types (Moore 1990; Boyle *et al*. 1997) and loss of wetlands and streams (Fisheries and Oceans Canada 1998; Moore *et al*. 2003). A limitation of these studies is that they generally apply to only a portion of the total habitats occupied by the Pacific water shrew and they do not address the scale of habitat loss in the past decade. Nevertheless, they demonstrate that historically and in the past decade forest and riparian habitats have disappeared from this species' range.

According to Boyle *et al*. (1997) much of the lower Fraser River basin before 1820 was covered in dense mature coniferous forest. The area also supported significant wetlands such as fens, marshes, bogs, and swamp forest. By the 1930s large areas had been logged and cleared for agriculture (Table 1). As a result of drainage and the construction of dykes, freshwater wetlands in this region declined about 87% from the period of first European contact in the 1820s to 1990. For example, Sumas Lake and its associated wetlands (an area with records of the Pacific water shrew in the late 1880s) was drained and dyked by 1924 with the loss of about 8,000 ha of marshland and slough (Moore 1990). Moore *et al*. (2003) conducted a detailed study quantifying the recent loss of wetlands in the region. Comparing 1989 inventory data from Ward *et al*. (1992) and 1999 orthophotos, they assessed changes in 320 freshwater wetlands. About 22% of the wetlands demonstrated some encroachment from urban or agricultural development with the loss of 965 ha (Table 2). Most of the loss resulted from agricultural activities such as cranberry production. Fisheries and Oceans Canada (1998) assessed the impact of habitat changes and water quality on 662 fish-bearing streams in the lower Fraser River valley (Table 3). They found that only 14% remained in their wild state; 15% of the streams were lost.

Table 1. Land cover changes in the Lower Fraser Basin Ecosystem from pre-1820 to 1990. Modified from Boyle *et al*. (1997). Only land cover types used by the Pacific water shrew (*Sorex bendirii*) are listed. Values in parentheses represent the percent of total of land cover including categories not used by the shrew.

Land Cover	Pre-1820	1930	1990
Coniferous	590,800 (71)	412,000 (50)	445,800 (54)
Deciduous/mixed	8,200 (1)	71,800 (8)	4,000 (0)
Fen	56,000 (7)	5,500 (1)	2,400 (0)
Swamp/bog/marsh	27,100 (3)	10,800 (1)	9,700 (1)
Agriculture	0	81,000 (9)	132,100 (16)
Urban	0	25,000 (3)	86,300 (10)
Cleared	0	79,200 (10)	8,600 (1)

Table 2. Changes from 1989 to 1999 in 320 wetlands of the Fraser River lowland region (Taken from Moore *et al*. 2003).

Encroachment Type	Area Lost (ha)	% of Total Area Lost	Number of Wetlands Affected
Agriculture	404	42	26
Golf Course	244	25	4
Landfill	150	16	1
Industrial	64	7	19
In Transition	49	5	12
Residential	38	4	11
Commercial	9	1	6
Transportation	6	1	14
All	965	101	

Table 3. Status of 662 fish-bearing streams in the lower Fraser River valley (Taken from Fisheries and Oceans Canada 1998).

Area	Still Wild	Endangered	Threatened	Lost[1]
Steveston-Langley	0	95	8	45
Abbotsford to Hope	27	142	58	6
Stave River to Hope	22	36	72	6
West Vancouver to Stave River	57	102	43	60
Total	106	375	181	117
Percent of total	14	48	23	15

[1]no longer exists as a surface runway–culverted, paved over, drained, or filled.

Habitat protection/ownership

The precise amount of habitat legally protected is unknown. Protected areas are limited to 26 provincial and regional parks (see Existing Protection or Other Status Designations section). Federal lands within the known range include 4 Department of

National Defence Properties (1,437 ha) and about 62 Indian Reserve lands (8,533 ha). These various federal lands are small and fragmented. The amount of habitat on provincial Crown land is small, probably less than 20%. Most Pacific water shrew habitat in Canada is on private land. The *Best Management Practices Guidelines for Pacific water shrew in Urban and Rural Areas* (Craig and Vennesland 2004b) developed by the province provide detailed guidelines for municipalities on protecting Pacific water shrew habitat,including a recommendation of 100-m buffers around streams or wetlands.

BIOLOGY

Except for diet and habitat, the basic biology of this species has been little studied. Information on life history traits is limited to a study of captive animals (Pattie 1969), a single study of food habits (Whitaker and Maser 1976), observations in various regional mammal synopses (e.g., Maser and Franklin 1974; Maser *et al*. 1984; Nagorsen 1996; Verts and Carraway 1998) and data associated with museum specimens. Some aspects of its life history can also be inferred from studies done on the common water shrew (Conaway 1952; Calder 1962), an aquatic shrew of comparable body size with similar ecological requirements. Although an aquatic shrew with several anatomical adaptations for an aquatic life style, the Pacific water shrew would be expected to demonstrate the typical life history traits of temperate shrews — a high metabolic rate and short life span.

