BC Environment

DISTRIBUTION AND ABUNDANCE OF FOUR SPECIES OF SMALL MAMMALS AT RISK IN A FRAGMENTED LANDSCAPE

by
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Ministry of Environment, Lands and Parks
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Canadian Cataloguing in Publication Data
Zuleta, Gustavo A.
Distribution and abundance of four species of small mammals at risk in a fragmented landscape.

(Wildlife working report, no. WR-64)

Includes bibliographical references. p. 24.
ISBN 0-7726-2085-7

1. Clethrionomys. 2. Shrews - British Columbia. 3. Moles (Animals) - British Columbia. 4. Voles - British Columbia. %. Wildlife habitat improvement - British Columbia. I. Galindo-Leal, Carlos. II. BC Environment. Wildlife Branch. III. Title. IV. Series.

QL737.I5Z84 1994 599.3'3 C94-960116-0

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SUMMARY

A sampling program directed to four taxa of small mammals considered at risk in the Lower Mainland of British Columbia [Washington Southern Red-backed Vole, (*Clethrionomys gapperi occidentalis*), Pacific Water Shrew (*Sorex bendirii*), Trowbridge's Shrew (*Sorex trowbridgii*), and Shrew-mole (*Neurotrichus gibbsii*)] was carried out to determine their distribution, abundance, and habitat use. Fifty-five sites in a variety of forest types were surveyed by pitfall trapping during late July-October 1992: in riparian coniferous (11); non-riparian coniferous (9); riparian mixed (26); and non-riparian mixed (9) forests.

A total of 999 individuals of 15 species of small mammals was captured. No *C. g. occidentalis* was found in any of the 18 sites that we surveyed over its historical range. *S. bendirii* was extremely rare (only three individuals were caught), restricted to riparian forested habitats, and distributed in a narrow range. Habitat loss and fragmentation are likely the major causes of local extinction. *S. trowbridgii* occupied both riparian and non-riparian mixed forests and its populations were abundant in the Lower Mainland. However, its range is decreasing, probably because of habitat loss and fragmentation. *N. gibbsii* inhabited all habitat types except riparian coniferous stands. Although Shrew-mole abundance was low all over its range, the species was present in a sufficient number of locations to be considered not at risk.

In order to protect the diversity of small mammals over their historical range in the Lower Mainland, our recommendations are:

1. to Red-list *S. bendirii* as for consideration for Threatened or Endangered designation;
2. to keep *S. trowbridgii* in the Blue List as a Vulnerable Species;
3. to down-list *N. gibbsii* to the Yellow List as a Species not at Risk if habitat is preserved;
4. to reintroduce *C. g. occidentalis* in the parks south of the Fraser River, if its absence is confirmed;
5. to protect by all possible means riparian forests along slow-moving watercourses at low elevations (< 200 m), preserving as much habitat as possible (no less than 100 m of forest at each side);
6. to establish new protected natural areas south of the Fraser River;
7. to inform the public about the importance of preserving riparian vegetation as shrew habitat; and
8. to urgently incorporate small mammals at risk into integrated wildlife and fisheries management guidelines.

As future research needs, we propose:

1. to evaluate the effect of habitat fragmentation on population viability, in order to improve habitat management recommendations;
2. to determine the impact of cat predation on small mammals at risk, in order to regulate cat activities in suburban or rural watercourses;
3. to determine the presence of *S. trowbridgii* in Tynehead and Derby Reach regional parks, and to confirm their extirpation in the area enclosed by the Nicomekl, Salmon and Fraser rivers; and
4. to verify whether *C. g. occidentalis* is a distinct taxon from adjacent subspecies.

1.0 INTRODUCTION

British Columbia harbours a very high diversity of wildlife species. However, resource management practices and industrial and urban developments are rapidly changing landscape mosaics and transforming wildlife habitat. Today, more than one hundred taxa are considered at risk in the province (Munro 1993). There is no question that populations of many species face great threats. It is uncertain, however, how different species will cope with landscape and habitat changes.

Southwestern British Columbia is the northern limit of the distributional range of a number of mammalian species. Their distribution in B.C. and Canada is restricted and overlaps greatly with the largest urban centre in the province. A major conservation problem in suburban areas is habitat loss and fragmentation (Burgman *et al.* 1992).

Rare species require most attention since small populations are subject to both deterministic and stochastic extinctions. Deterministic extinctions may be caused by such factors as habitat loss and overhunting. Stochastic extinctions result from natural, random environmental perturbations (Gilpin and Soulé 1986). Deterministic factors may reduce population size to a level where stochastic factors become important. For example, habitat loss results in a reduction in population size and distribution. In turn, a small population will be vulnerable due to demographic fluctuations, higher predation risk, increased genetic drift, loss of heterozygosity, and genetic variance (Gilpin and Soulé 1986).

There are different types of rarity (Rabinowitz *et al.* 1986). Species may be rare because of small geographic range, habitat specificity, small population size, or a combination of the above. Even among abundant species, population density might be lower closer to the boundaries of their distributional ranges (Brown 1984).

In this report we focus on four selected taxa of small mammals considered to be at risk: Pacific Water Shrew (*Sorex bendirii*), Trowbridge's Shrew (*Sorex trowbridgii*), Shrew-mole (*Neurotrichus gibbsii*), and Washington Southern Red-backed Vole (*Clethrionomys gapperi occidentalis*).

A common feature among these taxa is that they occur in coastal ecosystems in North America, from central/northern California to southern British Columbia (Hall 1981). All of them use, partially or exclusively, forested habitats (Anthony *et al.* 1987; George 1989; Aubry *et al.* 1991; Carraway and Verts 1991). The distributional ranges of the three insectivores are relatively small. They are certainly very restricted in Canada; their northern distributional limit occurs in the Lower Mainland. They differ, however, in habitat specificity and in population size.

The Pacific Water Shrew is a habitat specialist, strongly associated with riparian environments or wet ground in wooded areas (Pattie 1973; Anthony *et al.* 1987). It also occurs in low abundance all over its range (Kremsater and Andrusiak 1991).

Trowbridge's Shrew lives in a wide range of forested microhabitats (George 1989), but is rarely found in the same microhabitats that the Pacific Water Shrew uses (Dalquest 1941). It is the most abundant small mammal in the coastal region of Oregon and Washington states (Aubry *et al.* 1991; Gilbert and Allwine 1991; West 1991).

The Shrew-mole is found in wet, soft woodland soils and often shares that habitat with Trowbridge's Shrew (Dalquest and Orcutt 1942).

Finally, the Southern Red-backed Vole has a widespread distribution in Canada (Banfield 1974). However, the subspecies *C. g. occidentalis* is restricted to the forested ecosystems of the Pacific coast west of the Cascades (Nagorsen 1990).

The aims of this project are:

1. to assess the distribution and abundance of the selected species in the Lower Mainland;
2. to elaborate maps of species distribution;
3. to estimate relative abundance in different habitat types;

4. to provide recommendations for conservation and habitat management; and
5. to propose future research needs.

2.0 ACKNOWLEDGEMENTS

More than 60 people (Appendix 1), including private landowners, municipal and provincial officials, regional wildlife biologists, and university researchers, were contacted to request habitat/mapping/trapping information and/or entry permits. This project would not have been possible without their help. We thank Mike Gill for helping both in the field and in the lab preparing and identifying specimens. Susan Denike, Alex Frid, and John Boulanger provided help with fieldwork.

Special thanks are extended to Dave Nagorsen (Royal B.C. Museum) for providing access to an unpublished database of voucher specimens in North American museums and for identifying problematic specimens; to Dick Cannings for making available laboratory facilities and records from the University of B.C. Vertebrate Museum; and to Louise Waterhouse, from the Vancouver Forest District, for providing unpublished data of the Greater Vancouver Watersheds.

Finally, we thank Tom Sullivan, Mary Taitt, and Syd Cannings for their critical comments on the manuscript. Special thanks to Laura Friis for her continuous support throughout the development of the project.

3.0 METHODS

3.1 Study Area and Site Selection

Communities of small mammals were studied in 55 sites distributed in 39 locations (Figure 1) in southwestern British Columbia during late July-October, 1992. The approximately 4000 km^2 study area is a heterogeneous landscape. It includes three ecosections (Demarchi 1988): the Fraser Lowland (FRL), the Southern Pacific Ranges (SPR), and the Northwestern Cascade Ranges (NWC). The last two are within the Pacific and Cascade Ranges Ecoregion (Coast and Mountains Ecoprovince), and the former is within the Lower Mainland Ecoregion (Georgia Depression Ecoprovince). According to B.C. Ministry of Forests classification, the area includes one biogeoclimatic zone: the Coastal Western Hemlock Zone (Meidinger and Pojar 1991).

Sites were selected from topographic maps (1:50 000) and forest cover maps (1:20 000), using the presence of slow-moving watercourses as a major criterion. However, the selection of some sites was modified because of three factors. First, map information did not completely match with existing habitat types. Second, urbanization and other land uses generate a highly fragmented landscape where pure coniferous stands are almost nonexistent, particularly south of the Fraser River. Third, removal sampling was not permitted in provincial and regional parks. Site selection was restricted to locations at elevations below 600 m since most of the selected species are more likely to occur at lower altitudes (Nagorsen 1990). South of the Fraser River, many sites were in small, isolated patches of mixed or deciduous forest along watercourses. Logistics of surveying 7-12 locations simultaneously in areas > 1500 km^2 also directed choice of locations. Locations were never closer to one another than 1 km. Details of geographical characteristics and mapping information are indicated in Table 1. Some locations were particularly selected to confirm historical records (50-100 years ago), such as Sumas Mountain or Harrison Lake.

3.2 Trapping Procedure

The trapping method and intensity used in this study were chosen to meet the specific objectives of assessing the distribution and relative abundance of the particular small mammals over a relatively large geographical area, in a relatively short time frame, and with a limited budget. Ideally, a rigorous study of habitat use and population persistence should include different seasons and year-to-year variation. Demographic parameters should be documented to differentiate between temporary and persistent populations. Live-trapping should be carried out to document demographic parameters and movements, particularly when working with rare species. For this study, however, we

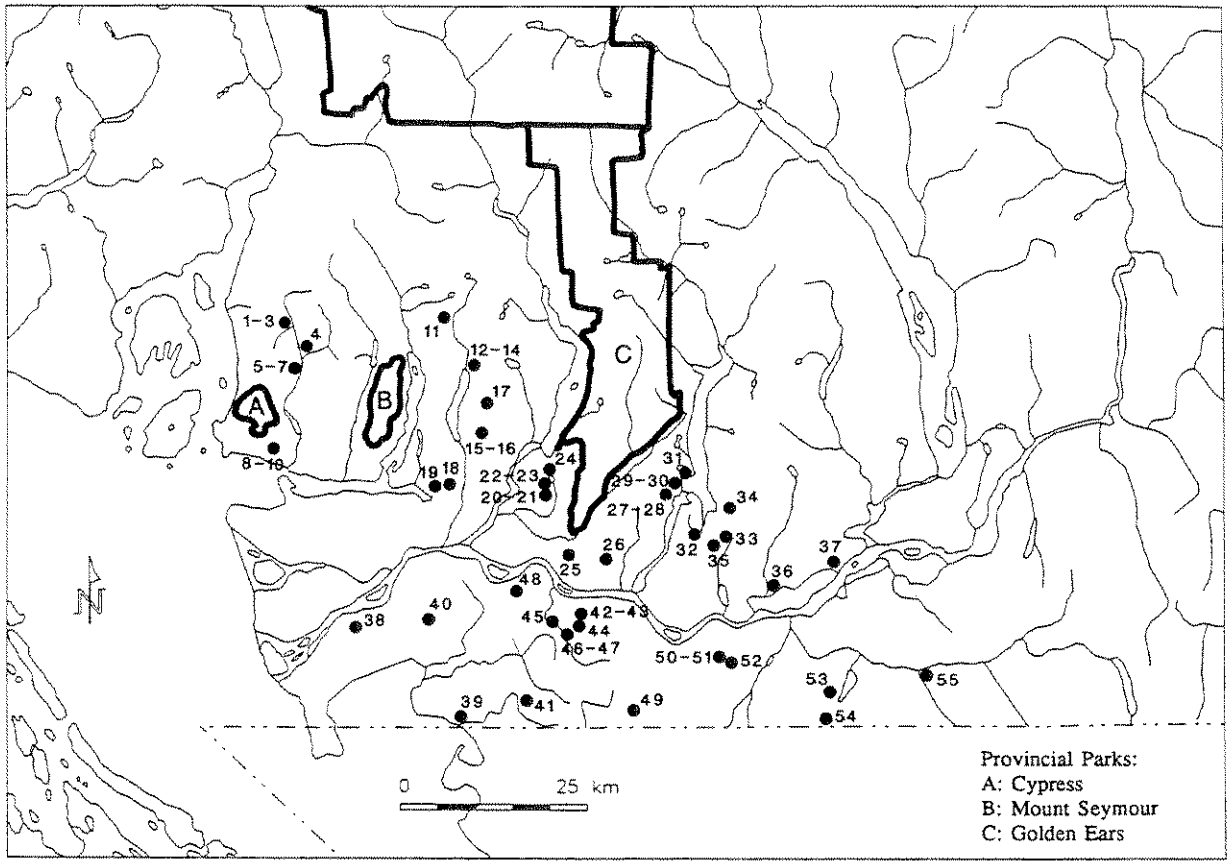


Figure 1. Distribution of sites surveyed during July-October 1992 in the Lower Mainland of B.C.

