

# EFFECTS OF FISH HABITAT RESTORATION ACTIVITIES ON PLANT COMMUNITIES IN THE SQUAMISH RIVER ESTUARY

---

## Summary Report

Prepared for:

**Squamish River Watershed Society**  
Box 1791 Squamish B.C.  
V0N 3G0

Prepared by:

Nick Page  
**Raincoast Applied Ecology**  
#102 – 1661 West 2<sup>nd</sup> Avenue,  
Vancouver, B.C.  
V6J 1H3



November 2, 2004



## **1. Introduction and Objectives**

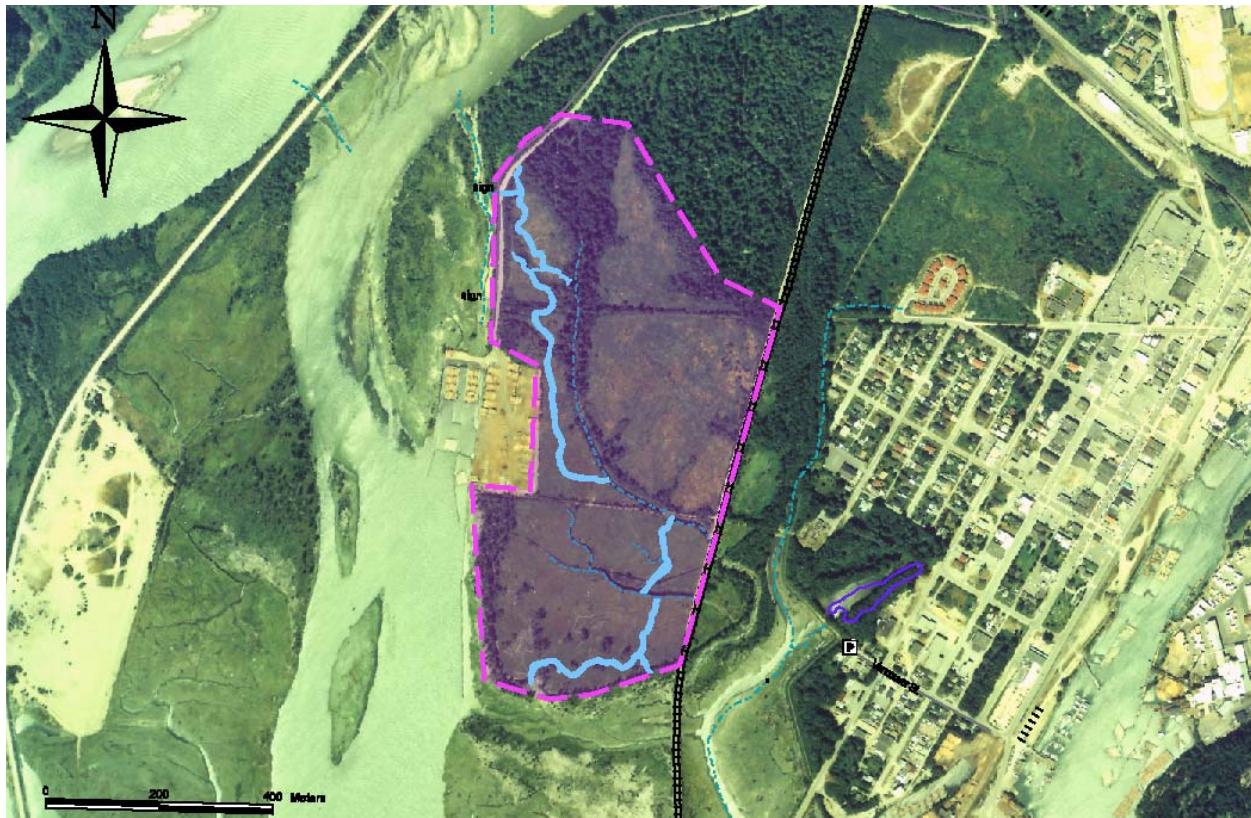
The purpose of this study was to assess the effects of fish habitat restoration activities on plant communities in a portion of Squamish Estuary Wildlife Management Area (SEWMA), and to provide management recommendations for plant community and plant species conservation. In the past three years tidal channels have been excavated through marsh and wet meadow communities to enhance estuarine fish habitat, principally for juvenile chinook salmon. Channel creation has resulted in the creation of more frequently flooded wetland areas in the bottom and sides of new channels and a drier, higher elevation area where excavated fill has been placed. Both changes affect plant species and plant communities by causing physical disturbance during construction, changing patterns of tidal inundation and soil drainage, and potentially affecting water and soil salinity. Fisheries and Oceans Canada has attempted to minimize vegetation disturbance by removing the vegetation matt prior to excavation and using it to cover soil fill areas, spreading the excavated material over a broad area to minimize the change in elevation of the soil surface, and confining construction to the winter when plants are dormant. Some removal of tree and shrub seedlings has also been undertaken to maintain open grass areas.