Life cycle and reproduction

The Pacific water shrew is primarily insectivorous, although it also consumes some vertebrate animals and plant material. Pattie (1969) observed this shrew foraging under water. Several recent museum records are from animals that drowned in submerged minnow traps, additional evidence for underwater foraging. A study in coastal Oregon (Whitaker *et al*. 1976) identified 26 food types with insect larvae, slugs, snails, mayfly naiads, and earthworms the dominant prey. At least 25% of the food items were aquatic. Of the five shrew species studied by Whitaker *et al*. (1976), the Pacific water shrew was the only species with mayfly naiads or earthworms as major prey. Other data on diet are limited to anecdotal observations. Lampman (1947) reported a water shrew (identified as *S. bendirii* from location; see Verts and Carraway 1998) capturing salmon parr in a small shallow pool. Maser and Franklin (1974) noted that on the Oregon coast a terrestrial snail (*Haplotrema vancouverense*) is commonly eaten by Pacific water shrews. *H*. v*ancouverense* is found in forested habitats in the Fraser River valley of British Columbia (Forsyth 2004). Dietary data on the Canadian population are scanty. A museum specimen taken 8 July 1929 at Peardonville had the notation “stomach contained water beetles, worms, insects” on its tag. Glen Ryder (pers. comm.) has observed Pacific water shrews feeding on salamander and dragonfly larvae in British Columbia.

No breeding data exist for the Canadian population. In Oregon the breeding season extends from February to August (Maser *et al*. 1984). Pregnant females have

been observed in April and May and nestlings found in March. Litter size for three females from Oregon ranged from 5 to 7 (Verts and Carraway 1998). The numbers of litters produced by a female in the breeding season has not been documented but it would be expected to be two or three, similar to the common water shrew (Conaway 1952). According to Pattie (1969), males do not reach sexual maturity in their first summer and first breed at about 10 months of age. Conaway (1952) reported a similar pattern of sexual maturity for male common water shrews. Age at sexual maturity is unknown for female Pacific water shrews but in the common water shrew successful pregnancy is uncommon for females in their first summer (Conaway 1952). The maximum life span would be expected to be about 18 months similar to that of the common water shrew (Conaway 1952). Assuming that most females do not breed in their first summer, the generation time is about one year.

Nothing is known about population structure or mortality rates.

Predation

Maser *et al*. (1984) speculated that Pacific water shrews are eaten by owls, domestic cats, fish, and Pacific giant salamanders (*Dicamptodon tenebrosus*). A Pacific water shrew skull was recovered in a Barn Owl (*Tyto alba*) pellet found near Burns Bog, British Columbia. Galindo-Leal and Runciman (1994) suggested that domestic cats were a major predator.

Physiology

No research has been done on physiological requirements. Typical of all species of the genus *Sorex*, it would be expected to have a high metabolic rate and high energy demands. Captive common water shrews, for example, consumed 10.3 grams of food per day (Conaway 1952). Although associated with aquatic habitats, the physical and chemical characteristics (e.g., temperature, pH, salinity, turbidity, water quality) of aquatic habitats tolerated by the Pacific water shrew have not been documented.

Dispersal/migration

Nothing is known about dispersal patterns or movements. Maser *et al*. (1984) noted that during winter rains there was a tendency for young-of-the-year to disperse, and Maser and Franklin (1974) reported that this shrew was “caught at great distances from water during the wettest season” but gave no specific details. Craig and Vennessland (2004a) speculated that most movements would be expected to be linear bordering riparian or water edge habitats. However, McComb *et al*. (1993), captured this shrew up to 350 m from streams in mature upland forests suggesting that it will disperse through forests that lack standing water. To what extent it disperses through disturbed forests or anthropogenic habitats such as cultivated fields, drainage ditches that border agricultural lands, and urban areas is unknown. However, paved roads, cultivated agricultural lands, and urban areas presumably would represent formidable barriers to movements.

Despite the lack of information on dispersal, this species' Canadian range appears to be fragmented. Because of intense urban and agricultural development, fragmentation is most pronounced in the municipality of Vancouver and in areas on the south side of the Fraser River. Zuleta (1993) estimated that of 270 forest fragments (most < 50 ha) in the Langley area, only 61 (23%) had suitable riparian forest for the Pacific water shrew. A recent GIS analysis for the Aldergrove area (Fig. 4) demonstrates the scale of fragmentation. Remaining forest fragments are small and widely scattered separated by large urban and agricultural areas. Streams and wetlands even with a 100-m buffer as recommended by the province's *Best Management Practices Guidelines for Pacific water shrew in Urban and Rural Areas* (Craig and Vennesland 2004b) are also disconnected.