Table 1. Summary of surveyed sites (geological and mapping characteristics*)

Site no.	Location		UTM East	UTM North	Lat	Long	Elev.	Asp.	Eco-Sec.	1:50 000 Map	# of Traps	Traps Set	Eff. Total	Date Setup	Date Close
1	Enchantment Creek	Capilano Watershed	49070	547160	49 29 19	123 07 44	310	S	SPR	92 G/6	15	206	521	Jul 28	Sep 02
2	Enchantment Creek	Capilano Watershed	49075	547160	49 29 19	123 07 42	310	S	SPR	92 G/6	15	206	521	Jul 28	Sep 02
3	Enchantment Creek	Capilano Watershed	49030	548180	49 29 30	123 07 54	340	S	SPR	92 G/6	15	199	514	Jul 28	Sep 02
4	Eastcap Creek	Capilano Watershed	49250	547800	49 27 26	123 06 14	310	SW	SPR	92 G/6	15	210	525	Jul 28	Sep 02
5	Sister Pass Creek	Capilano Watershed	49185	547740	49 27 12	123 07 44	322	SW	SPR	92 G/6	15	181	496	Jul 28	Sep 02
6	Sister Pass Creek	Capilano Watershed	49185	547745	49 27 10	123 07 44	322	SW	SPR	92 G/6	15	207	515	Jul 28	Sep 02
7	Sister Pass Creek	Capilano Watershed	49185	547750	49 27 08	123 07 44	322	SW	SPR	92 G/6	15	203	518	Jul 28	Sep 02
8	Lawson Creek	W. Vancouver	48840	546680	49 21 21	123 10 23	430	S	FRL	92 G/6	15	210	525	Jul 28	Sep 02
9	Lawson Creek	W. Vancouver	48845	546680	49 21 21	123 10 25	430	S	FRL	92 G/6	15	210	525	Jul 28	Sep 02
10	Lawson Creek	W. Vancouver	48850	546680	49 21 21	123 10 27	430	S	FRL	92 G/6	15	210	525	Jul 28	Sep 02
11	Coquitlam River	Coquitlam Watershed	51720	548610	49 31 45	122 45 40	530	E	SPR	92 G/10	17	238	612	Jul 29	Sep 03
12	Unnamed I Creek	Coquitlam Watershed	51750	547925	49 28 06	122 45 30	280	SW	SPR	92 G/7	15	196	526	Jul 29	Sep 03
13	Unnamed I Creek	Coquitlam Watershed	51750	547930	49 28 08	122 45 30	280	SW	SPR	92 G/7	15	203	533	Jul 29	Sep 03
14	Unnamed I Creek	Coquitlam Watershed	51750	547935	49 28 10	122 45 30	280	SW	SPR	92 G/7	15	210	533	Jul 29	Sep 03
15	Orr Creek (tributary)	Coquitlam Watershed	51770	546740	49 21 41	122 45 27	280	S	SPR	92 G/7	15	210	505	Jul 29	Sep 03
16	Orr Creek (tributary)	Coquitlam Watershed	51775	546740	49 21 41	122 45 29	280	S	SPR	92 G/7	20	280	713	Jul 29	Sep 03
17	Old growth	Coquitlam Watershed	51915	547210	49 24 11	122 44 08	470	W	SPR	92 G/7	21	294	609	Aug 05	Sep 03
18	North Hoy Creek	Coquitlam	51520	546020	49 17 47	122 47 21	85	S	FRL	92 G/7	15	210	435	Aug 05	Sep 03
19	Scott Creek	Coquitlam	51376	546030	49 17 49	122 48 36	190	S	FRL	92 G/7	7	84	189	Aug 05	Sep 03
20	Spring Creek	UBC Res. Forest	53105	545760	49 16 19	122 34 20	150	S	FRL	92 G/7	15	167	251	Sep 04	Sep 25
21	Spring Creek	UBC Res. Forest	53110	545760	49 16 19	122 34 18	150	S	FRL	92 G/7	15	171	276	Sep 04	Sep 25
22	Blaney Creek	UBC Res. Forest	53055	545980	49 17 32	122 34 45	340	S	SPR/FRL	92 G/7	15	189	294	Sep 04	Sep 25
23	Blaney Creek	UBC Res. Forest	53050	545980	49 17 32	122 34 47	340	S	SPR/FRL	92 G/7	15	189	189	Sep 11	Sep 25
24	Loon Creek	UBC Res. Forest	53055	546040	49 17 54	122 34 45	350	S	SPR	92 G/7	11	122	185	Sep 04	Sep 25
25	Kanaka Creek	Maple Ridge	53520	545185	49 13 11	122 30 59	80	S	FRL	92 G/2	8	120	120	Sep 10	Sep 25
26	Whonnock Creek	Maple Ridge	54065	545020	49 12 21	122 26 27	150	S	FRL	92 G/1	15	210	435	Aug 27	Sep 25
27	Seventynine Creek	Mission, Stave Lake	54680	545900	49 17 02	122 21 12	140	E	FRL	92 G/8	15	133	133	Aug 27	Sep 11
28	Seventynine Creek	Mission, Stave Lake	54680	545905	49 17 04	122 21 12	140	E	FRL	92 G/8	15	56	56	Aug 27	Sep 11
29	Unnamed II Stream	Mission, Stave Lake	54865	546115	49 18 11	122 19 55	110	N	SPR	92 G/8	15	122	311	Aug 27	Sep 24
30	Unnamed II Stream	Mission, Stave Lake	54860	546115	49 18 11	122 19 53	110	N	SPR	92 G/8	15	99	276	Aug 27	Sep 24
31	Sayres Creek	Mission, Sayres Lake	54930	546240	49 18 45	122 19 53	120	S	SPR	92 G/8	15	96	96	Sep 17	Sep 25
32	Cardinals Creek	Mission, Steelhead	55180	545435	49 14 32	122 17 16	140	N	SPR/FRL	92 G/1	22	308	616	Aug 27	Sep 24
33	Lagace Creek	Dewdney-Alouette	55670	545340	49 13 58	122 13 16	90	SW	FRL	92 G/1	15	195	384	Aug 28	Sep 24

* Standard trapping effort includes only the first two weeks. Total trapping effort includes all weeks of trapping.

Table 1. (Continued).

Site no.	Location		UTM East	UTM North	Lat	Long	Elev.	Asp.	Eco-Sec.	1:50 000 Map	# of Traps	Traps Set	Eff. Total	Date Setup	Date Close
34	Davis Creek	Dewdney-Alouette	55630	545870	49 16 54	122 13 31	130	S	SPR	92 G/8	12	156	296	Aug 28	Sep 24
35	Belcharton Creek	Dewdney-Alouette	55490	545215	49 13 19	122 14 50	20	S	FRL	92 G/1	15	210	210	Sep 10	Sep 24
36	Inches Creek	Dewdney-Alouette	56135	544705	49 10 24	122 09 28	0	S	FRL	92 G/1	9	126	243	Aug 28	Sep 24
37	Elbow Creek	Dewdney-Alouette	57640	545658	49 15 32	121 56 58	30	E	FRL	92 H/5	15	210	405	Aug 28	Sep 24
38	Burns Bog	Delta	50005	544150	49 07 52	122 55 58	0		FRL	92 G/2	15	210	210	Oct 16	Nov 06
39	Fergus Creek	White Rock	51815	542930	49 01 05	122 45 07	10	S	FRL	92 G/2	15	210	315	Sep 22	Oct 13
40	Mahood Creek	Surrey	51315	544350	49 08 47	122 49 13	15	E	FRL	92 G/2	15	196	301	Sep 22	Oct 13
41	Anderson Creek	Langley	52758	543223	49 02 39	122 37 21	70	W	FRL	92 G/2	15	210	308	Sep 22	Oct 13
42	West Creek	Langley, Sperling	53460	544235	49 08 06	122 31 32	40	NW	FRL	92 G/2	16	224	301	Sep 22	Oct 13
43	West Creek	Langley, Sperling	53460	544235	49 08 04	122 31 32	55	NW	FRL	92 G/2	15	210	315	Sep 22	Oct 13
44	Coghlan Creek	Langley, Sperling	53405	544125	49 07 31	122 32 02	55	W	FRL	92 G/2	15	196	294	Sep 22	Oct 13
45	Salmon River (mid)	Langley, Forest Knolls	52955	544230	49 08 03	122 35 40	10	NW	FRL	92 G/2	15	210	315	Sep 22	Oct 13
46	Salmon River (head)	Langley, Hopington	53235	543945	49 06 29	122 33 21	25	NW	FRL	92 G/2	15	203	308	Sep 22	Oct 13
47	Salmon River (head)	Langley, Hopington	53230	543945	49 06 29	122 33 23	60	NW	FRL	92 G/2	15	210	315	Sep 22	Oct 13
48	Yorkson Creek	Langley, Walnut Grove	52540	544620	49 10 11	122 39 08	10	N	FRL	92 G/2	15	203	203	Sep 29	Oct 13
49	Papin Creek	Matsqui, Aberdeen	54235	543085	49 01 49	122 25 12	60	SW	FRL	92 G/1	15	203	308	Sep 22	Oct 13
50	Clayburn Creek (mid)	Matsqui, Clayburn	55525	543630	49 04 54	122 14 38	20	W	FRL	92 G/1	15	210	315	Sep 22	Oct 13
51	Clayburn Creek (mid)	Matsqui, Clayburn	55525	543625	49 04 52	122 14 38	40	W	FRL	92 G/1	15	203	301	Sep 22	Oct 13
52	Clayburn Creek (head)	Matsqui, Sumas	55725	543540	49 04 15	122 12 59	220	W	FRL	92 G/1	15	196	301	Sep 22	Oct 13
53	Unnamed III Creek	Chilliwack, Vedder Mtn.	57120	543350	49 02 08	122 01 32	570	SW	NWC	92 G/1	15	203	203	Sep 29	Oct 13
54	Frosst Creek	Lindell, Columbia V.	57025	542910	49 00 39	122 02 21	190	N	NWC	92 G/1	15	210	315	Sep 22	Oct 13
55	Tamihi Creek	Chilliwack	58465	543565	49 04 26	121 50 25	140	N	NWC	92 H/4	13	175	266	Sep 22	Oct 13

* Standard trapping effort includes only the first two weeks. Total trapping effort includes all weeks of trapping.

chose pitfall trapping because of its low cost and high effectiveness for a diverse fauna, especially for shrews (Williams and Braun 1983, Szaro *et al.* 1988). In addition, several shrew species can be difficult to identify in the field, and removal trapping allowed us to identify problematic species in the lab. Currently, methods are being developed to carry out such identifications in the field without removal (Vanessa Craig, pers. comm).

In every location, one to three sites were established; one site was alongside a watercourse and one to two sites were 50-100 m into the forest. Every site had a trapline with 15 stations situated 15 m apart with one pitfall trap per station. Pitfall traps (2 l plastic buckets) were filled with 0.5-1 l of 20% alcohol to preserve specimens. The buckets had two small holes at mid-height to reduce flooding. Corn oil was added (5 ml) on top of the alcohol to minimize evaporation. A total of 55 traplines were installed and the total trapping effort was 19 810 trap-nights (TN). Traps were checked weekly for two to five weeks and specimens were collected. Trapping information a he schedule for each site are indicated in Table 1. Traps were rarely disturbed by wildlife or humans. Only two traplines, near Stave Lake, were eliminated because of continuous disturbance by bears.

The number of individuals per 100 TN was used as an index of relative abundance. The index was standardized by including only the first two weeks of trapping. This was the minimum trapping effort used at all sites. The standardization represents a more adequate index of the abundance of resident populations. The index for the total trapping period is also included.

3.3 Criteria for Habitat Classification

We assigned every site to a broad habitat category according to the dominant tree species. We were unable to use the Broad Habitat Classes of the Wildlife Branch (Lea 1992) because habitats with deciduous species are under-represented in this classification. Habitat categories are indicated by the initials of the dominant species (Table 2). We encountered 11 tree species: western hemlock

Table 2. Number of sites in different habitat categories.*

	Habitat	Number of Sites
Deciduous		
D	Deciduous	1
Mixed		
AM	Alder/Mixed	11
DM	Deciduous/Mixed	8
HA	Hemlock/Alder	7
HM	Hemlock/Mixed	2
RA	Redcedar/Alder	3
RD	Redcedar/Deciduous	1
RM	Redcedar/Mixed	2
Coniferous		
H	Hemlock	1
HF	Hemlock/Fir	5
HR	Hemlock/Redcedar	12
P	Pine	1
RF	Redcedar/Fir	1
Total		**55**

* A=alder
H=hemlock
R=western redcedar
F=fir;
P=pine
D=deciduous (presence of bigleaf maple, alder, black cottonwood)
M=mixed (joint presence of some of the following species: bigleaf maple, hemlock, cedar, alder, fir.

(*Tsuga heterophylla*), western redcedar (*Thuja plicata*), Douglas-fir (*Pseudotsuga menziesii*), Pacific silver fir (*Abies amabilis*), Sitka spruce (*Picea sitchensis*), Pacific yew (*Taxus brevifolia*), lodgepole pine (*Pinus* cf. *contorta*), red alder (*Alnus rubra*), bigleaf maple (*Acer macrophyllum*), black cottonwood (*Populus balsamifera* ssp. *trichocarpa*), and vine maple (*Acer circinatum*).

Successional stages were classified as 3 (young forest), 4 (mature forest), and 5 (old-growth forest) (Lea 1992). Young forest was defined as lacking trees with > 50 cm d.b.h. Mature forest was defined as having some trees with > 50 cm d.b.h. Old growth was defined as having many trees with > 50 cm, d.b.h., but there were usually several trees with > 150 cm d.b.h. With this classification, however, there is high variation among mature forest classes; ranging from truly mature forest to areas where only a few large trees remain.

3.4 Taxonomic Identification

Insectivores were identified following van Zyll de Jong (1983) and Nagorsen (1990). Rodents were identified following Ingles (1965), Maser and Storm (1970), and Hall (1981). Since some of the *Sorex* species are difficult to distinguish, we cleaned the skulls of all specimens that were not reliably identified by external characteristics (282 out of 672). Most of the problematic identifications (207) have already been confirmed by David Nagorsen with 91% agreement. Most disagreements (78%) occurred between *S. monticolus* and *S. vagrans*. Only four cases included *Sorex trowbridgii*. Three individuals could only be identified as *Sorex* spp. because cranial features were too worn. Voucher specimens were deposited in the Royal B.C. Museum and in the University of B.C. Vertebrate Museum. Species are coded following the B.C. standard taxonomic classification (Campbell and Harcombe 1985).