The following tasks were undertaken as part of this project:

1. Existing information on plant communities and plant species in the Squamish River estuary was reviewed;
2. Historical air photos were used to assess vegetation change in the last 50 years in the study area;
3. Plant communities were described from non-forest portions of the study area including disturbed and undisturbed sites;
4. The proposed alignment of the 2004/05 habitat restoration works was assessed to determine potential conflicts with rare or uncommon plant species or plant communities; and,
5. Recommendations were developed to minimize negative impacts to plant communities or species if additional fish habitat restoration work is undertaken.

## **2. Study Area**

The study area encompassed the non-forested portion of the eastern estuary between the BC Rail line to the east, the log sort to the west, the forest margin to the north, and the old dyke to the south (Figure 1). The total area is approximately 3.2 ha. This area was diked historically and vegetation in the area appears to have been modified by changes to the frequency of tidal inundation. Anecdotal information suggests that much of the study area was used for pasture or other farming activities, although no signs of fences or roads were observed. This area was designated as part of the *East Estuary* in Lim and Levings (1973).



**Figure 1.** Location of study area, adjacent to City of Squamish, BC.

### 3. Previous Vegetation Work

Extensive ecological work has been undertaken on different aspects of the Squamish River estuary including some studies on plant distribution or plant ecology. However, no studies or reports I reviewed specifically discussed vegetation in the northern portion of the east estuary that was the focus of this study. Dawe et al., (1986) is the most relevant information source because it examined vegetation in the area immediately to the east of the study area. Many reports discuss previous vegetation sampling or mapping that was undertaken in the 1960s or early 1970s, particularly Lim and Levings (1973). Relevant reports and studies with a brief summary of relevant information area are provided below.

Dawe, N.K., D.E.C. Trethewey, A.C. Duncan. 1986. Vegetation of the Cattermole Creek Marsh, a Planned Stormwater Impoundment Basin, Squamish Estuary, September 1984. Canadian Wildlife Service, Technical Report Series No. 3., Pacific and Yukon Region.

*Report on the detailed assessment and analysis of vegetation immediately east of the study area, in preparation for the development of a stormwater storage facility. Surveys were undertaken in September 1984 using transects across the site. Four vegetation communities were described using multivariate ordination including: i) Ruppia maritima community; ii) Carex lyngbyei community; iii) Carex lyngbyei – Potentilla pacifica community; and, iv) Agrostis alba – Juncus balticus community. Species lists are also provided.*

Hoos, L.M. and C.L Vold. 1975. The Squamish River Estuary: Status of Environmental Knowledge to 1974. Report of the Estuary Working Group, Department of the Environment Regional Board, Pacific Region.

*Summary of previous work including a section entitled “Flora” with subsections on aquatic vegetation, deltaic vegetation, and terrestrial vegetation. It includes a map demarcating the study area vegetation as “sedges-rushes” (from Paish and Associates, 1972). Main information sources referenced are Orloci’s (1964) classification work on floodplain forest and Lim and Levings’ (1973) mapping of estuarine vegetation.*

Levings, C.D. and A.I. Moody. 1976. Studies of intertidal vascular plants, especially sedge (*Carex lyngbyei*), on the disrupted Squamish River delta, British Columbia. Fisheries and Marine Service Technical Report No. 606.

*An ecological study of the extent and productivity of Lyngby’s sedge in the Squamish River estuary. The study did not extend in the study area. Mapping was based on Lim and Levings (1973). A species list for the East Delta are provided as an appendix.*

Lim, P.G. 1972. Vegetation Study of the Squamish Estuary. Fisheries Research Board of Canada, Pacific Environment Institute, West Vancouver, BC.

*Preliminary description of vascular plant flora of the Squamish River delta. The study was undertaken as part of a larger study assessing the impact of port development on the delta. It includes descriptions of 25 species, and species lists from different parts of the estuary. Maps are also provided and appear to be the same as presented in Lim and Levings (1973).*

Lim, P.G. and C.D. Levings. 1973. Distribution and Biomass of Intertidal Vascular Plants on the Squamish Delta. Fisheries Research Board of Canada, Manuscript Report Series No. 1219., Pacific Environment Institute, West Vancouver, B.C.

*A more detailed description of plant distribution and vegetation communities based on the work in Lim (1972). It includes species lists from different parts of the estuary, as well as maps of vegetation communities that have been used extensively by other reports. Vegetation mapping of the East Delta does not extend in to the study area.*

Paish and Associates. 1972. An Environmental Perspective on a Squamish Coal Port: An Environmental Impact Assessment of a Proposed Coal Terminal at Mamquam Blind Channel, Squamish, B.C.