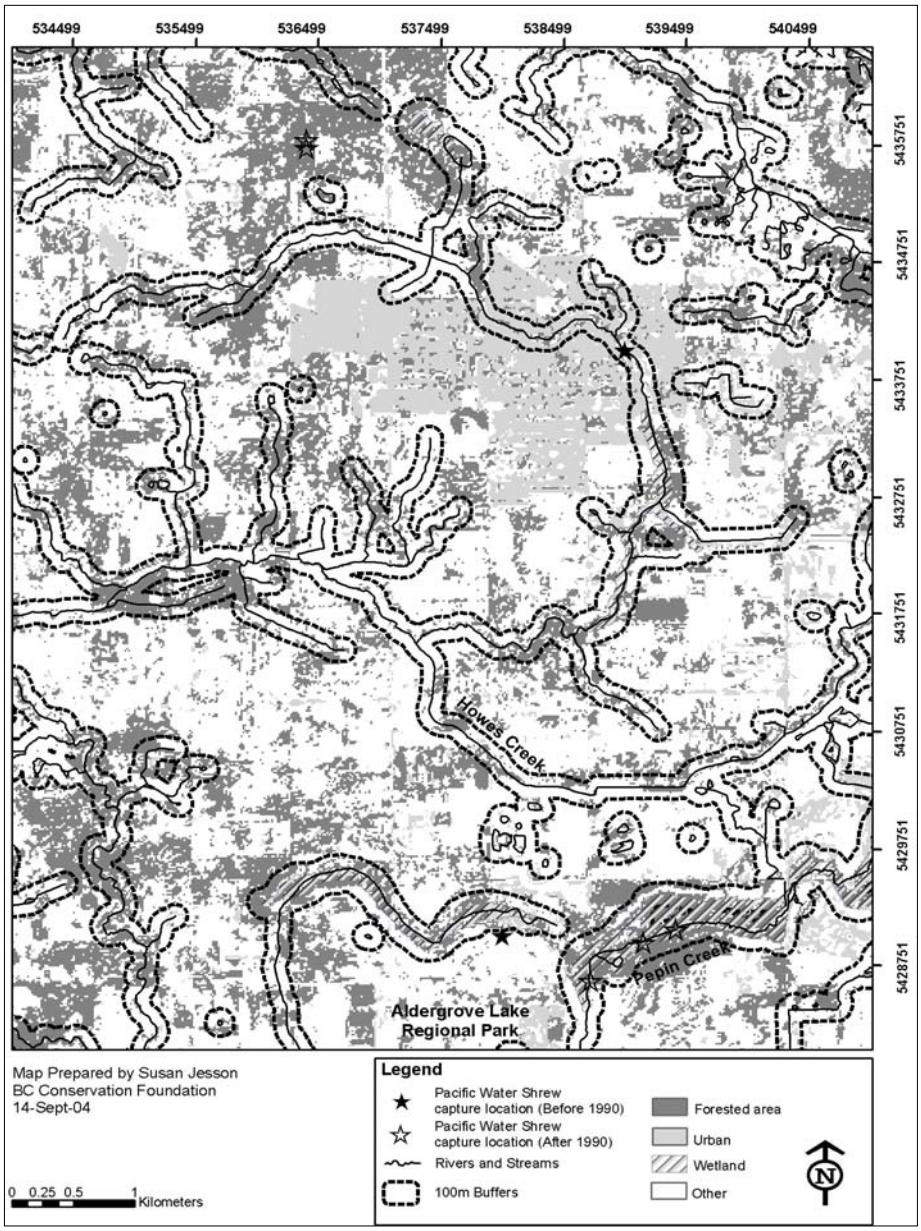

Figure 4. Map derived from a GIS analysis illustrating habitat fragmentation in the Aldergrove area of southwestern British Columbia.

Interspecific interactions

Four other shrew species are sympatric with the Pacific water shrew in southwestern British Columbia: common shrew (*Sorex cinereus*), dusky shrew (*Sorex monticolus*), Trowbridge's shrew (*Sorex trowbridgii*), and vagrant shrew (*Sorex vagrans*). Because of differences in body size, diet, behaviour, and microhabitat (Nagorsen 1996), competition with the Pacific water shrew is likely minimal. Competition with the common water shrew, an aquatic shrew similar in body size to the Pacific water shrew, is a possibility. The two species are generally allopatric in southwestern British Columbia segregated by elevation (Nagorsen 1996), but their distributions are parapatric in parts of the southern Coast Mountains on the north side of the Fraser River and in the Chilliwack Valley. To what extent this distributional pattern is maintained by competitive exclusion is unknown.

Adaptability

Semi-aquatic, the Pacific water shrew is capable of swimming and diving in water. Air trapped under the fur provides buoyancy and possibly insulation while in water. Swimming movements are derived from alternate strokes of the hind feet. Pattie (1969) observed swimming periods up to 3.5 minutes in captive animals. Dives probably do not exceed 60 seconds in duration (Calder 1969). Churchfield (1990) noted that despite their semi-aquatic life-style, the European water shrew (*Neomys fodiens*) and North American water shrews (*S. bendirii*, *S. palustris*) have no physiological adaptations for diving. Their specializations for swimming are rudimentary consisting of fimbriated hind feet, water-resistant pelage, and a large body size that reduces heat loss. Evidently the Pacific water shrew can run on top of the water without submerging for 3 to 5 seconds. Presumably this species frequently grooms and dries its fur after swimming similar to the common water shrew (Calder 1969) and European water shrew (Vogel 1990) to reduce thermal conductance and heat loss. Pattie (1969) observed captive animals caching excess earthworms after immobilizing them by a series of bites. The Pacific water shrew is unable to enter daily torpor (McNab 1991) and food caching would be an important foraging strategy for coping with periodic food shortages.

The only available data on home range size is Harris' (1984) estimate of 1.09 ha. However, Harris (1984) gave no information about the source of his estimate. Based on Harris' estimate and an assumption that a Pacific water shrew's home range would be 25-m wide on a streamside, Craig and Vennesland (2004a) calculated that the home range would extend about 400 m along a water body. Nothing is known about the social structure of this shrew or the extent that home ranges overlap among individuals. Radio-tracking studies are required to determine the home range size and social structure.