4.0 RESULTS

We captured 999 individuals of 15 species of small mammals (Table 3). Five common species accounted for 91% of the total capture: Deer Mouse (*Peromyscus maniculatus*; 26%), Masked Shrew (*Sorex cinereus*; 19%), Dusky Shrew (*S. monticolus*; 19%), Wandering Shrew (*S. vagrans*; 16%), and Trowbridge's Shrew (*S. trowbridgii*; 11%). The remaining ten species were rare. These included species not adequately sampled by pitfall traps (Coast Mole, *Scapanus orarius*), and three out of the four selected species (Pacific Water Shrew, Shrew-mole, and Southern Red-backed Vole). In Appendix 2, data from forms for the Conservation Data Centre are presented. Only selected insectivore species were included.

Table 3. Total number of captures per species.

INSECTIVORES		**RODENTS**	
Sorex bendirii	3	*Clethrionomys gapperi*	11
Sorex palustris	1	*Peromyscus maniculatus*	264
Sorex cinereus	190	*Microtus oregoni*	21
Sorex monticolus	186	*Microtus longicaudus*	2
Sorex trowbridgii	107	*Microtus townsendii*	1
Sorex vagrans	160	*Zapus princeps*	1
Sorex spp.	25	*Zapus trinotatus*	2
Neurotrichus gibbsii	16	Voles (not identified to sp.)	8
Scapanus orarius	1		
Subtotal	689	Subtotal	310
TOTAL MAMMALS	**999**		
Other vertebrates:			
Frogs	162		
Salamanders	172		
Birds	1		

4.1 Geographical distribution

Maps of species distribution in North America (Hall 1981) usually do not consider landscape heterogeneity and/or habitat availability. They include areas defined by the outermost records of the taxa. Since habitat fragmentation is a major process in our study area, we present maps of localities instead of maps of species distribution. We used the distribution of locations of voucher specimens in North American museums (Nagorsen 1992) to compare our results with the historical range of the selected species.

Pacific Water Shrew (*Sorex bendirii*) — The Pacific Water Shrew was extremely rare. We caught only three individuals (0.4% of all insectivores, n = 689; Table 3) in three different sites. These were more than 35 km apart and there was no continuous habitat in between (Figure 2). All sites were within the historical distribution of the species (Figure 3). Two sites were north of the Fraser River: North Hoy Creek in Coquitlam, and Davis Creek in Dewdney-Alouette. The third site, Fergus Creek, was in White Rock, near the U.S. border. All sites were near suburban areas. Pacific Water Shrews were trapped 5 m, 20 m, and 120 m away from public ways in Davis Creek, North Hoy Creek, and Fergus Creek sites, respectively. They were present in two ecosections: FRL and SPR. They were not found in the NWC Ecosection.

We did not find Pacific Water Shrews in sites where they had been trapped before, such as Chilliwack, Sumas, Aldergrove, Blaney Lake, Loon Lake, and Orr Creek. North Hoy Creek was the nearest site to locations with previous records. However, the previous record is about 100 years old: eight Pacific Water Shrews were caught in Port Moody between 1894-1897 (Nagorsen 1992; Figure 3).

Trowbridge's Shrew (*Sorex trowbridgii*) — Trowbridge's Shrew was present in almost all sites south of the Fraser River (Figure 4), but only in one site north of the Fraser (Elbow Creek). Most records obtained in this study coincide with the historical distribution (Figure 5). However, Trowbridge's Shrew seems to be absent from the area enclosed by the Nicomekl, Salmon and Fraser Rivers (Municipal Districts of Delta and Surrey). Trowbridge's Shrews were present in two ecosections: FRL and NWC. They were not found in the SPR Ecosection.

Shrew-mole (*Neurotrichus gibbsii*) — Shrew-moles were trapped occasionally, but their distribution was widespread (Figure 6). They were present in eight sites distributed all over the study area. These records are within the boundaries of their historical distribution (Figure 7). Shrew-moles have been recorded in locations not included in our study area, such as Sechelt, Hope, and Skagit (Nagorsen 1992). Shrew-moles were present in two ecosections: FRL and SPR. They were not found in the NWC Ecosection, but are likely to occur there since they were recorded as far east as Manning Park.

Southern Red-backed Vole (*Clethrionomys gapperi* spp.) — Red-backed Voles (subspecies identification not yet completed) were found in seven sites, all north of the Fraser River (Figure 8). The species was present in two ecosections: FRL and SPR. They were not found in the NWC Ecosection, but are likely to occur there since they have been recorded across Canada.

4.2 Habitat Use and Requirements

For this report we present preliminary trends in habitat use only (Table 2). A more detailed analysis of microhabitat structure will be carried out in the future (see Appendix 3 for general habitat descriptions of sites).

Pacific Water Shrew (*Sorex bendirii*) — Pacific Water Shrews were caught in only three sites. Therefore, it is difficult to infer habitat use patterns. The main characteristics of these sites were as follows: all of the sites had creeks; habitats were dominated by both conifers (HR) and mixed forests (AM, DM); all sites had mature forest (4) with canopy cover greater than 50%. Pacific Water Shrews were found alone (one site), with Southern Red-backed Voles (one site), and with both Trowbridge's Shrews and Shrew-moles (one site).

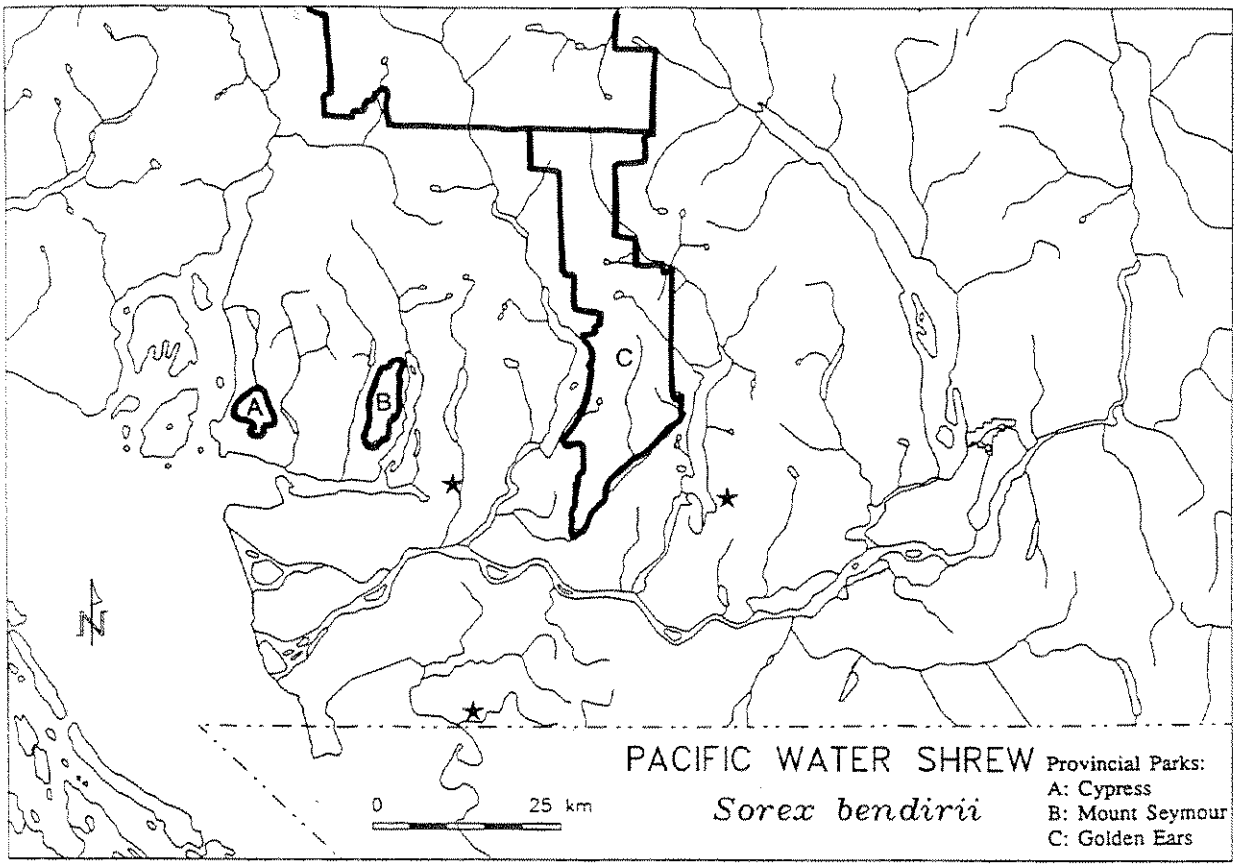
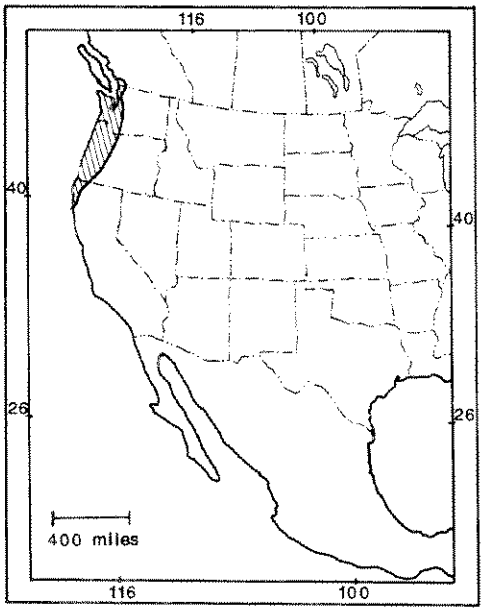


Figure 2. Distribution of sites where the Pacific Water Shrew (*Sorex bendirii*) was recorded during July-October 1992 in the Lower Mainland of B.C.

Geographical distribution of *S. bendirii* in North America (Hall and Kelson 1981).



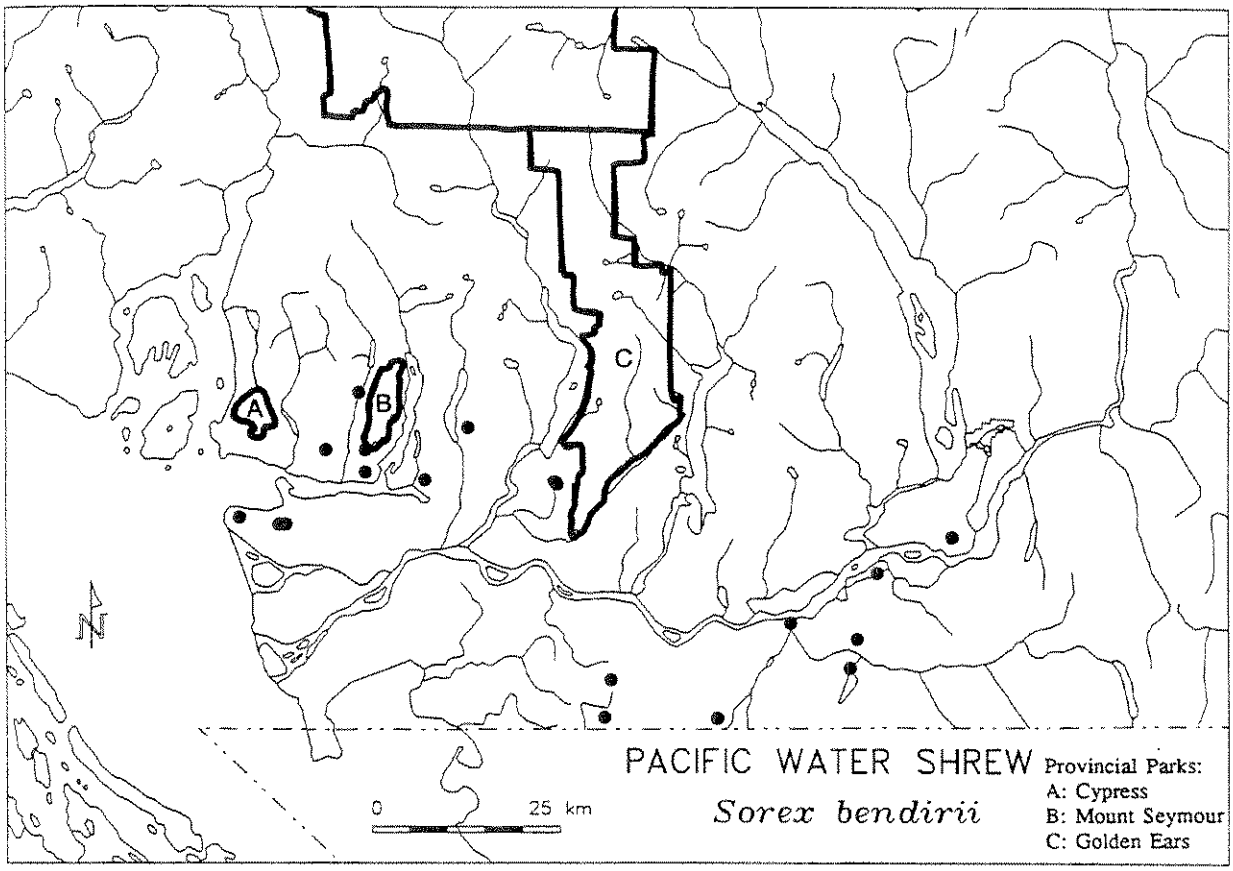


Figure 3. Distribution of sites where the Pacific Water Shrew (*Sorex bendirii*) has historically been recorded in the Lower Mainland of B.C. (Nagorsen 1992).