*Cursory information on plant community zones in the estuary. No detailed mapping, species lists, or community descriptions provided.*

#### **4. Plant Community Descriptions**

Vegetation was measured in 58 plots in the non-forested portions of the study area between July 29 and August 12, 2004. Plots were 5 m by 5 m and plant species richness and abundance (%)

cover) were estimated visually. Plots were distributed throughout the study area and I selected sites to encompass range of plant communities, as well as disturbed (e.g., berm crests) and undisturbed areas. Note that the term “plant community” is a broader and less rigorous term than “plant association”. BC Conservation Data Centre uses the term *Natural Plant Community* for naming and ranking rare vegetation types but relies on the definitions for description and naming provided by the US National Vegetation Classification System.

Plant communities were described using cluster analysis which groups plots together because of their similarities in terms of plant species presence or plant species abundance. Once groups had been formed, an indicator species analysis was undertaken to identify plant species that were common and abundant in each of the groups. Nominal species were selected from group of species with the highest indicator values.

The six non-forested plant communities described in the study area are:

1. *Ruppia maritima* (widgeon-grass) Community
2. *Carex lyngbyei* (Lyngby's sedge) Community
3. *Lathyrus palustris – Potentilla anserina* (marsh peavine – Pacific silverweed) Community
4. *Agrostis stolonifera – Rumex crispus* (creeping bentgrass – curled dock) Community
5. *Sonchus arvensis – Aster subspicatus* (perennial sow-thistle – Douglas' aster) Community
6. *Juncus effusus / Alnus rubra* (common rush / red alder) Community

Plant communities are generally aligned on an elevational and successional gradient from lowest and least terrestrial (e.g., *Ruppia maritima* Community) to highest and most terrestrial (*Juncus effusus / Alnus rubra* Community). An ordination technique (NMDS) was used to examine relationships between plots and plant communities (Appendix 3). The graphical depiction of the analysis showed that drier areas with *Juncus effusus / Alnus rubra* Community were clearly separated from wetter meadow communities. As well, plots from sites recently disturbed by channel creation were similar and clustered together; they also showed some overlap with plots from dry, undisturbed areas.

More detail on each community is presented in the Table 1. Appendix 1 provides a complete species list of plants identified in the study area, as well as species lists for each community in order of highest to lowest indicator value.

## 5. Historical Air Photo Assessment

Historical air photos were used to assess vegetation change in the study area during the last 50 years. Air photos from 1957, 1964, 1973, 1976, 1982, 1994, and 1999 were scanned and digitally scaled for analysis. More detailed analysis of photos from 1957, 1976, and 1999 was undertaken to assess the changes to tree and shrub boundaries in the study area. Tree and shrub edges were delineated in Adobe Illustrator and a composite map was created to show the location and extent of encroachment into wet meadow communities during the last 50 years.

The assessment indicates that shrub thicket and forest encroachment has reduced the amount of wet meadow, but that the rate of encroachment is variable. It was most pronounced in the

**Table 1.** Summary characteristics of plant communities in the Squamish Estuary study area.

Plant Community	Description and Characteristic Plant Species	Representative Photo
1. <i>Ruppia maritima</i> (widgeon-grass) Community	<i>Ruppia maritima</i> (widgeon-grass) is the dominant plant species within recently excavated tidal channels. It is generally monotypic and no other vascular plants occur in this habitat. It is used extensively by waterfowl for grazing.	
2. <i>Carex lyngbyei</i> (Lyngby's sedge) Community	<i>Carex lyngbyei</i> (Lyngby's sedge) is the dominant sedge in estuaries through the north Pacific Coast. It forms monotypic stands at lower elevations and is major component of higher elevation wet meadows. It was more prevalent in the southern portion of the study area and on banks of new channels. Other species: <i>Chenopodium rubrum</i> , <i>Deschampsia cespitosa</i> , <i>Hierochloe hirta</i> , <i>Potentilla anserina</i> , <i>Hordeum brachyantherum</i> , <i>Triglochin maritimum</i> .	
3. <i>Lathyrus palustris</i> – <i>Potentilla anserina</i> (marsh pea-vine – Pacific silverweed) Community	This community occurs throughout the study area but appears to be at slightly lower elevations than other wet meadow communities. <i>Potentilla anserina</i> (Pacific silverweed) and <i>Lathyrus palustris</i> (marsh pea) are indicative of seasonal flooding. Species richness is generally low with the nominal species forming dense cover on most sites. <i>Hordeum brachyantherum</i> and <i>Galium trifidum</i> were also encountered in some plots.	
4. <i>Agrostis stolonifera</i> – <i>Rumex crispus</i> (creeping bentgrass – curled dock) Community	<i>Agrostis stolonifera</i> (creeping bentgrass) is common throughout the study area but forms is most prevalent in wetter areas on the eastern side near the BC Rail line. In combination with <i>Rumex crispus</i> (curled dock) and <i>Typha latifolia</i> (cattail), it is considered a distinct wetland plant community. It tends to be patchy with some areas dominated by creeping bentgrass and others with higher diversity. Other species include <i>Bidens amplissima</i> and <i>Lathyrus palustris</i> .	
5. <i>Sonchus arvensis</i> – <i>Aster subspicatus</i> (perennial sow-thistle – Douglas' aster) Community	This community is the most species rich of the communities of the study area, and includes a variety of showy wildflowers. It occurs in seasonally flooded areas but does not undergo daily tidal flooding. It is likely sensitive to hydrologic change. It contains <i>Sidalcea hendersonii</i> , <i>Achillea millefolium</i> , <i>Angelica lucida</i> , <i>Conioselinum pacificum</i> , <i>Elymus repens</i> , <i>Rubus spectabilis</i> , and <i>Maianthemum dilatum</i> . It is similar to a red listed plant community from Van Island.	
6. <i>Juncus effusus</i> / <i>Alnus rubra</i> (common rush / red alder) Community	This community occurs along the recently created berm crests and near forest margins. It is the driest of the plant communities in the study area and is considered transitional to shrub thicket or young forest. It contains a variety of weedy species, including some common nonnative species. Common species include: <i>Calamagrostis canadensis</i> , <i>Holcus lanatus</i> , <i>Phleum pretense</i> , <i>Rubus armeniacus</i> , <i>Sambucus racemosa</i> , and <i>Agrostis stolonifera</i> .	