POPULATION SIZES AND TRENDS

Search effort

Most of the occurrence records for this species in Canada are based on incidental captures or observations by museum collectors and naturalists or recent surveys with

pitfall traps (Craig and Vennesland 2004b) conducted in very limited geographic areas as part of environmental assessments. However, two intensive surveys have been done for this species in Canada that can be used to assess presence-absence and sampling effort. From 1989-1991, Seip (unpublished data) and Seip and Savard (1990) sampled 22 sites in clear-cut, second growth, and old growth forest stands within the range of the Pacific water shrew in the Capilano, Seymour, and Coquitlam rivers' watersheds in the southern Coast Mountains (Fig. 5). They employed pitfall traps consisting of cans, Museum Special snap traps and Sherman live traps with a sampling effort of 17,315 pitfall trap nights, 6,054 snap trap nights and 4,791 Sherman live trap nights. Only 5 Pacific water shrews were taken at 2 of 22 sites during this sampling period. All were taken in pitfall traps. Seip and Savard (1990) give no information on the proximity of their traps to water or riparian habitats.

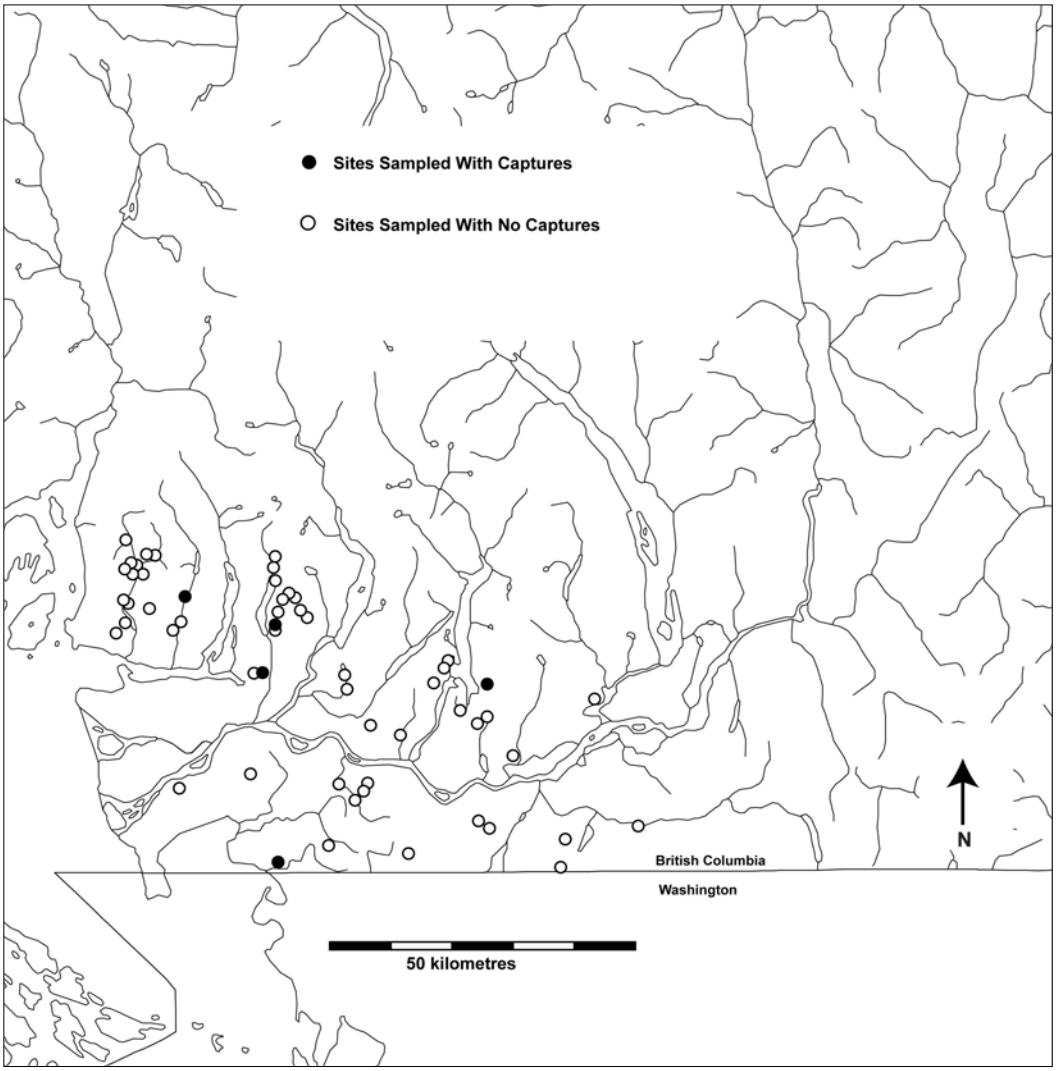

Figure 5. Presence-absence data for Pacific water shrews (*Sorex bendirii*) at 61 locations surveyed within its range. Based on 22 locations surveyed from 1989-1992 by Seip (unpublished data) and Seip and Savard (1990) and 39 locations sampled in 1992 by Zuleta and Galindo-Leal (1994).

In 1992, Zuleta and Galindo-Leal (1994) surveyed 55 sites at 39 locations (Fig 5) for Pacific water shrews and other small mammals employing plastic bucket traps. Their study area covered most of the Canadian range of the Pacific water shrew, although a limitation was that no sampling was done in regional or provincial parks. At each location, their sampling design consisted of one trap line of 15 trap stations set along a watercourse (distance from water not given) and one or two other trap lines set 50-100 m from watercourses in forest. Traps were set at a location for two to five weeks. Their sampling effort of 13,462 trap nights produced only 3 Pacific water shrew captures at 3 separate locations.