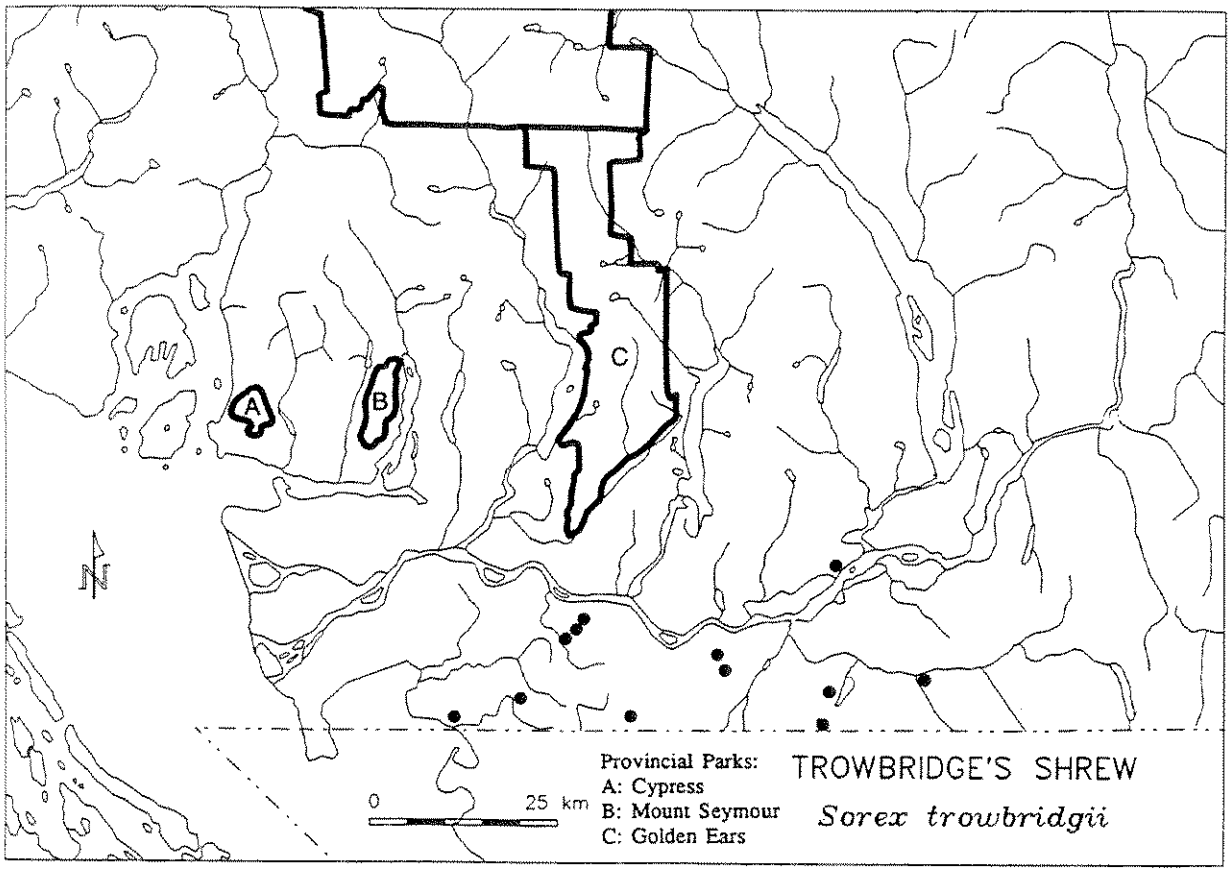
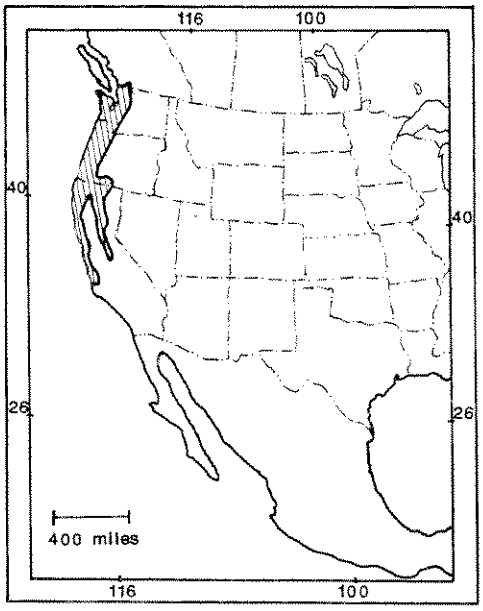


Figure 4. Distribution of sites where the Trowbridge's Shrew (*Sorex trowbridgii*) was recorded during July-October 1992 in the Lower Mainland of B.C.

Geographical distribution of *S. trowbridgii* in North America (Hall and Kelson 1981).



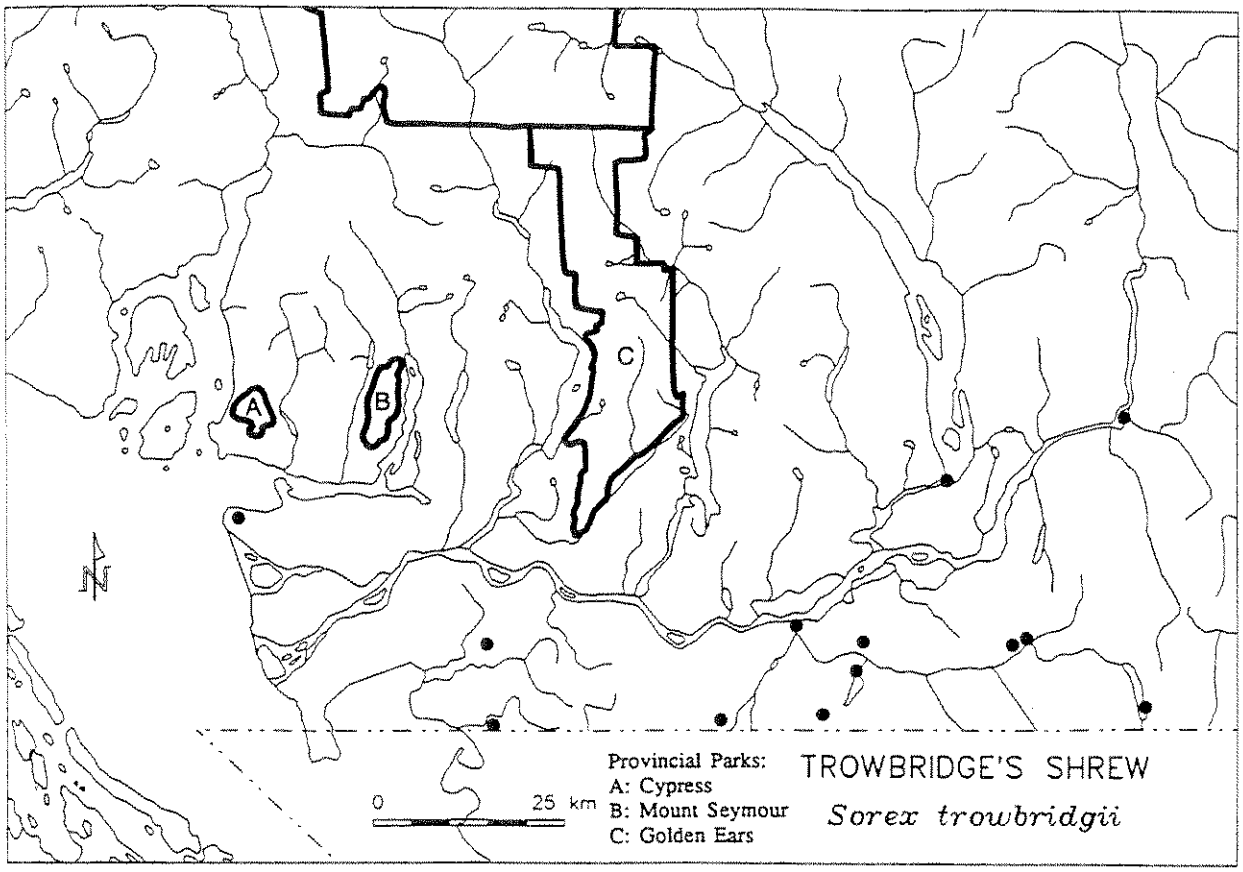


Figure 5. Distribution of sites where the Trowbridge's Shrew (*Sorex trowbridgii*) has historically been recorded in the Lower Mainland of B.C. (Nagorsen 1992).

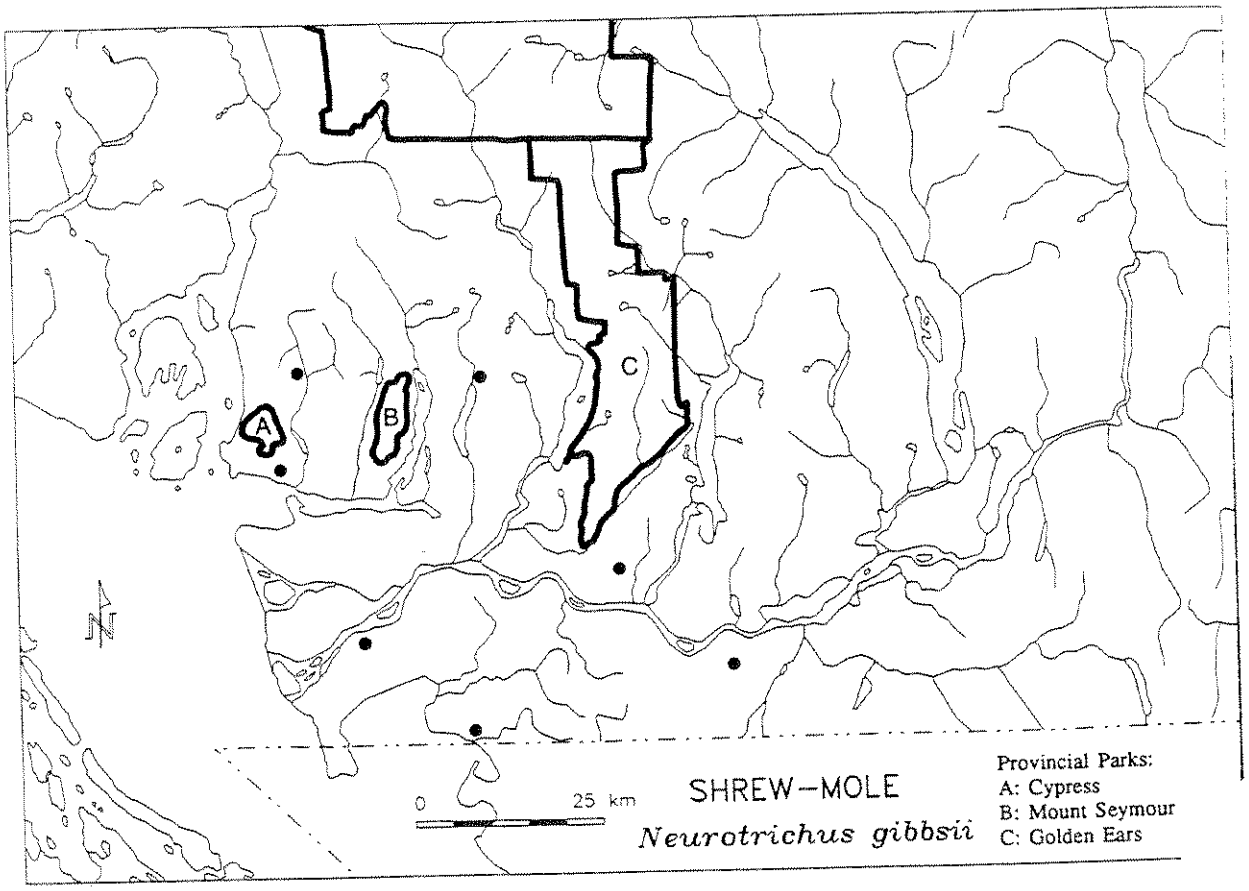
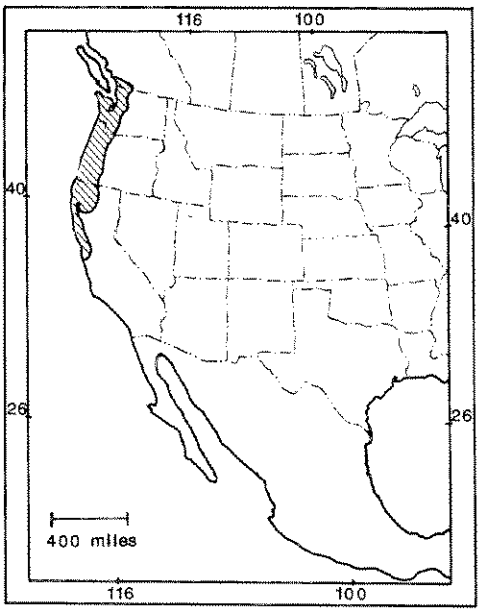


Figure 6. Distribution of sites where the Shrew-mole (*Neurotrichus gibbsii*) was recorded during July-October 1992 in the Lower Mainland of B.C.

Geographical distribution of *N. gibbsii* in North America (Hall and Kelson 1981).