northwest corner of the site, and along the western edge of forested area. This suggests that warmer and drier sites are more rapidly colonized by tree and shrub seedlings than more shaded sites. Forest has also developed along the margins of the central drainage ditch (e.g., east of the log sort) and manmade dikes; both areas are drier than surrounding wet meadow areas.

Appendix 2 presents air photos depicting vegetation change since 1957 using a photo from 1999 as a base. Additional air photos (e.g., raw scans) are provided in an accompanying cd-rom.

## 6. Plant Species and Communities of Conservation Concern

Based on the findings of this study and a review of the BC Conservation Data Centre (BC CDC), no endangered or threatened plant species were encountered in the study area. Two blue listed species and two yellow listed species were found:

*Bidens amplissima* (Vancouver Island beggarticks) = G3 S3 (blue; special concern)

*Sidalcea hendersonii* (Henderson's checkermallow) = G3 S3 (blue; special concern)

*Lathyrus palustris* (marsh peavine) = G5 S3S4 (yellow)

*Fritillaria camschatcensis* (Northern riceroot) = G5 S5 (yellow)

Based on current BC CDC information, the designation S3 indicates the species is *Vulnerable* because it is rare and local, found only in a restricted range (even if abundant at some locations), or because of some other factor(s) making it susceptible to extirpation or extinction (e.g., typically 21 to 100 existing occurrences). S4 means the species is *Apparently Secure* and is considered uncommon but not rare, and usually widespread in the province. There is possible cause for long-term concern (e.g., typically more than 100 existing occurrences).

Similarly, no endangered or threatened plant communities were identified. Very few estuarine plant communities are ranked by the BC CDC at present. A community described as *Deschampsia cespitosa – Sidalcea hendersonii* (tufted hairgrass – Henderson's checkermallow) is ranked as S1S2 (red; endangered or threatened) on southeastern Vancouver Island. It is considered similar to, but floristically distinct from, the species rich wet meadow community in the study area (*Sonchus arvensis / Aster subspicatus* Community). More assessment of estuarine plant communities in BC will likely increase the number of plant communities that are tracked by the BC CDC.

## 7. 2004 / 2005 Fish Habitat Creation Alignment

The proposed alignment of the 2004/05 fish habitat creation project was reviewed in September 2004. The proposed work is a channel similar in design and configuration to previous channels, however, more micro-channels will be incorporated in to the new channel.

Most of the alignment is within a seasonally wet area vegetated with *Agrostis stolonifera* (creeping bentgrass) and *Typha latifolia* (cattail). This area is encompassed by the *Agrostis stolonifera – Rumex crispus* Community, which is the least diverse of the wet meadow communities. *Bidens amplissima* (Vancouver Island beggarticks) is relatively common,

particularly on the northern half of the meadow, because of the seasonal flooding and waterfowl use.

The most southern margin (e.g., adjacent to the pedestrian trail) supports more diverse vegetation with *S. hendersonii* (Henderson's checkermallow), *A. subspicatus* (Douglas' aster), *S. arvensis* (perennial sow-thistle), and other species characteristic of the *Sonchus arvensis – Aster subspicatus* Community present.