Abundance

No estimates of population density exist for this species from any part of its range, and the total number of individuals and the number of mature animals in Canada is unknown. The Pacific water shrew appears to be rare throughout its range. Few captures of this species were taken in small mammal studies done in coastal Oregon and Washington (Aubry *et al*. 1991) and its relative abundance in various habitats was low compared with other shrew species. With its large body size and specialized feeding niche, the Pacific water shrew would be expected to be a rare species in shrew communities. A general pattern consistent among shrew communities in temperate regions (Churchfield 1991) is that the intermediate-sized species tend to be numerically dominant. The 8 captures of Pacific water shrew taken by Seip and Savard (1990) and Zuleta and Galindo-Leal (1994) despite an intensive sampling effort of 41,622 trap nights (Fig. 5) can be attributed to both the difficulty of detecting this shrew even with effective traps such as pitfalls (see Bury and Corn 1987) and its natural rarity. As an example of the difficulty in detecting this species and determining its absence, Zuleta and Galindo-Leal (1992) captured no Pacific water shrews at three separate locations in Clayburn Creek on Sumas Mountain in their 1992 survey. Yet a Pacific water shrew was accidentally captured in a Gee-type minnow trap set in Clayburn Creek in 1995 during a fish survey.

Fluctuations and trends

Nothing is known about yearly population fluctuations in the Pacific water shrew. Long-term population trends can only be inferred from anecdotal accounts and evidence based on the capture of museum specimens. The only published information on the status of mammals in the lower Fraser River valley in early historical time was the review by Allan Brooks (Brooks 1902). He described the Pacific water shrew as “fairly common” in the Chilliwack region and he collected a large series of museum specimens from this area in the late 1800s. Of the 114 Canadian museum specimens (collected from 1888-1999) that exist for this species, 29 (25%) were taken by Brooks in a 3-year period from 1895-1897 at “Sumas” a location that probably refers to the Sumas Prairie where according to Laing (1979) much of Brooks’ collecting was done in this period. The Sumas Prairie was a large wetland of marshes and sloughs associated with Sumas Lake that was drained by 1924 (Moore 1990). Given the primitive and inefficient traps available in the late 1800s, and the low capture rates of Pacific water shrew in the

1990s using more effective pitfalls traps (see previous section), Brooks' capture of 29 animals in 3 years is noteworthy, suggesting the possibility of higher population densities in the late 1880s before large scale habitat change.

Rescue effect

The Pacific water shrew inhabits Whatcom County in Washington adjacent to the Canadian border. According to John Fleckstein (pers. comm.) Washington has re-classified this species as S4 from S5 because of habitat change in the Puget Sound lowlands. The general habitat model in Johnson and Cassidy (1997) shows this species widespread adjacent to the Canadian border. However, because little is known about the actual distribution and population status of this shrew in areas adjacent to the Canadian population, it is difficult to evaluate the potential for rescue effect from Washington. It is noteworthy that the portion of the Canadian range adjacent to the Washington population is an area heavily impacted by habitat loss. Suitable habitat for immigrants would be minimal and highly fragmented.

LIMITING FACTORS AND THREATS

The Pacific water shrew is at the northern limits of its range in Canada, where it inhabits a restricted area in the lower Fraser River basin. Biological factors that determine its limited range in Canada are essentially unknown but competitive exclusion with the ecologically similar common water shrew probably contributes to its distributional limits. Although this species is not at risk in the United States portion of its range, in Canada its distribution coincides with a heavily urbanized area undergoing rapid development and habitat change (Fig. 6).

In 2004, the total population for the Greater Vancouver Regional District and the Fraser Valley Regional District was about 2.4 million (Table 4). This represents a population increase from 1996 of about 11%. There are no data on the amount of land used for this population growth, but Environment Canada (1992) estimated that growth and development from 1987 to 1992 in the Fraser Basin required about 934 ha of land per year. Most of the land for urban expansion was agricultural land (Moore 1990). Although the rate of conversion of rural to urban land has been declining because of more intensive use of available land, the supply of new developable land is finite and diminishing in the region. According to Environment Canada (1992), future population growth and development pressures will increase proposals for the development of remaining agricultural lands, wetlands, foreshore areas, forested land, and mountain slopes.