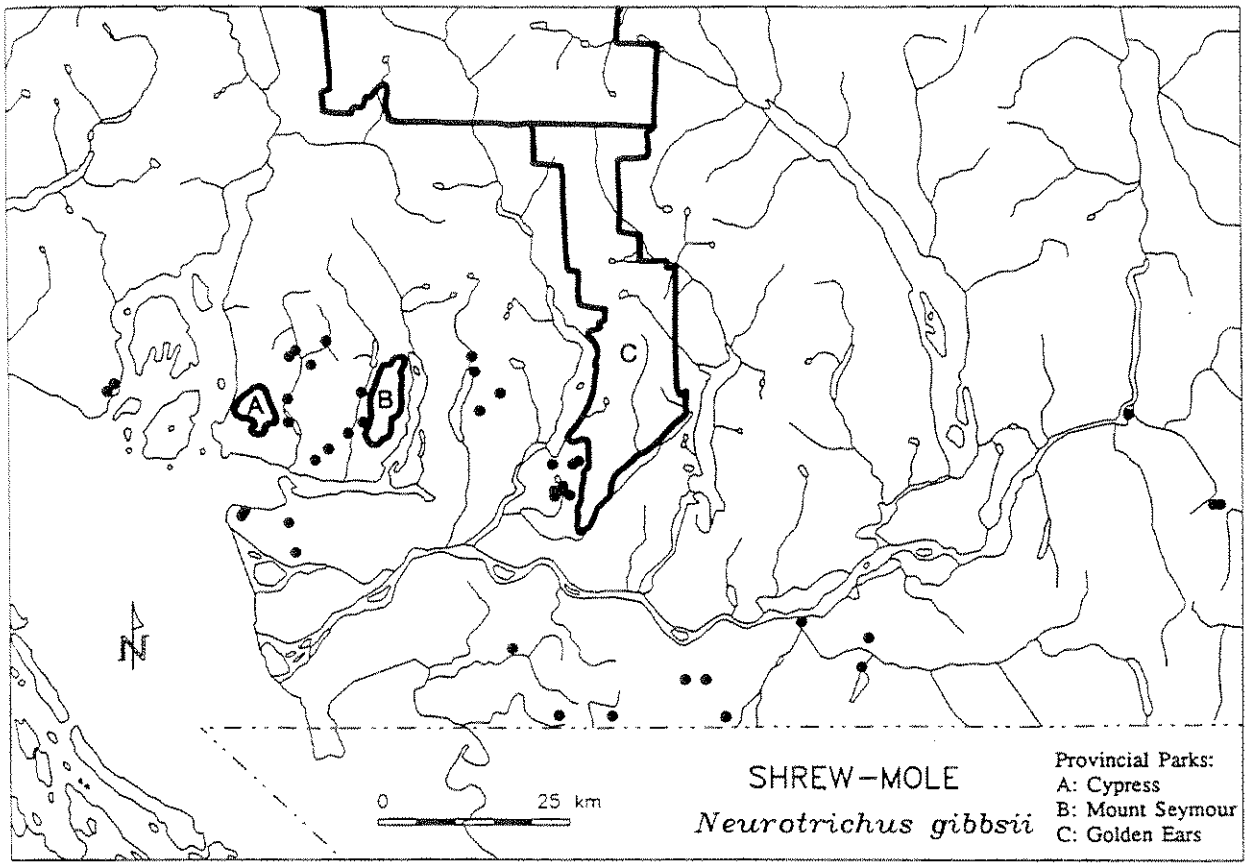
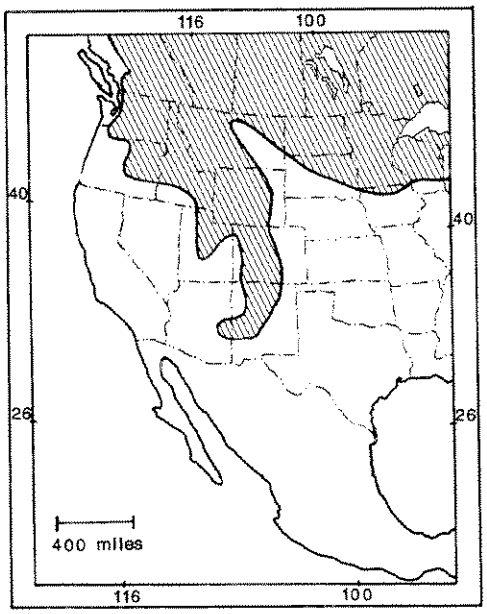


Figure 7. Distribution of sites where the Shrew-mole (*Neurotrichus gibbsii*) has historically been recorded in the Lower Mainland of B.C. (Nagorsen 1992).

Geographical distribution of *C. gapperi* in western North America (Hall and Kelson 1981).



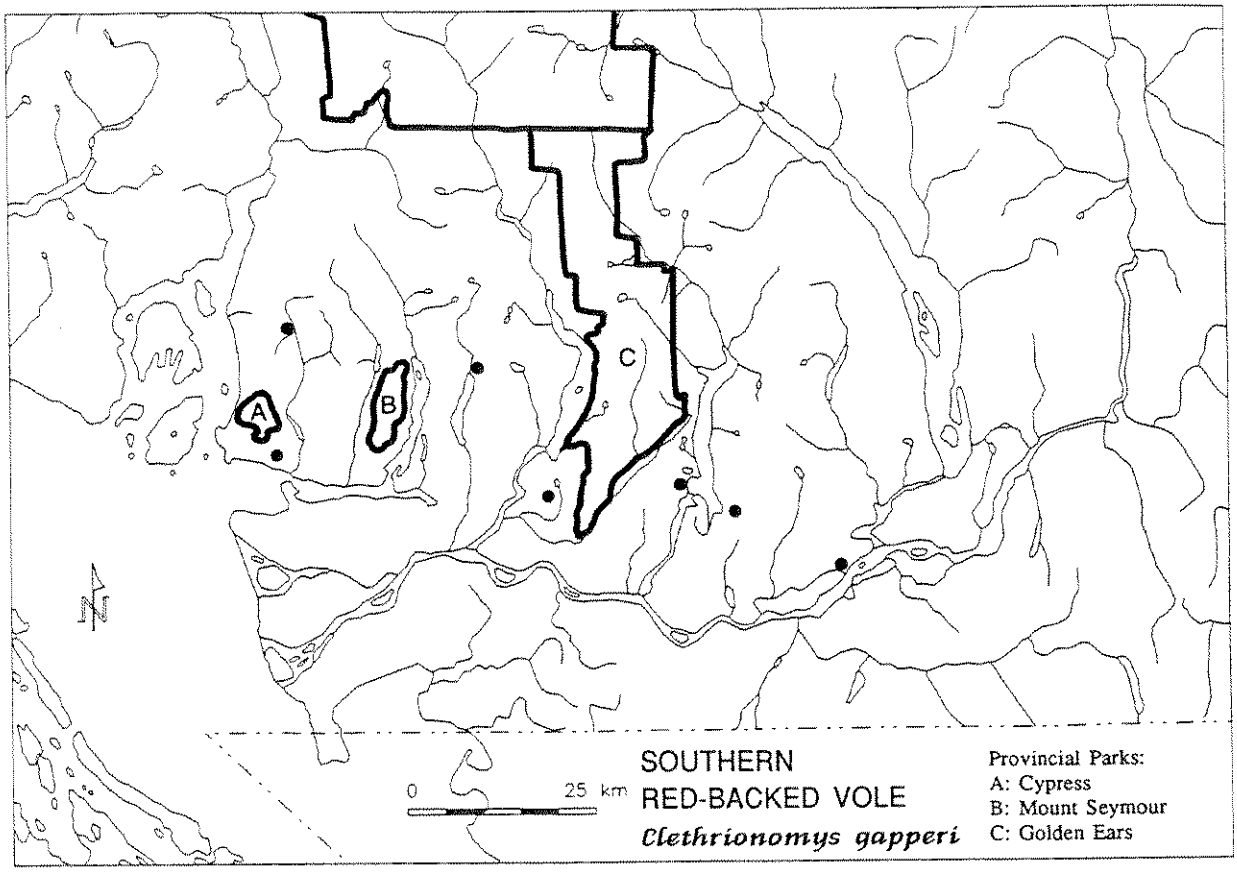


Figure 8. Distribution of sites where the Southern Red-backed Vole (*Clethrionomys gapperi*) has been recorded in the Lower Mainland of B.C. (Nagorsen 1992).

Trowbridge's Shrew (*Sorex trowbridgii*) — Trowbridge's Shrews were caught in 15 sites, of which 80% had water present. Most of the creeks (83%) were permanent. Habitats were dominated mostly by mixed forest (AM, DM, HM, RM, RD). They were not caught in habitats dominated solely by conifers. They were found in young forests (20%) and mature forests (80%). However, young forests were used only when canopy cover was high. In all sites, canopy cover was greater than 58%. Trowbridge's Shrews shared sites with Shrew-moles (three sites), Pacific Water Shrews (one site) and Southern Red-backed Voles (one site).

Shrew-mole (*Neurotrichus gibbsii*) — Shrew-moles were caught in ten sites. In most sites there were creeks (50%) or other water present (30%). The Shrew-moles were found both in habitats dominated mostly by coniferous forest (P, HR), and by mixed forest (AM, DM, HA, HM, RM). They were found both in young (18%) and in mature forests (82%). Canopy cover was usually greater than 47%. Shrew-moles shared sites with Southern Red-backed Voles (two sites), Pacific Water Shrews (one site) and Trowbridge's Shrews (three sites).

Southern Red-backed Vole (*Clethrionomys gapperi spp.*) — Southern Red-backed Voles were caught in eight sites, of which 63% had water. Habitats were dominated mostly by coniferous forest (HF, HR) and mixed forest with a strong coniferous component (HM, RA, RD). They were not caught in habitats dominated mostly by deciduous species. They were found both in mature (75%) and in old-growth forests (25%). In all sites canopy cover was greater than 50%, and in most sites it was greater than 72%. Southern Red-backed Voles shared sites with Shrew-moles (two sites), Pacific Water Shrews (one site) and Trowbridge's Shrews (one site).

Most of the sites where these species were not found had either low canopy cover, or were pure stands of deciduous or conifers.

4.3 Relative Abundance

Relative abundance according to habitat types is shown in Table 4. Habitat categories were grouped into four broad classes by forest type (coniferous *vs.* mixed) and the presence of water (present *vs.* absent). One site with pure deciduous habitat, where none of the selected species were trapped, is not included.

Table 4. Relative abundance[a] (mean ± SE) in different habitat types.[b]

	Relative abundance per site type			
	Coniferous		Mixed	
	Water Present	Water Absent	Water Present	Water Absent
Number of sites	11	9	25	9
Sorex bendirii	0.06 (±0.06) (max: 0.64)	0	0.04 (±0.03) (max: 0.48)	0
Sorex trowbridgii	0	0	0.96 (±0.35) (max: 7.14)	2.77 (±1.15) (max: 8.67)
Neurotrichus gibbsii	0	0.23 (±0.20)[c] (max: 1.90)	0.10 (±0.06) (max: 1.43)	0.16 (±0.08) (max: 0.49)
Clethrionomys gapperi	0.12 (±0.08) (max: 0.82)	0.08 (±0.05)[c] (max: 0.38)	0.04 (±0.04) (max: 0.95)	0.05 (±0.05) (max: 0.48)

[a] Relative abundance (captures/100 trap nights)

[b] Standard values are shown; max: maximum values; all minimum values were 0. Species taxonomic codes follow Campbell and Harcombe (1985).

[c] total relative abundance (all weeks of trapping included).

All Pacific Water Shrews were captured within the first week of trapping and only in habitats with water, both coniferous and mixed.

With the exception of one site (37), Trowbridge's Shrews were the most common small mammal in locations where they occurred (Figure 4). This species represented 35% (n = 306) of all small mammals captured. Trowbridge's Shrews were not caught in pure coniferous stands. In mixed habitats, Trowbridge's Shrews were more abundant in non-riparian than in riparian stands (Table 5).

Shrew-moles occurred at low abundance in all habitat types and were not caught in coniferous stands with water. Their abundance was higher in habitats without water.

Southern Red-backed Voles also occurred in low abundances in all habitat types but were slightly more abundant in coniferous stands with water.

5.0 DISCUSSION

5.1 Pacific Water Shrew (*Sorex bendirii*)

Pacific Water Shrews are extremely rare in British Columbia and, therefore, in Canada. An extensive trapping regime throughout much of their historical range resulted in the capture of only three specimens. They were caught in three different, completely isolated locations. In all cases, Pacific Water Shrews were caught in riparian habitats, in both coniferous and mixed forests. These data were too limited to infer habitat requirements other than riparian elements in mature forest, which were already known (Pattie 1973; Anthony *et al.* 1987; Gomez and Anthony 1990). McComb (1989) estimated significantly higher abundance in riparian (1.7/100 TN) than in non-riparian (0.02/100 TN) forested stands in Oregon. Our estimates in riparian habitats (0.04-0.06/100 TN) were well below those of McComb.

A century ago (1889-1901), 50 Pacific Water Shrews were recorded in locations such as Port Moody (six specimens in July 1894), Sumas (16 specimens in April-June 1895; 15 specimens in May-July 1896) and Chilliwack (Nagorsen 1992). During our study, only one specimen was recorded in Coquitlam, adjacent to Port Moody, and none in Sumas and Chilliwack (Figure 2). We have insufficient information on habitat availability and trapping effort for the 100-year-old surveys to be able to compare them with our information. In addition, we were unable to obtain similar numbers in our survey of 37 riparian habitats (Table 5), even using the most efficient technique (pitfall trapping, Williams and Braun 1983). Over the last 20 years, only five specimens with positive identification had been recorded in the Lower Mainland (Nagorsen 1992). Two of those were collected in non-riparian habitats in two locations of the U.B.C. Research Forest (Maple Ridge) by Sullivan in 1973-1974. We sampled the same locations in both riparian and non-riparian habitats, but no Pacific Water Shrews were trapped. More recently, the presence of four water shrews (abundance: 0.01-0.40/100 TN) was reported in the Greater Vancouver watersheds (Seip and Savard 1992). Since no voucher specimens are available, there are some doubts whether these specimens were *S. bendirii* or *S. palustris* (Nagorsen, pers. comm.). We surveyed 14 sites in Capilano and Coquitlam watersheds, but no water shrews were found.