Where possible, the channel location should be selected to minimize disturbance to the *Sonchus arvensis – Aster subspicatus* Community, as well as large patches of *Biden amplissima*. More survey data is needed to evaluate how channel excavation will improve drainage; additional drainage may reduce the predominance of *Agrostis stolonifera – Rumex crispus* Community and reduce the value of the area for wetland plants, including *B. amplissima*, and waterfowl.

## **8. Summary Discussion**

- The study area contains a variety of ecologically interesting plant species and communities, although none are currently tracked by the BC Conservation Data Centre. Several are regionally rare.
- The open nature of the grass- and forb-dominated wet meadows contributes to their ecological and aesthetic value.
- The highest plant species richness occurs on sites with high productivity and infrequent flooding (*Sonchus arvensis – Aster subspicatus* Community).
- Air photo review indicates that shrub thicket and forest encroachment has reduced the amount of wet meadow in the last 50 years. Encroachment has been most rapid on dykes and along the southwest edge of forested areas.
- The berms associated with fish habitat channels has reduced the amount of wet meadow and created sites suitable for tree and shrub growth.
- The older dikes provide a precedent for understanding how plant communities will respond to changes in elevation related to fish habitat creation. Forest and shrub communities are predicted to become more prevalent over the next 50 years.

## **9. Recommendations**

- Long-term objectives for vegetation management are required for the SEWMA. Objectives should define which plant communities are most desirable from an ecological, aesthetic, or cultural perspective, as well as the level of management and restoration that is appropriate.
- Additional inventory and mapping would be valuable for incorporating plant community information into management of the SEWMA. Further assessment should focus on developing a comprehensive vegetation classification scheme that is compatible with provincial programs (e.g., BC CDC), and GIS mapping of the distribution of plant communities.
- A botanical survey day or weekend should be organized to develop a more comprehensive survey of plant species in the SEWMA. This should combine professional botanists (paid at charge-out rate or paid an honorarium) with local naturalists. The survey should occur in late June or early July when flowering plants are most easily identified.

- Permanent monitoring plots should be developed to track changes in plant communities.
- Elevation surveys to determine the critical elevation for tree and shrub growth would assist in designing future habitat restoration projects.
- Future fish habitat restoration work should avoid the most diverse plant communities (*Aster subspicatus* – *Sonchus arvensis* Community), as well as species of local ecological value (*S. hendersonii*, *F. camschatcensis*, *B. amplissima*).
- Excavated soils should be placed near existing forest and shrub edges to avoid fragmenting open meadows.
- Alternate construction methods for removing some portion of excavated fill should be investigated.
- The possibility of using fill to create a higher viewing platform should also be investigated; this will reduce the amount of area affected by berthing.
- Construction work should continue to be undertaken during the dormant season.
- The vegetation matt should continue to be removed and used for revegetation.
- Exposed soils should be seeded with a mix of wetland grasses (*Agrostis spp*, *Deschampsia cespitosa*, *Hordeum brachyantherum*, etc) in combination with seeds collected from the site (*Angelica lucida*, *A. subspicatus*, *S. hendersonii*, *L. palustris*, etc).
- Tree and shrub seedlings should be manually removed from existing berm areas using brush cutters or hand pulling.
- Areas of open soil on the existing berms should be seeded as soon as possible with the seed mix described above.

# Appendices.

**Appendix 1.1.** Plant species recorded in the SEWMA study area - July/August 2004

Note, species are ranked by frequency (% of plots present), as well as mean abundance (% cover in plots where present).