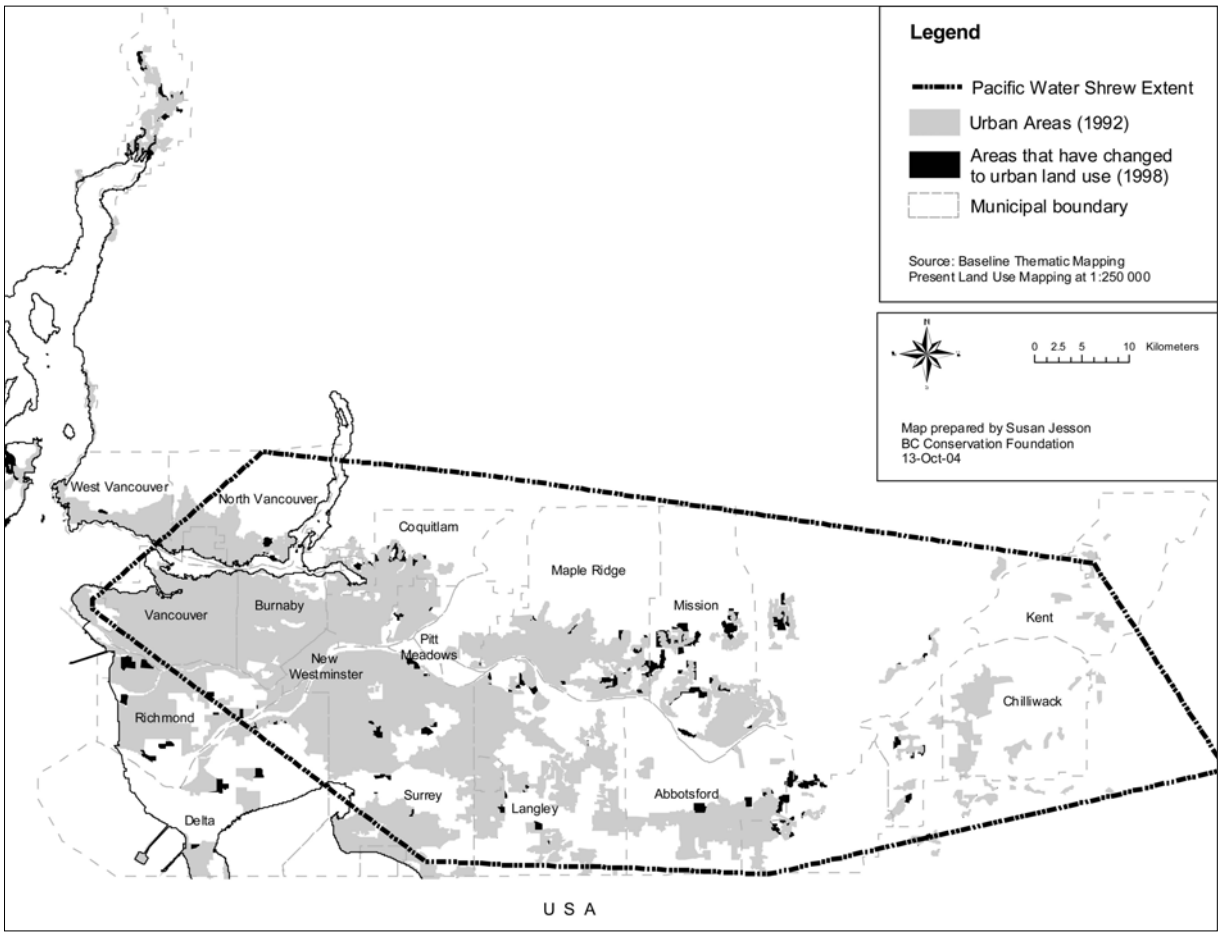

Figure 6. The amount of urbanized area within the range (extent of occurrence) of the Pacific water shrew (*Sorex bendirii*) in Canada.

Rarity, coupled with its restriction to riparian and wetland habitats, makes the Pacific water shrew susceptible to habitat loss, fragmentation, and degradation. Although agriculture and forest harvesting activities impact this species, development is likely its greatest threat. Housing, commercial, recreational (such as golf courses), and industrial development reduces forested areas and riparian habitats that border streams or wetlands and degrade habitat from run-off and storm water management (Craig and Vennesland 2004a). More research is needed to determine the distances and habitats that this shrew will disperse through in natural and modified landscapes. Its use of culverts and anthropogenic habitats such as agricultural drainage ditches also is unknown. But highways and roads are major barriers that would limit movements and increase fragmentation. No research has been done on the effect of water quality on this shrew. Changes in water quality resulting from sedimentation or contaminants could

impact aquatic invertebrates that are eaten by the Pacific water shrew. Water contaminants such as oil would be expected to reduce the insular efficiency of its pelage. With much of this shrew's range on private land, development activity in riparian areas will mostly be regulated by municipalities (see next section). The *Best Management Practices Guidelines for Pacific water shrew in Urban and Rural Areas* (Craig and Vennesland 2004b) recommend 100-m buffers around wetlands, streams, and creeks. Given the potential conflict between these recommendations and future development proposals, municipalities may choose to ignore the guidelines.

Table 4. Changes in population estimates for the Greater Vancouver Regional District and the Fraser Valley Regional District from 1996-2004. Data from BC Stats, Service BC, Ministry of Management Services.

Regional District	1996	2004	1996-2004 % change
Greater Vancouver	1,906,492	2,132,697	10.6
Fraser Valley	230,976	260,247	11.2

Potential threats to this species include mortality from accidental captures in minnow traps and domestic cat predation. Pacific water shrews occasionally drown in minnow traps used by fisheries biologists for fish surveys. The scale of this accidental mortality is probably minimal. Galindo-Leal and Runciman (1994) emphasized the role of domestic cats as a major predator of Pacific water shrews in urban and agricultural landscapes. Because no studies have been on domestic cat diets in the lower Fraser River valley, the impact of this predator cannot be assessed.

SPECIAL SIGNIFICANCE OF THE SPECIES

The Pacific water shrew is a member of the Pacific Coastal faunal element, a group of coastal mammals that range from northern California to British Columbia and southeastern coastal Alaska (Nagorsen 2004). In Canada, this species is endemic to the Pacific Maritime Ecozone. A rare cryptic mammal, this shrew is largely unknown to naturalists.

EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

This species is not listed by the IUCN. It was first designated Threatened by COSEWIC in 1994 (Galindo-Leal and Runciman 1994). It was re-examined and confirmed as Threatened in 2000 based on the 1994 report with an addendum of new occurrence records. The global heritage status rank is G4 (apparently secure), national ranks are N4 (apparently secure) for the United States and N1N2 (critically imperiled or imperiled) for Canada. State rankings are California S3S4 (vulnerable to apparently secure), Oregon S4, and Washington S4 (apparently secure). British Columbia has designated this species as S1S2 (critically imperiled or imperiled).

In British Columbia, the Pacific water shrew is protected from being killed or collected under the provincial Wildlife Act. This species is listed as an Identified Wildlife Species under the province's Forest and Range Practices Act. Species listed under the Act are considered to be at risk and require special management by establishing Wildlife Habitat Areas (WHA). Guidelines under the Forest and Range Practices Act (Lindgren 2004) specify that a WHA for the Pacific water shrew must include a 30-m core area and a 45-m management zone on each side of a stream or wetland. Various recommendations are provided for silviculture. To date no WHAs have been designated for the Pacific water shrew. Some guidelines for protecting riparian habitats also exist under the Act. Despite the various guidelines, the provincial Forest and Range Practices Act provides minimal protection for this shrew. The Act only applies to provincial Crown land. Because less than 20% of the Canadian range is on Crown land, much of this species' habitat is exempt from the Act. Moreover, the most serious threat to this species is loss of habitat from urban development on private lands—areas not covered by the Act.

Riparian habitat protection is also provided by the Riparian Areas Regulation of the provincial Fish Protection Act (British Columbia Ministry of Water, Air and Land Protection 2004). This new regulation comes into effect 31 March 2005 and it will transfer control of regulating riparian habitats to local municipalities. The regulations apply only to streams, creeks, ditches, or wetlands with fish or that are connected to freshwater ecosystems with fish in association with new residential, commercial and industrial development on land under local government jurisdiction. The Department of Fisheries and Oceans (DFO) also has guidelines for establishing Fisheries Sensitive Zones to protect fish and fish habitat (Fisheries and Oceans Canada 1993). The provincial Riparian Areas Regulation and the DFO regulations apply only to fish-bearing streams and creeks. Because the Pacific water shrew inhabits non-fish-bearing streams and small wetlands, these regulations are inadequate to protect this shrew (Craig and Vennesland 2004a).

None of the Pacific water shrew's range is in a national park. Its known distributional area includes 5 provincial parks and 26 regional parks (Table 5). They encompass some 1,292 km^2. However, the amount of Pacific water shrew habitat contained in these protected areas is much smaller. For example, the two largest, Golden Ears and Pinecone Burke, are largely outside the known range of *S. bendirii*. Moreover, they and other large parks in the Coast Mountains such as Cypress, Mount Seymour and Lynn Headwaters contain large areas above 800 m elevation, the upper elevational limits of this shrew. It is noteworthy that the largest and most extensive system of protected areas is on the north side of the Fraser River. In the heavily urbanized area on the south side of the Fraser River where the Pacific water shrew is most fragmented, protected areas consist of small and highly isolated regional parks with no connectivity.

Table 5. Provincial and regional district parks within the known range of Pacific water shrew (*Sorex bendirii*).

Park	Area (ha)	*Sorex bendirii* Records	Comments
Provincial Parks			
Cypress	3,012		large area above elevational range
Cultus Lake	2,561	historical specimens	
Golden Ears	62,540		mostly outside species range
Indian Arm	6,826		
Kilby	3		
Mount Seymour	3,508	historical specimens	large area above elevational range
Pinecone Burke	38,000		mostly outside species range
Rolley Lake	115		
Greater Vancouver Regional District Parks			
Aldergrove Lake	280	recent observations	
Belcarra	1,116		
Boundary Bay	182		
Brae Is. Reserve	71		
Burnaby Lake	311		
Campbell Valley	549	historical observations	
Capilano River	143		
Colony Farm	262		
Deas Island	72		
Derby Reach	297		
Fraser River Island	209		
Glen Valley	112		
Grant Narrows	6		
Kanaka Creek	413		
Lynn Headwaters	4,685		large area above elevational range
Matsqui Trail	117		
Minnekhada	211		
Pacific Spirit	809	historical specimens	
Surrey Bend	362		
Tynehead	261		
Widgeon Marsh	559		
Fraser Valley Regional District Parks			
Neilson	10		
Cascade Falls	10		
Fraser River	17		
Sumas Mountain	1,497	recent captures	
Cheam lake	93	recent captures	

TECHNICAL SUMMARY

Sorex bendirii
Pacific water shrew musaraigne de Bendire
Range of Occurrence in Canada: British Columbia