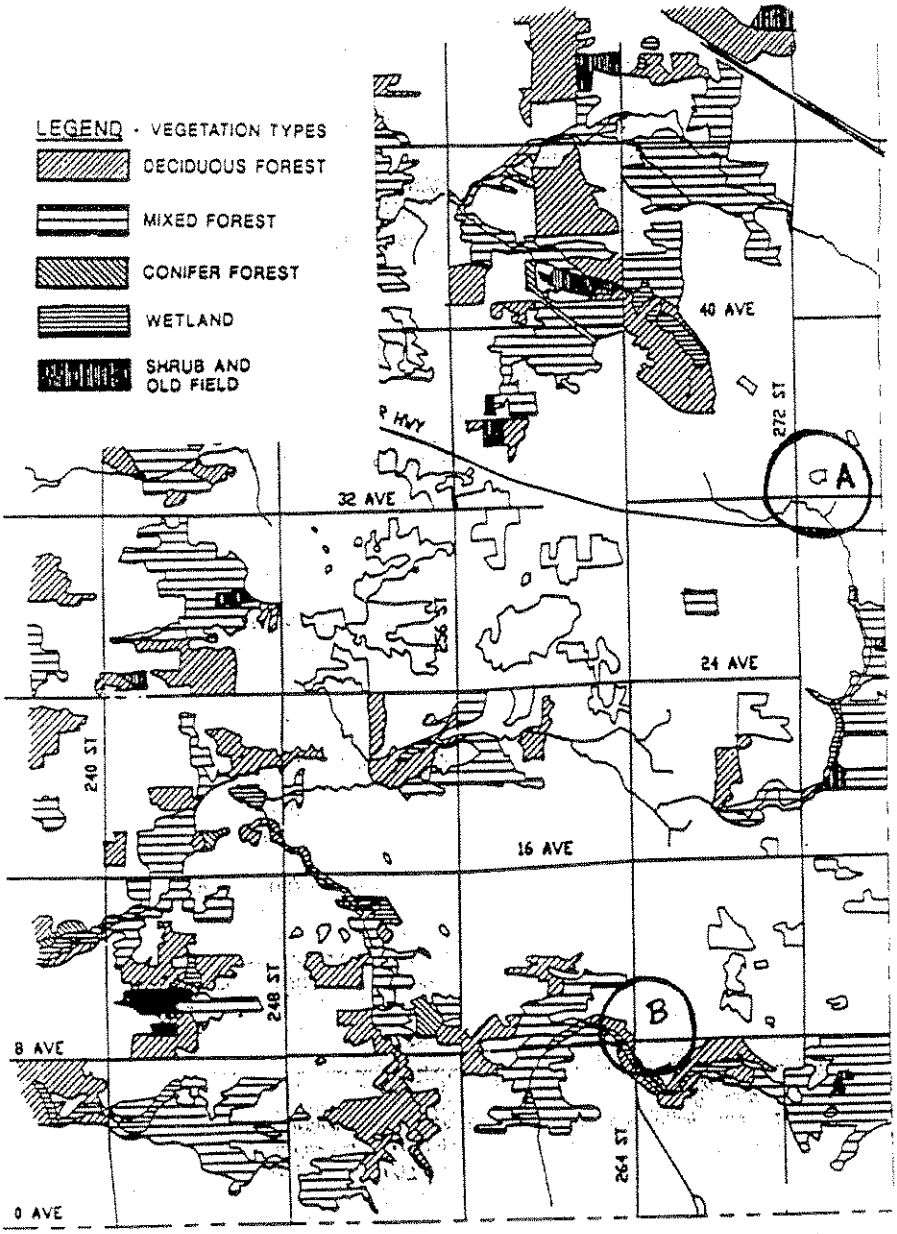
Kremsater and Andrusiak (1991) stated that Pacific Water Shrew habitat is relatively abundant in the Lower Mainland. However, during the site selection stage (see Section 3.1), the appropriate habitat was not easily found: riparian forested habitat along slow-moving creeks in low elevation sites. These environmental conditions match totally with human settlement preferences. Large areas south of the Fraser River and most of the historical habitat along the north shore of both the Fraser River and Burrard Inlet are completely altered. Most slow-moving watercourses, even those protected by BC Environment for fisheries management, are lacking mature forest. Roads are close to creeks, leaving only a few metres of vegetation. Thus, the elongated form and the edge- effect of riparian habitats are exacerbated. In Langley, for example, most fragments are small and isolated deciduous or mixed forest patches (Figure 9; Cook *et al.* 1993). We did not measure

Table 5. Site characteristics and species occurrence. (Habitat, age, site number, presence of water, total canopy cover, and species occurrence. Columns are sorted by habitat and decreasing canopy cover).

Habitat	Age	Site number	Water[a]	Total cover	SOBE[b]	SOTR	NEGI	CLGA
H	4	30	no	98				
HF	4	7	no	90				
HF	4	6	no	88				
HF	4	23	no	85				
HF	4	21	no	80				
HF	4	4	yes P	50				
HR	4	3	no	95				
HR	4	15	yes P	85				
HR	4	29	yes T	85				
HR	4	31	yes T	80				
HR	5	12	yes T	76				
HR	4	32	yes P	75				
HR	5	13	no	74				
HR	5	14	no	72				
HR	5	17	yes T	68				
HR	4	34	yes T	50				
HR	4	24	yes P	40				
HR	4	11	yes P	40				
P	3	38	no	47				
RF	4	22	yes P	63				
HA	4	16	no	89				
HA	4	10	no	80				
HA	4	5	yes P	80				
HA	4	28	no	65				
HA	4	27	yes T	65				
HA	4	20	yes P	60				
HA	4	25	yes P	45				
HM	3	53	yes T	88				
HM	4	1	yes P	76				
RA	4	9	no	93				
RA	4	8	yes P	90				
RA	4	48	yes P	75				
RD	4	37	yes P	76				
RM	4	54	yes P	80				
RM	4	2	no	78				
AM	3	44	yes T	85				
AM	4	39	yes P	85				
AM	4	41	yes P	83				
AM	4	42	yes P	80				
AM	4	46	yes P	70				
AM	3	40	yes P	60				
AM	4	55	yes P	58				
AM	3	19	yes P	57				
AM	3	33	yes P	55				
AM	3	26	yes P	50				
AM	4	35	yes P	45				
DM	4	47	no	95				
DM	4	36	yes P	93				
DM	3	52	yes P	83				
DM	4	43	no	83				
DM	4	18	yes P	76				
DM	4	51	no	70				
DM	4	50	yes P	64				
DM	4	49	yes P	58				
D	3	45	yes P	28				

[a] Water: P = permanent; T = temporary.

[b] Species taxonomic codes follow Campbell and Harcombe (1985).
SOBE = *Sorex bendirii* NEGI = *Neurotrichus gibbsii*
SOTR = *Sorex trowbridgii* CLGA = *Clethrionomys gapperi*



NOTE: Areas where *Sorex bendirii* was captured are in circles: A = Aldergrove in 1930, B = Peardonville in 1929.

Figure 9. Example of habitat fragmentation in southeastern Langley (Modified from Cook *et al.* 1993).

habitat fragmentation; however, it is evident that Pacific Water Shrew habitat is disappearing. The few fragments left (e.g., south of the Fraser River) might not be large or clumped enough to sustain populations of *S. bendirii*. Even where they were found, populations might be close or below minimum viable numbers. Therefore, the absence of the species from most surveyed locations with appropriate habitat could be explained by secondary extinctions (Wilcove *et al.* 1986).

Unfortunately, industrial and urban development in the Lower Mainland are happening at an unprecedented rate. For example, according to the latest topographic map (see Map G/7 Port Coquitlam, scale 1:50 000), one of the sites (North Hoy Creek in Coquitlam) where we found *S. bendirii* was a natural area in 1986. It was also 500 m away from the nearest housing area. Today, this site is almost enclosed by urban development. One Pacific Water Shrew was caught there only 20 m away from a public street.

In summary, *Sorex bendirii* is an extremely rare species in Canada. Pacific Water Shrews have exceptionally small population sizes, a narrow geographical distribution, and are restricted to riparian habitats. Habitat fragmentation is likely to be the major cause of secondary extinctions.

5.2 Trowbridge's Shrew (*Sorex trowbridgii*)

Trowbridge's Shrews were present in almost all locations surveyed south of the Fraser River (Figure 4), as in their historical range in British Columbia (Figure 5). This species was the most abundant small mammal in most locations. They use both riparian and non-riparian mixed forests, but were not caught in habitats dominated solely by conifers (Table 5). However, this does not necessarily mean that *S. trowbridgii* avoids them. Pure coniferous stands are simply scarce south of the Fraser River. Most of the coniferous stands sampled are north of the Fraser River, where Trowbridge's Shrew is very restricted (Figure 5). We caught only one individual in this type of stand, near Harrison Lake (Figure 4). Only four out of 130 Canadian specimens deposited in North American museums come from north of the Fraser (Nagorsen 1992). Historical factors, such as the time of colonization (Futuyuma 1979), could explain why Trowbridge's Shrews were not found there, even though appropriate habitat is available.

In western Washington and Oregon, throughout most of their range, Trowbridge's Shrew is the most common small mammal species in forested ecosystems (Aubry *et al.* 1991; Gilbert and Allwine 1991; West 1991). They live in a wide range of microhabitats (Dalquest 1941; George 1989), ranging from clearcuts to old-growth forests (Gunther *et al.* 1983; Corn and Bury 1991). In the Lower Mainland, at the edge of the species range, most *S. trowbridgii* habitat has been logged. Many of the patches left are now mixed forests. In all of those where *S. trowbridgii* was present, canopy cover was greater than 58% and Trowbridge's Shrews were the most common small mammal. Their abundances (0.96-2.77/100 TN) were similar to those of most studies in the United States (0.95-2.55/100 TN - Corn and Bury 1991; Aubry *et al.* 1991; West 1991).

Habitat fragmentation may be leading to secondary extinctions and reducing *S. trowbridgii* historical range. Trowbridge's Shrews were not found in any of the locations (4) in the area enclosed by the Nicomekl, Salmon and Fraser rivers (Figure 5; see also topographic map G2-New Westminster, scale 1:50 000). The area includes the municipal districts of Delta, Surrey, and western Langley, with the highest degree of urbanization (G.V.R.D. 1983) of the Lower Mainland south of the Fraser River. One site (Yorkson Creek), protected by BC Environment for fisheries management, was located in the middle of the Walnut Grove neighbourhood (Langley) with houses as close as 50 m. The habitat was assessed as highly appropriate (Table 5). In this location, no Trowbridge's Shrew were found; probably because of insularization (Wilcove *et al.* 1986). Urbanization and other land use are rapidly expanding eastward (L.M.R.P.B. 1992). As this trend persists, we predict the extirpation of Trowbridge's Shrew populations in fragments left after urbanization, particularly in the Central Fraser Valley Regional District.

In summary, Trowbridge's Shrew is abundant in locations where the species is still present. How-

ever, its distribution is the narrowest in Canada among insectivores, after the Townsend's Mole (Banfield 1974). Moreover, its historical range is decreasing, probably due to habitat loss and fragmentation.

5.3 Shrew-mole (*Neurotrichus gibbsii*)

Shrew-moles were found all over the study area, in eight different locations (Figure 6). These records fall within their historical distribution in Canada (Figure 7). Shrew-moles used primarily non-riparian coniferous stands, but also mixed forests. In other studies in B.C., *N. gibbsii* was found in a broad habitat range, from moist, mature forest to shrub habitat (for a review see Kremsater *et al.* 1993). In the U.S., Shrew-moles are also a habitat generalist (Terry 1981; Gomez and Anthony 1990; Aubry *et al.* 1991; Carraway and Verts 1991), although some studies recorded higher abundance in riparian habitats (Dalquest and Orcutt 1942; Anthony *et al.* 1987; Doyle 1990). In the Lower Mainland, at the edge of its range, *N. gibbsii* do not seem to be more abundant in riparian habitats than in other habitat types.

Shrew-moles occurred at low abundance (0.10-0.23/100 TN). Similar estimates were recently recorded both in Greater Vancouver watersheds (0.10-0.38/100 TN - Seip and Savard 1992), and in Oregon and Washington (0.06-0.34/100 TN - Corn and Bury 1991; Aubry *et al.* 1991; West 1991). Historical records account for 186 specimens collected throughout an area of approximately 10 000 km^2 in B.C. (Figure 7), covering two ecoprovinces (Georgia Depression and Coastal Mountains). *N. gibbsii* numbers are low over all its range, and it is never one of the common species in the small mammal fauna of western forested ecosystems. However, they are present in many locations and their habitat is widespread outside urban areas.

It is not clear whether habitat fragmentation affects Shrew-mole populations. The highest abundance (1.9/100 TN) was recorded in Burns Bog, in the municipality of Delta, a location isolated from large forest tracts. This site, a pine stand, is at the edge of the sphagnum bog habitat where no Shrew-mole was captured in a survey during April, 1992 (Terra Planning Ltd. 1992).

5.4 Southern Red-backed Vole (*Clethrionomys gapperi* spp.)

In the Lower Mainland of B.C., Southern Red-backed Voles were caught in seven out of 37 locations, all north of the Fraser River (Figure 8). The habitat was coniferous forest or mixed stands with a strong coniferous component. They were not caught in habitats dominated mostly by deciduous species. However, throughout their range, Southern Red-backed Voles use a broad range of habitats (Merritt 1981). In Canada, they occupy coniferous, deciduous and mixed forest, as well as willow shrubs, spruce and fir bogs, sedge marshes, rocky ridges, mesic prairie, and tundra (Morris 1955; Gabbutt 1961; Clough 1964; Fuller 1969; Pruitt 1972; Wrigley 1974). In our study, Southern Red-backed Voles occurred in low abundance in all habitat types, but in slightly higher abundance in coniferous stands with water. We do not know whether such low abundance corresponds to cyclic oscillations or whether populations are typically low. Across its range, *C. gapperi* shows high, low, or cyclic abundance (Morris 1955; Grant 1976; West 1991).

C. gapperi is one the best known rodent species in North America. By 1981, at least 400 studies had been published (Merritt 1981). Twenty-nine subspecies have been proposed for the Red-backed Vole (Hall 1981). They are distributed in all continental Canadian jurisdictions and in 25 U.S. states. Therefore, its range is one of the widest among North American small mammals (Hall 1981). The Washington Southern Red-backed Vole, *C. g. occidentalis*, occurs in a narrow range in North America, from the Lower Mainland in B.C. to northwestern Washington (Figure 8). In Canada, it is known only from one single specimen from Point Grey (Cowan and Guiguet 1965). Southern Red-backed Voles occurring north of the Burrard Inlet and the Fraser River are considered another subspecies: *C. g. caurinus* (Hall 1981, Merritt 1981). A priori, all our records are likely to belong to the latter subspecies. If this is the case, then *C. g. occidentalis* is probably absent over its historical range in Canada. No Washington Southern

Red-backed Voles were found in 18 sites that we surveyed south of the Fraser River.

5.5 Domestic Cats as Predators of Suburban Wildlife.

Habitat fragmentation increases the proportion of edge habitat per unit area. Along with this effect, there is likely to be an increase in predation rate (Wilcove *et al.* 1988). In the Lower Mainland, most watercourses are now surrounded by narrow, elongated pieces of forest, with houses as close as 50 m. Many householders have cats which provide an additional source of predation on wildlife.