Species	Frequency	Abundance
	% of Plot	% Cover where Present
<i>Potentilla anserina</i> ssp. <i>pacifica</i>	68.6%	16.8%
<i>Agrostis stolonifera</i>	60.9%	27.5%
<i>Lathyrus palustris</i>	51.7%	19.3%
<i>Atriplex patula</i>	43.4%	6.2%
<i>Sonchus arvensis</i> var. <i>arvensis</i>	42.9%	7.1%
<i>Carex lyngbyei</i>	27.8%	30.2%
<i>Aster subspicatus</i>	24.1%	16.6%
<i>Triglochin americanum</i>	22.6%	6.2%
<i>Hordeum brachyantherum</i>	21.7%	1.3%
<i>Calamagrostis canadensis</i> var. <i>canadensis</i>	19.1%	16.6%
<i>Achillea millefolium</i>	19.0%	3.9%
<i>Galium trifidum</i>	19.0%	0.9%
<i>Typha latifolia</i>	15.9%	21.2%
<i>Juncus effusus</i>	15.5%	48.4%
<i>Sidalcea hendersonii</i>	14.3%	4.8%
<i>Rubus spectabilis</i>	14.1%	4.1%
<i>Alnus rubra</i>	12.6%	2.7%
<i>Bidens amplissima</i>	12.4%	5.8%
<i>Angelica lucida</i>	10.5%	6.8%
<i>Juncus articus</i>	10.5%	14.4%
<i>Ranunculus cymbalaria</i>	10.5%	4.8%
<i>Conioselinum pacificum</i>	10.3%	3.2%
<i>Maianthemum dilatatum</i>	10.3%	24.2%
<i>Chenopodium rubrum</i> var. <i>rubrum</i>	8.6%	2.6%
<i>Deschampsia caespitosa</i>	8.6%	25.2%
<i>Picea sitchensis</i>	8.6%	13.6%
<i>Rumex crispus</i>	8.6%	0.6%
<i>Festuca</i> sp.	8.6%	0.0%
<i>Vicia gigantea</i>	7.2%	1.3%
<i>Lonicera involucrata</i>	7.1%	11.6%
<i>Elymus repens</i>	6.9%	38.8%
<i>Holcus lanatus</i>	5.3%	0.7%
<i>Myrica gale</i>	5.3%	4.0%
<i>Epilobium ciliatum</i>	5.2%	0.1%
<i>Phleum pratense</i>	5.2%	0.2%
<i>Plantago major</i>	5.2%	0.7%
<i>Rosa nutkana</i>	5.2%	30.0%
<i>Symporicarpus albus</i>	5.2%	5.7%
<i>Vicia</i> sp. ( <i>V. americana</i> or <i>V. cracca</i> ?)	5.2%	8.3%
<i>Eleocharis palustris</i>	3.4%	36.0%
<i>Epilobium angustifolium</i>	3.4%	0.3%
<i>Fritillaria lanceolata</i>	3.4%	1.5%
<i>Hierochloe odorata</i>	3.4%	1.3%
<i>Malus fusca</i>	3.4%	2.6%
<i>Poa pratensis</i>	3.4%	1.1%
<i>Senecio</i> species	3.4%	0.3%
<i>Solanum dulcamara</i>	3.4%	7.6%
<i>Heracleum lanatum</i>	1.9%	2.3%
<i>Polystichum munitum</i>	1.9%	2.3%

Appendix 1.1. (continued)

Species	Frequency	Abundance
	% of Plot	% Cover where Present
<i>Rubus armeniacus</i>	1.9%	2.3%
<i>Spergularia species</i>	1.9%	2.3%
<i>Anaphalis margaritacea</i>	1.7%	0.5%
<i>Athyrium felix-femina</i>	1.7%	5.0%
<i>Claytonia sibirica</i>	1.7%	0.5%
<i>Dicranum scoparium</i>	1.7%	5.0%
<i>Dodecatheon pulchellum</i>	1.7%	1.0%
<i>Eurhynchium oreganum</i>	1.7%	25.0%
<i>Gaultheria shallon</i>	1.7%	1.0%
<i>Hypochaeris radicata</i>	1.7%	0.1%
<i>Isothecium stoloniferum</i>	1.7%	2.0%
<i>Juncus bufonius</i>	1.7%	0.1%
<i>Lactuca muralis</i>	1.7%	1.0%
<i>Plantago maritima</i> ssp. <i>juncoides</i>	1.7%	2.0%
<i>Polygonum persicaria</i>	1.7%	0.5%
<i>Prenanthes alata</i>	1.7%	2.0%
<i>Quercus species</i>	1.7%	2.0%
<i>Rhamnus purshiana</i>	1.7%	2.0%
<i>Rhytidadelphus loreus</i>	1.7%	40.0%
<i>Rumex acetosella</i>	1.7%	1.0%
<i>Ruppia maritima</i>	1.7%	65.0%
<i>Salix species</i>	1.7%	0.5%
<i>Sambucus racemosa</i>	1.7%	0.5%
<i>Tsuga heterophylla</i>	1.7%	0.5%

## **Appendix 1.2.** Plant species in the *Ruppia maritima* Community.

<b>Species</b>	<b>Ind. Value*</b>
<i>Ruppia maritima</i>	100

### **NOTES**

\* Indicator Value based on % of perfect indication based on combining relative abundance and relative frequency.

### **Appendix 1.3. Plant species in the *Carex lyngbyei* Community.**

<b>Species</b>	<b>Ind. Value*</b>
<i>Carex lyngbyei</i>	97
<i>Hierochloe odorata</i>	16
<i>Chenopodium rubrum</i> var. <i>rubrum</i>	12
<i>Atriplex patula</i>	11
<i>Triglochin americanum</i>	10
<i>Hordeum brachyantherum</i>	8
<i>Deschampsia caespitosa</i>	7
<i>Potentilla anserina</i> ssp. <i>pacifica</i>	7
<i>Typha latifolia</i>	4
<i>Ranunculus cymbalaria</i>	3
<i>Sonchus arvensis</i> var. <i>arvensis</i>	3
<i>Eleocharis palustris</i>	2
<i>Lathyrus palustris</i>	2
<i>Aster subspicatus</i>	1

#### **NOTES**

\* Indicator Value based on % of perfect indication based on combining relative abundance and relative frequency.