Extent and Area Information	
• *Extent of occurrence (EO)(km²)* **Map (Fig. 3) of historical and recent occurrences**	3,350 km²
• *Specify trend in EO*	Unknown
• *Are there extreme fluctuations in EO?*	No
• *Area of occupancy (AO) (km²)* **Unknown**	-
• *Specify trend in AO*	-
• *Are there extreme fluctuations in AO?*	-
• *Number of known or inferred current locations*	44
• *Specify trend in #*	Unknown
• *Are there extreme fluctuations in number of locations?*	No
• *Specify trend in area, extent or quality of habitat*	Habitat declining
Population Information	
• *Generation time (average age of parents in the population)*	1 year
• *Number of mature individuals*	Unknown
• *Total population trend:*	Unknown
• *% decline over the last/next 10 years or 3 generations.*	
• *Are there extreme fluctuations in number of mature individuals?*	No
• *Is the total population severely fragmented?*	Yes
• *Specify trend in number of populations*	-
• *Are there extreme fluctuations in number of populations?*	-
• List populations with number of mature individuals in each:	
Threats (actual or imminent threats to populations or habitats)	
Habits loss and habitat fragmentation from urban development (roads, housing, commercial, industrial) Habitat loss from forest harvesting Water quality degradation from development	
Rescue Effect (immigration from an outside source)	
• *Status of outside population(s)?* **USA: Washington S4, status in county bordering Canada unknown**	
• *Is immigration known or possible?*	Yes
• *Would immigrants be adapted to survive in Canada?*	Yes
• *Is there sufficient habitat for immigrants in Canada?*	No?
• *Is rescue from outside populations likely?* **Quantitative Analysis**	No?
Current Status COSEWIC: Threatened in April 1994 and May 2000 Endangered in April 2006	

Status and Reasons for Designation

Status: Endangered	**Alpha-numeric code**: B1ab(i,iii)

Reasons for Designation:

The habitat of this rare species, confined to the lower Fraser valley region of British Columbia, continues to decline and fragment as a result of development. There is little chance of rescue. It is extremely rare throughout its range.

Applicability of Criteria

Criterion A: While there is no direct evidence of a declining population trend, the available habitat is rapidly declining. However, there are no data on population size. It appears to be rare throughout its range.

Criterion B: EO less than 5,000 km^2; AO is unknown; Continued decline in suitable habitat and remaining habitat patches are highly fragmented.

Criterion C: Total population size is unknown but likely in the thousands. No direct evidence for decline, but suitable habitat has declined dramatically.

Criterion D: Total population size is unknown but likely in the thousands.

Criterion E: Not available.

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Day, Joanne. Information Coordinator, Fisheries and Oceans Canada, Vancouver, BC.
Fleckstein, John. Zoologist, Washington Natural Heritage Program, Olympia, WA, USA.
Friis, Laura. Species Specialist, Biodiversity Monitoring and Reporting Section, Ministry of Water, Land and Air Protection. Victoria, BC.
Forsyth, Robert. Smithers, BC.
Fraser, Dave. Endangered Species Specialist, Ministry of Water, Land and Air Protection. Victoria, BC.
Goulet, Gloria. Coordinator, Aboriginal Traditional Knowledge, COSEWIC Secretariat, Canadian Wildlife Service, Environment Canada, Ottawa ON.
Guy, Stewart. Project Manager, Wildlife Conservation Planning, Ministry of Water, Land and Air Protection, Victoria, BC.
Haid, Susan. Greater Vancouver Region District (GVRD) Parks. Vancouver, BC.
Hureau, Stephen. Conservation Biologist, Canadian Wildlife Service, Environment Canada, Delta, BC.
Johnson, Richard. Associate Professor, School of Biological Sciences, Washington State University, Pullman, WA, USA.
Knopp, Denis. BC's Wild Heritage. Chilliwack, BC.
Lewis, Jeff. Washington Department of Fish and Wildlife, Olympia, WA, USA.
Moore, Kathleen. Canadian Wildlife Service, Environment Canada, Delta, BC.
Ramsay, Leah. Zoologist, Conservation Data Centre, Ministry of Sustainable Resources Management, Conservation Data Centre, Victoria, BC.
Schmidt, Chris. Seacor Environmental Inc. Vancouver, BC.
Smith, Danielle. Natural Resources Coordinator, CFB Esquimalt, Maritime Pacific Forces, Department of National Defence, Victoria, BC.
Vennesland, Ross. Chair, Pacific water shrew Recovery Team, Ministry of Water, Land and Air Protection, Surrey, BC.
Wornell, Heather. Area Planner, Greater Vancouver Region District (GVRD) Parks. Burnaby, BC.

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BIOGRAPHICAL SUMMARY OF REPORT WRITER

Dave Nagorsen holds a B.Sc. degree from the University of Guelph, and an M.Sc. degree in Zoology from the University of Toronto. He was curatorial assistant in the Mammalogy Department of the Royal Ontario Museum, Toronto for 10 years and mammal curator at the Royal British Columbia Museum for 20 years. He is a Departmental Associate in the Centre for Biodiversity and Conservation Biology at the Royal Ontario Museum, in Toronto. He has a broad interest in mammals. During his career he has conducted mammalian field work and inventories in the Caribbean, and various regions of Canada including the Canadian Shield, Hudson Bay Lowlands, the northern Yukon Territory, and British Columbia. He has authored or co-authored more than 50 published scientific papers and reports, three books, a number of unpublished reports, and many publications for a general audience; he is an associate editor for the Canadian Field-Naturalist. Dave is involved with a number of conservation initiatives including the Vancouver Island Marmot Recovery Team; the Pacific water shrew Recovery Team, the Terrestrial Mammals Specialist Group for COSEWIC; and the Rodent Specialist Group, Species Survival Commission of the IUCN.

COLLECTIONS EXAMINED

Canadian Museum of Nature, Ottawa
The Field Museum, Chicago
Museum of Comparative Zoology, Harvard University, Cambridge
Museum of Vertebrate Zoology, University of California, Berkeley
Royal British Columbia Museum, Victoria
Royal Ontario Museum, Toronto
Cowan Vertebrate Museum, University of British Columbia, Vancouver
United States National Museum, Washington, DC.