Domestic cats are well-known for their hunting habits (Turner and Meister 1988), and are often kept as pets for their pest-killing abilities in both farmlands and urban environments. Cats are very efficient predators of small mammals such as rats, mice, voles, and squirrels, as well as birds, reptiles, and even bats (Kitchener 1991). Studies of domestic cat dietary and hunting patterns have been performed in North America, Europe, Australia, New Zealand and other Pacific islands (Fitzgerald 1988; Kitchener 1991), but none in western Canada. However, estimations from the Nova Scotia Land and Forests Department (*The Vancouver Sun* 1992), considered that Canada's five million domestic cats may kill between 42 million to 70 million wild birds each year.

Although cats rarely eat shrews (about 2% of their diet), they regularly catch and kill them in large numbers (up to 80% of the overall captures) sufficient to be considered the major predators of these animals in suburban habitats in many parts of the world (Fitzgerald 1988). Cats either bring shrews into or near the house or put them in a "mortuary" (i.e., underneath a tree; Tabor 1984). These characteristics make cats an additional threat for small mammals at risk in the Lower Mainland.

Future studies should assess the impact of domestic cat predation on small mammals.

5.6 Selected Species in Parks of the Lower Mainland

There is a lack of information about both provincial and regional parks of the Lower Mainland (Nagorsen 1992). Removal trapping was not permitted in the parks, but except for pure coniferous forests at very low elevations (below 50 m), most of the habitat types in those areas were represented in our study. Therefore, the four selected taxa are expected to still occur in the parks.

In the summer of 1950, eight specimens of *Sorex bendirii* were recorded in Pacific Spirit Regional Park. The park has several streams and a relatively large area (650 ha) appropriate for Pacific Water Shrews. However, it is completely isolated from any other patch and we do not know for how long such conditions will sustain viable populations. Shrew-moles are expected to be abundant in most of the parks, since they preserve large areas of second growth forest with down material and organic soil. Trowbridge's Shrews are also likely to occur in most parks south of the Fraser River, but because many parks are small and isolated, their persistence may be threatened. *C. g. occidentalis* may only remain in Pacific Spirit Regional Park.

5.7 Recommendations for Conservation

As a result of this study and analyses of related information, we propose the following actions:

Pacific Water Shrew (*Sorex bendirii*)

- Place the Pacific Water Shrew on the Red List, for consideration for designation as an Endangered or Threatened Species in British Columbia and, therefore, in Canada. Proposed rank: 1.

- Protect, by all possible means, riparian habitats in the Lower Mainland, particularly slow-moving watercourses at low elevations (< 200 m). Forested vegetation

strips, either coniferous or mixed, alongside watercourses have to be wide enough to sustain Pacific Water Shrew populations. A minimum of 100 m of habitat on each side is recommended until further research establishes minimum size. Watercourses in suburban or expanding urbanization areas must be urgently protected.

Trowbridge's Shrew (*Sorex trowbridgii*)

- Maintain the Trowbridge's Shrew on the Blue List as a Vulnerable Species in British Columbia and, therefore, in Canada. Proposed rank: 3-4.

- Establish new protected natural areas south of the Fraser River and enlarge the areas of those already established.

- Monitor population abundance within five years in selected locations throughout the range of Trowbridge's Shrew. Population monitoring is required to update the species' status, particularly as urbanization increases.

Shrew-mole (*Neurotrichus gibbsii*)

- Down-list the Shrew-mole to the Yellow List[1] as an Species not at risk in British Columbia and, therefore, in Canada, unless habitat is not preserved. Proposed rank: 4-5.

- Monitor population abundance within ten years in selected locations throughout Shrew-mole range. Population monitoring is required to update the species' status, particularly if urbanization increases in excess of currently determined rates.

Southern Red-backed Vole (*Clethrionomys gapperi occidentalis*)

- Reintroduce the subspecies in parks of the Lower Mainland, south of the Fraser River, if its absence there is confirmed.

5.8 General recommendations

- Inform the public about the importance of preserving riparian vegetation as shrew and other wildlife habitat. There is increasing private ownership of lands bordering watercourses, and landowners' cooperation will be essential.

- Without further delay, incorporate small mammals at risk into integrated wildlife and fisheries management, especially when designing habitat protection guidelines. For example, two creeks protected for fisheries, Mahood (in Surrey) and Yorkson (in Langley), are lacking two species at risk: *Sorex bendirii* and *Sorex trowbridgii*.

- Increase all forms of habitat protection to minimize the effects of habitat loss and fragmentation until further studies are performed.

5.9 Future Research Needs

Some of the immediate research needs are:

- Study habitat fragmentation effects to better evaluate the effects of urbanization and to improve habitat management recommendations. Such a study should determine the number of fragments available, their size, degree of isolation, and land ownership. All parks and Wildlife Management Areas in the Lower Mainland should be sampled.

- Perform a population viability analysis of *Sorex bendirii* to forecast the likelihood of persistence. Note, however, that research on this species is labour-intensive and time-consuming. Live-trapping is unlikely to provide the necessary information, unless methods are improved.

- Determine the impact of domestic cat predation on small mammals, primarily shrews, in order to regulate activities of

[1] The Shrew-mole was moved from the Blue List to the Yellow List subsequent to this study (Munro 1993).

cats inhabiting nearby suburban or rural watercourses.

- Verify the absence of Trowbridge's Shrew in Tynehead and Derby Reach regional parks, in order to confirm their extirpation in the area enclosed by the Nicomekl, Salmon and Fraser Rivers.

- Verify the taxonomic status of *C. g. occidentalis*. Since only one specimen has been recorded in B.C., it must be determined whether or not it is a taxon distinct from adjacent subspecies.

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Appendix 1. Summary of people contacted requesting entry permits and additional information.

Name	Position	Agency/Institution	Location
Alam, Kim	Director	Forestry Department, District of Mission	Mission
Anderson, Blair	Water Attendant Assistant	Municipality of West Vancouver	West Vancouver
Arthur, Gerry	Landowner (survey volunteer)		Langley
Ashby, Pat	Landowner		Sechelt
Bekhuse, Tim	Vice President	Terra Planning Ltd.	Vancouver
Bowyer, Michael	Landowner		Langley
Brocklesby, B.R.	Landowner		Langley
Bunnell, Fred	Professor	Dept. of Forest Sciences, UBC	Vancouver
Cannings, Dick	Curator	Vertebrate Museum, UBC	Vancouver
Carter, J.	Landowner		Langley
Cedar Rim Nursery	Landowner		Langley
Challenger, Derek	Forester	MOF, Vancouver Forest Region	Burnaby
Cook, Kathy	Graduate Student	Resource Management Program, UBC	Vancouver
Craig, Vanessa	Graduate Student	Dept. of Forest Sciences, UBC	Vancouver
Dunbar, Dave	Nongame Biologist	BC Environment, Lower Mainland Region	Surrey
Egan, Mike	Manager	Tanac Land Development Corp.	Vancouver
Elliott, Barry	Administrator	Parks and Recreation, Municipality	Coquitlam
England, Peter	Water Administrator	Dewdney-Alouette Regional District	Mission
Evans, George	Inventory Resource Officer	MOF, Chilliwack District	Rosedale
Giannico, Guillermo	Graduate Student	Dept. of Zoology, UBC	Cultus Lake
Goodwind, Marilyn	Manager	Sumas Mountain Campground	Sumas
Haas, Gordon	Graduate Student	Dept. of Zoology, UBC	Vancouver
Haggstrom, R.	Landowner		Langley
Hardy, Dianne	Biologist	GVRD Parks	Burnaby
Harestad, Alton	Associate Professor	Dept. of Biological Sciences, SFU	Burnaby
Harper, Paul	Resource Officer	Ministry of Forests	Sechelt
Isaac-Renton, Judy	Medical Pathologist	Vancouver General Hospital	Vancouver
Jones, Bob	Administrator	Quality Control, GVWD	Burnaby
Knutson, Russ	Resource Officer	MoF, Chilliwack District	Rosedale
Kremsater, Laurie	Research Associate	Dept. of Forest Sciences, UBC	Vancouver
Lees, Erik	Manager	Parks and Recreation, Municipality	West Vancouver
Lindahl, Bill	Manager	Parks and Recreation, Municipality	Langley
Millar, Judy	Resource Officer	BC Parks	North Vancouver
Moll	Major	Canadian Forces Base	Vedder Crossing
Monroe	Lieutenant	Canadian Forces Station	Aldergrove
Morrison, Mike	Landowner		Langley
MacInnes, Gene	Resource Officer	MOF, Chilliwack District	Rosedale
McMurchy, John	Superintendent	Parks and Recreation, Municipality	Coquitlam
Nagorsen, Dave	Curator, Mammals	Royal BC Museum	Victoria
Palidwor, Dave	Parks Design Technician	Parks and Recreation, Municipality	Coquitlam
Payne, John	Superintendent of Works	District of Squamish	Squamish
Rathonyi-Reusz, T.	Director	Parks and Recreation, Municipality	Port Moody
Rittberg, David	Site Coordinator	Tanac Land Development Corp.	Vancouver
Salas, Laurie	Manager	Soowahlie Indian Reserve	Cultus Lake
Sanders, Peter	Director	UBC Research Forest	Maple Ridge
Seip, Dale	Wildlife Ecologist	Ministry of Forests	Burnaby
Smith, Fred	Landowner		Langley
Smith, George	Administrator	Canadian Parks and Wilderness Society	Sechelt
Spencer, M.	Landowner		Matsqui
Staniforth, Sue	Biologist	GVRD Parks	Burnaby
Sullivan, Tom	Assistant Professor	Dept. of Forest Sciences, UBC	Vancouver
Switzer, Joley	Administrator	GVRD Parks	Burnaby
Taitt, Mary	Research Associate	Dept. of Zoology, UBC	Vancouver
Taylor, Janna	Director	Parks and Recreation, Municipality	Port Coquitlam
Teskey, Judy	Habitat Protection	BC Environment	Chilliwack
Trapp, Heide	Landowner		Langley
Walton	Landowner		Sechelt
Waterhouse, Louise	Wildlife Technician	Ministry of Forests	Burnaby

Appendix 2. Data collected on species of concern during survey.

NOTE: Data forms for the use of the Conservation Data Centre. Only selected insectivores and selected information included.
Data compiler/collector: Gustavo Zuleta
Geographical location (both UTM and lat/long): see Table 1
Habitat/elevation/aspect: see Table 1
Mapping (1:50 000): see maps with site numbers. Precision estimate: S (within 100m)
SPP: Species (SOBE *Sorex bendirii*; NEGI *Neurotrichus gibbsii*; SOTR *Sorex trowbridgii*)
TL: Total length (mm); TAIL: total tail (mm); HF: hind foot (mm); SITE: see Table 1; DATE: year/month/day;
ID: field identification number

SPP	TL	TAIL	HF	SITE	DATE	ID
SOBE						
	154	69	16.80	18	19920812	244
	152	68	16.60	34	19920904	616
	153	62	17.05	39	19920929	907
NEGI	123	42	12.55	1	19920808	152
	121	40	13.85	1	19920825	351
	123	42	12.30	2	19920808	143
	123	43	14.45	5	19920808	156
	121	41	13.90	10	19920808	104
	126	41	13.25	14	19920903	538
	125	42	14.55	26	19920917	730
	106	36	13.25	38	19921023	1335
	122	36	13.7	38	19921023	1336
	118	40	14	38	19921023	1337
	115	37	13.05	38	19921023	1338
	112	35	12.8	39	19921013	1273
	114	35	13.2	50	19920930	1034
	118	35	14.05	50	19920930	1049
	113	33	13.4	50	19921007	1251
	115	34	13.3	51	19921007	1243
SOTR	122	57	12.55	37	19920904	579
	122	58	12.50	39	19920929	902
	119	52	12.30	39	19920929	904
	0	0		41	19920929	1067
	123	57	12.10	42	19920929	1112
	122	55	11.65	42	19920929	1124
	120	56	11.8	42	19920929	1125
	120	56	12.05	42	19920929	1129
	126	55	11.65	42	19921006	1188
	122	53	11.65	42	19921006	1191
	123	57	12.75	43	19920929	1084
	123	53	12.5	43	19920929	1087
	126	59	12.55	43	19920929	1088
	116	54	11.95	43	19920929	1090
	121	55	12.15	43	19920929	1091
	123	54	12.45	43	19920929	1093
	120	55	11.95	43	19920929	1095
	122	55	12.1	43	19920929	1104

Appendix 2. (Continued).

SPP	TL	TAIL	HF	SITE	DATE	ID
SOTR (cont.)	126	57	12.1	43	19920929	1105
	125	56	11.55	43	19920929	1106
	117	54	10.35	43	19920929	1115
	128	57	12.35	44	19920929	1056
	126	58	12.3	44	19920929	1057
	116	50	11.45	44	19921006	1178
	118	53	12	46	19921006	1200
	113	48	11	47	19920929	918
	124	55	12	47	19920929	919
	116	51	11.95	47	19920929	920
	122	56	12.3	47	19920929	921
	124	57	12.1	47	19920929	922
	125	58	11.85	47	19920929	926
	123	53	12.65	47	19920929	927
	120	54	12.05	47	19920929	928
	126	57	12.5	47	19920929	929
	119	55	11.85	47	19920929	930
	117	52	12.15	47	19920929	931
	123	55	12.15	47	19920929	932
	122	56	12.45	47	19920929	934
	119	54	11.65	47	19920929	935
	120	55	12	47	19921006	1199
	120	54	11.8	47	19921006	1204
	125	55	11.85	47	19921006	1205
	123	54	12.45	47	19921013	1259
	123	55	12.55	47	19921013	1264
	121	54	12.4	47	19921013	1266
	120	54	12.25	49	19921006	1194
	122	57	12.2	50	19920930	1035
	119	54	12.15	50	19920930	1039
	123	56	12.6	50	19920930	1043
	125	56	11.6	50	19920930	1044
	123	53	11.95	50	19920930	1050
	121	54	12.55	50	19921007	1240
	124	52	11.85	50	19921007	1242
	121	53	12.15	51	19920930	1014
	123	56	12.05	51	19920930	115
	122	55	12.25	51	19920930	1017
	120	55	11.8	51	19920930	1021
	121	54	12.2	51	19920930	1029
	122	55	12.7	51	19921007	1250
	123	55	11.95	52	19920930	951
	115	54	12.3	52	19920930	955
	125	56	11.95	52	19920930	956
	123	59	11.55	52	19920930	957
	123	54	11.55	52	19920930	958
	123	56	12.25	52	19920930	959
	120	56	12.2	52	19920930	960
	123	59	12.35	52	19920930	961
	124	57	12.7	52	19920930	962

Appendix 2. (Continued).