#### **Appendix 1.4.** Plant species in the *Lathyrus palustris* - *Potentilla anserina* Community.

<b>Species</b>	<b>Ind. Value*</b>
<i>Lathyrus palustris</i>	66
<i>Potentilla anserina</i> ssp. <i>pacifica</i>	58
<i>Galium trifidum</i>	26
<i>Hordeum brachyantherum</i>	26
<i>Agrostis stolonifera</i>	10
<i>Chenopodium rubrum</i> var. <i>rubrum</i>	10
<i>Juncus articus</i>	8
<i>Festuca</i> sp.	6
<i>Bidens amplissima</i>	5
<i>Sonchus arvensis</i> var. <i>arvensis</i>	5
<i>Aster subspicatus</i>	3
<i>Elymus repens</i>	2
<i>Typha latifolia</i>	2
<i>Atriplex patula</i>	1
<i>Triglochin americanum</i>	1

#### **NOTES**

\* Indicator Value based on % of perfect indication based on combining relative abundance and relative frequency.

## **Appendix 1.5. Plant species in the Agrostis stolonifera - Rumex crispus Community.**

<b>Species</b>	<b>Ind. Value*</b>
<i>Agrostis stolonifera</i>	65
<i>Rumex crispus</i>	26
<i>Typha latifolia</i>	23
<i>Atriplex patula</i>	22
<i>Potentilla anserina</i> ssp. <i>pacifica</i>	13
<i>Lathyrus palustris</i>	11
<i>Achillea millefolium</i>	5
<i>Myrica gale</i>	3
<i>Triglochin americanum</i>	3
<i>Bidens amplissima</i>	2
<i>Chenopodium rubrum</i> var. <i>rubrum</i>	2
<i>Aster subspicatus</i>	1
<i>Sidalcea hendersonii</i>	1
<i>Sonchus arvensis</i> var. <i>arvensis</i>	1
<i>Vicia gigantea</i>	1

### **NOTES**

\* Indicator Value based on % of perfect indication based on combining relative abundance and relative frequency.

**Appendix 1.6.** Plant species in the *Sonchus arvensis* - *Aster subspicatus* Community.

<b>Species</b>	<b>Ind. Value*</b>
<i>Sonchus arvensis</i> var. <i>arvensis</i>	33
<i>Achillea millefolium</i>	27
<i>Sidalcea hendersonii</i>	26
<i>Angelica lucida</i>	24
<i>Conioselinum pacificum</i>	24
<i>Maianthemum dilatatum</i>	24
<i>Aster subspicatus</i>	22
<i>Elymus repens</i>	21
<i>Picea sitchensis</i>	16
<i>Rubus spectabilis</i>	16
<i>Ranunculus cymbalaria</i>	15
<i>Epilobium ciliatum</i>	12
<i>Plantago major</i>	12
<i>Triglochin americanum</i>	11
<i>Vicia gigantea</i>	11
<i>Deschampsia caespitosa</i>	9
<i>Festuca</i> sp.	9
<i>Atriplex patula</i>	8
<i>Epilobium angustifolium</i>	8
<i>Fritillaria lanceolata</i>	8
<i>Lonicera involucrata</i>	8
<i>Poa pratensis</i>	8
<i>Senecio</i> species	8
<i>Solanum dulcamara</i>	8
<i>Symporicarpus albus</i>	8
<i>Rosa nutkana</i>	7
<i>Bidens amplissima</i>	5
<i>Chenopodium rubrum</i> var. <i>rubrum</i>	5
<i>Galium trifidum</i>	5
<i>Myrica gale</i>	5
<i>Potentilla anserina</i> ssp. <i>pacifica</i>	5
<i>Anaphalis margaritacea</i>	4
<i>Athyrium felix-femina</i>	4
<i>Claytonia sibirica</i>	4
<i>Dicranum scoparium</i>	4
<i>Dodecatheon pulchellum</i>	4
<i>Eleocharis palustris</i>	4
<i>Eurhynchium oreganum</i>	4
<i>Gaultheria shallon</i>	4
<i>Heracleum lanatum</i>	4
<i>Hordeum brachyantherum</i>	4
<i>Hypochaeris radicata</i>	4
<i>Isothecium stoloniferum</i>	4
<i>Juncus articus</i>	4
<i>Juncus bufonius</i>	4
<i>Lactuca muralis</i>	4
<i>Malus fusca</i>	4