SPP	TL	TAIL	HF	SITE	DATE	ID
SOTR (cont.)	122	54	12.05	52	19921006	1210
	122	54	12.15	52	19920930	966
	120	54	11.95	52	19920930	967
	119	54	12.05	52	19920930	968
	119	52	11.95	52	19920930	972
	125	58	12.25	52	19920930	974
	120	53	11.95	52	19920930	975
	124	57	12.05	52	19920930	988
	122	55	12.15	53	19921007	1226
	112	48	11.7	53	19921007	1231
	122	55	12	53	19921007	1232
	125	59	12.75	53	19921007	1236
	123	55	11.55	53	19921014	1290
	119	54	12.6	54	19920930	990
	119	54	12.3	54	19920930	996
	121	57	12.7	54	19920930	997
	127	57	12.6	54	19920930	998
	126	53	12.25	54	19920930	999
	125	55	12.25	54	19920930	1002
	119	54	12	54	19920930	1003
	124	54	12.05	54	19920930	1007
	124	55	12.4	54	19920930	1008
	121	58	12.55	54	19920930	1009
	123	55	11.65	54	19920930	1010
	120	54	11.25	54	19920930	1011
	124	55	12.1	54	19921007	1219
	120	53	12.2	54	19921007	1221
	124	57	12.05	54	19921007	1222
	119	54	12.25	54	19921014	1284
	120	53	12.45	54	19921014	1285
	120	54	12	55	19921014	1294

Appendix 3. Habitat descriptions of sites surveyed during the project (See Table 3 for habitat codes).

1. HM Permanent, sandy creek, 2 m wide. Dominant species: western hemlock, western redcedar, alder; other species: Pacific silver fir, vine maple. High canopy cover, mostly coniferous. Shrubs, forbs, mosses.

2. RM Pond and temporary, small creek. Dominant species: western redcedar, western hemlock; other species: Pacific silver fir, alder. High canopy cover, mostly coniferous.

3. HR Temporary creek, 50 cm wide. Dominant species: western redcedar, western hemlock; other species: Pacific silver fir, vine maple, yew. High canopy cover, mostly coniferous. Ferns.

4. HF Marsh. Dominant species: western hemlock; other species: Pacific silver fir, western redcedar, moss. Low canopy cover, mostly coniferous. Shrubs, forbs, mosses.

5. HA Permanent, rocky creek, 1 m wide. Dominant species: western hemlock, alder; other species: vine maple, Pacific silver fir, western redcedar. High canopy cover, coniferous and deciduous. Shrubs, ferns, mosses.

6. HF No creek present. Dominant species: western hemlock, Pacific silver fir; other species: western redcedar, alder, Douglas-fir. High canopy cover, mostly coniferous. Ferns, mosses.

7. HF No creek present. Dominant species: Pacific silver fir, western hemlock; other species: western redcedar. High canopy cover, mostly coniferous. Mosses.

8. RA Permanent creek, 1 m wide, rocky. Dominant species: alder, western redcedar; other species: Douglas-fir, alder. High canopy cover, coniferous and deciduous. Shrubs, ferns, mosses.

9. RA Temporary creek. Dominant species: alder, western redcedar; other species: Douglas-fir, western hemlock. High canopy cover, coniferous and deciduous. Shrubs, ferns, forbs, mosses.

10. HA Temporary, small creek. Dominant species: alder, western hemlock; other species: western redcedar. High canopy cover, coniferous and deciduous. Shrubs, ferns, forbs, mosses.

11. HR Permanent, sandy, slow-moving creek, 2 m wide. Dominant species: western redcedar, western hemlock, fairly open, shrubs, skunk cabbage, grasses. Low canopy cover, mostly coniferous. Shrubs, mosses.

12. HR Small, temporary creek, 1 m wide. Dominant species: western redcedar; other species: western hemlock, vine maple. Very large trees (>1.5 m dbh). High canopy cover, mostly coniferous. Shrubs, ferns, mosses.

13. HR Small, temporary creek, 1 m wide. Dominant species: western redcedar, western hemlock, large trees; other species: Douglas-fir. High canopy cover, mostly coniferous. Ferns, mosses.

14. HR Small, temporary creek, 1 m wide. Dominant species: western redcedar, western hemlock, very large trees. High canopy cover, mostly coniferous. Shrubs, ferns, mosses.

15. HR Permanent creek, slow, sandy, 1 m wide. Dominant species: western redcedar, western hemlock; other species: vine maple, alder, skunk cabbage. High canopy cover, mostly coniferous. Shrubs, ferns, forbs, mosses.

16. HA No creek present. Dominant species: alder, western hemlock; other species: western redcedar, vine maple, salal. High canopy cover, coniferous and deciduous. Shrubs, ferns, forbs, mosses.

17. HR Temporary, small creek, 1 m wide. Dominant species: western hemlock, western redcedar, large trees. High canopy cover, mostly coniferous. Shrubs, ferns, forbs, mosses.

Appendix 3. (Continued).

18. DM Rocky creek, 2 m wide. Dominant species: alder, bigleaf maple; other species: vine maple, western hemlock, western redcedar. High canopy cover, deciduous and coniferous. Shrubs, ferns, mosses.

19. AM Permanent creek with boulders, 4 m wide. Dominant species: alder; other species: vine maple, fir (*Abies* spp.), western redcedar, western hemlock. High canopy cover, mostly deciduous. Shrubs, forbs.

20. HA Permanent creek, rocky. Dominant species: western hemlock, alder; other species: fir (*Abies* spp.). High canopy cover, coniferous and deciduous. Shrubs, ferns, forbs, mosses.

21. HF Permanent creek. Dominant species: western hemlock, Douglas-fir; other species: alder, vine maple, western redcedar, dense understorey. High canopy cover, mostly coniferous. Shrubs, ferns, mosses.

22. RF Permanent, large creek, rocky, 2 m wide, creek bed 8 m wide. Dominant species: western redcedar, Douglas-fir; other species: western hemlock, alder. High canopy cover, mostly coniferous. Shrubs, forbs.

23. HF No creek present. Dominant species: western hemlock, Douglas-fir; other species: western redcedar, vine maple. High canopy cover, mostly coniferous. Shrubs, mosses.

24. HR Permanent creek and marsh. Dominant species: western redcedar; other species: western hemlock, skunk cabbage, yew. Low canopy cover, mostly coniferous. Shrubs, forbs, mosses.

25. HA Permanent creek by road and houses, rocky, 3 m wide, creek bed 7 m wide. Dominant species: alder, western hemlock; other species: vine maple, western redcedar. Low canopy over, coniferous and deciduous. Shrubs, ferns, forbs.

26. AM Permanent creek, 2 m wide, creek bed 5 m wide. Rocky. Dominant species: alder, western hemlock; other species: western redcedar, maple, vine maple, cottonwood (one), fairly open. Low canopy cover, mostly deciduous. Shrubs, ferns, forbs, mosses.

27. HA Temporary creek, rocky, 2 m wide, creek bed 6 m wide. Dominant species: western hemlock, alder; other species: Douglas-fir, western redcedar, yew. Moderate canopy cover, mostly coniferous. Shrubs, ferns, forbs, mosses.

28. HA Temporary creek, rocky, 2 m wide, creek bed 6 m wide. Dominant species: western hemlock, alder; other species: Douglas-fir, western redcedar, yew. Moderate canopy cover, mostly coniferous. Shrubs, ferns, forbs, mosses.

29. HR Temporary creek, rocky, 1 m wide, creek bed 4 m wide. Dominant species: western hemlock; other species: western redcedar, vine maple, Douglas-fir. High canopy cover, mostly coniferous. Shrubs, ferns, forbs, mosses.

30. H Temporary creek, rocky, 1 m wide, creek bed 4 m wide. Dominant species: western hemlock; other species: closed forest, little understorey. High canopy cover, coniferous. Mosses.

31. HR Temporary creek, 1 m wide, creek bed 3 m wide. Dominant species: western redcedar; other species: western hemlock. High canopy cover, coniferous. Mosses.

32. HR Permanent creek, rocky, 4 m wide, creek bed 6 m wide. Dominant species: western hemlock, western redcedar; other species: alder, vine maple, fir (*Abies* spp.). High canopy cover, mostly coniferous. Shrubs, ferns, forbs, mosses.

Appendix 3. (Continued).

33. AM Permanent creek, sandy, 4 m wide, creek bed 8 m wide. Dominant species: alder, western redcedar; other species: western hemlock, vine maple, bigleaf maple. Moderate canopy cover, mostly deciduous. Shrubs, ferns, forbs, mosses.

34. HR Temporary creek with boulders, 50 cm wide. Dominant species: western hemlock, western redcedar; other species: alder. Moderate canopy cover, coniferous and deciduous. Shrubs, ferns, forbs, grasses.

35. AM Permanent, small, rocky creek, 2 m wide, creek bed 4 m wide. Dominant species: alder, western hemlock; other species: western redcedar, bigleaf maple. Low canopy cover, mostly deciduous. Shrubs, forbs, grasses.

36. DM Permanent, sandy creek, 4 m wide. Dominant species: alder, bigleaf maple; other species: western redcedar, vine maple. High canopy cover, mostly deciduous. Shrubs.

37. RD Permanent, fast, rocky creek, 4 m wide, creek bed 6 m wide. Dominant species: western redcedar; other species: bigleaf maple, alder, western hemlock. High canopy cover, coniferous and deciduous. Shrubs, ferns, forbs, mosses.

38. P No creek present. Dominant species: pine; other species: salal, Labrador tea, birch, western hemlock. Low canopy cover, coniferous. Shrubs, ferns.

39. AM Permanent, temporary, sandy creek, 5 m wide. Dominant species: alder; other species: western redcedar, bigleaf maple, Sitka spruce (old), western hemlock. High canopy cover, mostly deciduous. Shrubs, ferns, forbs, mosses.

40. AM Permanent, slow creek, 6 m wide. Dominant species: alder; other species: Sitka spruce, vine maple, western redcedar, western hemlock. Moderate canopy cover, mostly deciduous. Shrubs, forbs.

41. AM Temporary, small, rocky creek, 2 m wide, creek bed 7 m wide. Dominant species: western redcedar, alder; other species: bigleaf maple, western hemlock, cottonwood, vine maple, fir (*Abies* spp.). High canopy cover, mostly deciduous. Shrubs, forbs, mosses.

42. AM Permanent sandy creek, 6 m wide. Dominant species: alder, western redcedar; other species: fir (*Abies* spp.), cottonwood, bigleaf maple, western hemlock. High canopy cover,mostly deciduous. Shrubs, ferns, forbs, mosses.

43. DM Temporary creek present. Dominant species: bigleaf maple; other species: western redcedar, alder, western hemlock. High canopy cover, mostly deciduous. Ferns.

44. AM Temporary, small, rocky creek, 3 m wide, creek bed 5 m wide. Dominant species: alder, western redcedar; other species: bigleaf maple, western hemlock. High canopy cover, mostly deciduous. Shrubs, ferns, forbs, mosses.

45. D Permanent, sandy, slow creek, 4 m wide. Dominant species: alder, bigleaf maple. Fairly open; other species: western hemlock. Low canopy cover, mostly deciduous. Shrubs, forbs, grasses, mosses.

46. AM Permanent river, fast, 6 m wide. Dominant species: alder, bigleaf maple; other species: western redcedar, western hemlock, shrubs. High canopy cover, mostly deciduous. Shrubs, forbs.

47. DM No creek present. Dominant species: bigleaf maple, western redcedar; other species: western hemlock, cottonwood, alder. High canopy cover, coniferous and deciduous. Shrubs, ferns, mosses.

Appendix 3. (Continued).

48. RA Permanent, slow-moving creek 3 m wide. Dominant species: western redcedar, alder; other species: bigleaf maple, cottonwood. High canopy cover, coniferous and deciduous. Shrubs, forbs, mosses.

49. DM No creek present. Dominant species: bigleaf maple; other species: western redcedar, alder, western hemlock, fir (*Abies* spp.). Moderate canopy cover, mostly deciduous. Shrubs, ferns, forbs, mosses.

50. DM Permanent, small, sandy creek, 3 m wide, creek bed 5 m wide. Dominant species: alder. Other species: cottonwood, bigleaf maple, western redcedar. Moderate canopy cover, mostly deciduous. Shrubs, ferns, forbs, mosses.

51. DM No creek present. Dominant species: bigleaf maple, alder; other species: western redcedar,western hemlock, vine maple. High canopy cover, mostly deciduous. shrubs, ferns, forbs.

52. DM No creek present. Dominant species: bigleaf maple, alder; other species: western redcedar, western hemlock, vine maple. High canopy cover, mostly deciduous. shrubs, ferns, forbs, mosses.

53. HM Temporary, muddy, small creek, 1 m wide. Dominant species: western redcedar, western hemlock, alder; other species: vine maple, fir (*Abies* spp.), bigleaf maple. High canopy cover, coniferous and deciduous. Shrubs, ferns, forbs, mosses.

54. RM Permanent, rocky creek, 6 m wide, creek bed 15 m wide. Dominant species: western redcedar, western hemlock; other species: alder, cottonwood, bigleaf maple, vine maple Douglas-fir. High canopy cover, coniferous and deciduous. shrubs, ferns, forbs, mosses.

55. AM Permanent, fast creek, 15 m wide. Dominant species: alder, western hemlock; other species: western redcedar, bigleaf maple. Moderate canopy cover, coniferous and deciduous. Shrubs, ferns, forbs, mosses.

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