<i>Plantago maritima</i> ssp. <i>juncoides</i>	4
<i>Polygonum persicaria</i>	4
<i>Polystichum munitum</i>	4
<i>Prenanthes alata</i>	4
<i>Quercus</i> species	4
<i>Rhamnus purshiana</i>	4
<i>Rhytidadelphus loreus</i>	4
<i>Rumex acetosella</i>	4
<i>Ruppia maritima</i>	4
<i>Salix</i> species	4
<i>Spergularia</i> species	4
<i>Tsuga heterophylla</i>	4
<i>Lathyrus palustris</i>	3
<i>Agrostis stolonifera</i>	2
<i>Phleum pratense</i>	2
<i>Alnus rubra</i>	1
<i>Calamagrostis canadensis</i> var. <i>canadensis</i>	1
<i>Carex lyngbyei</i>	1

**NOTES**

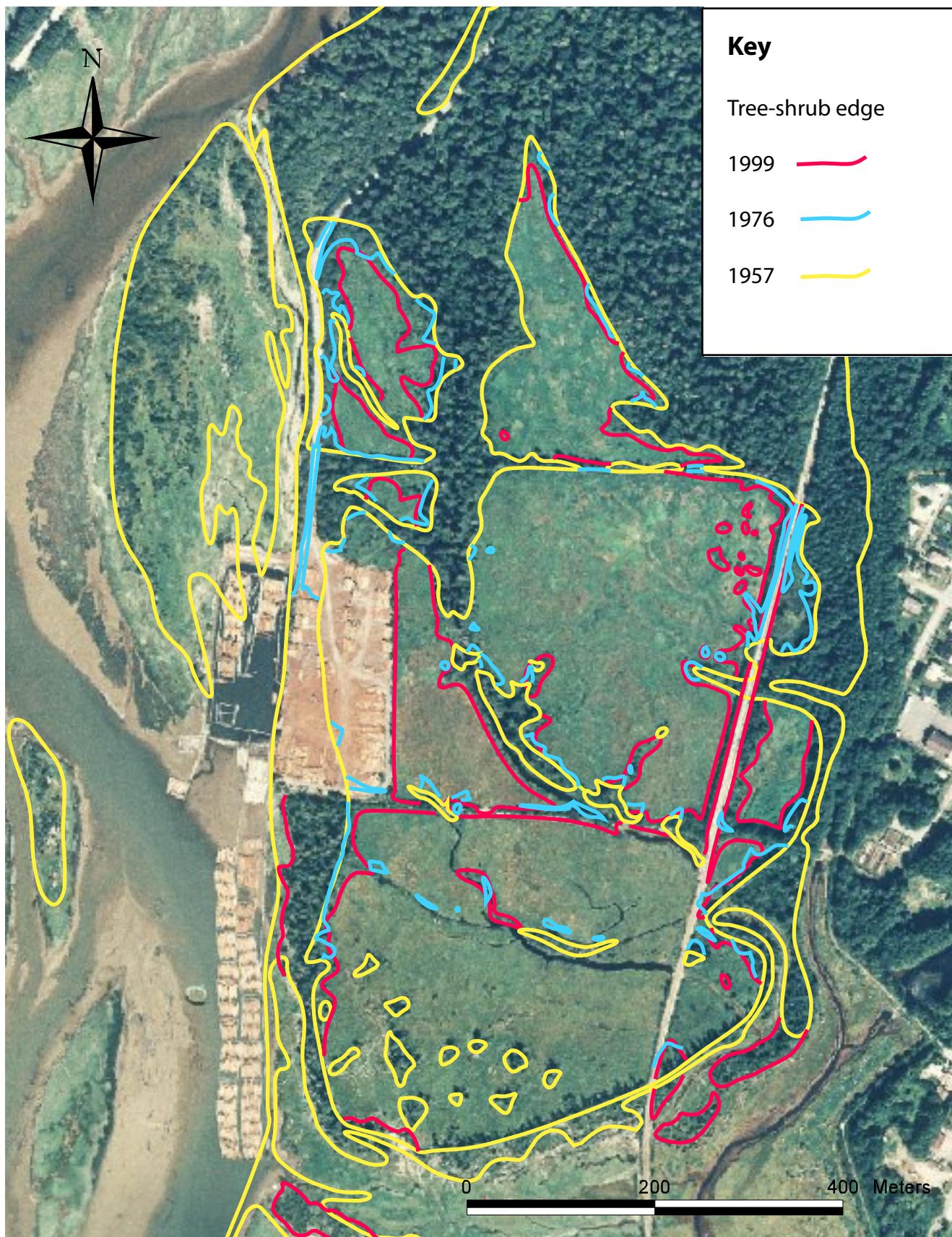
\* Indicator Value based on % of perfect indication based on combining relative abundance and relative frequency.

## **Appendix 1.7. Plant species in the *Juncus effusus* - *Alnus rubra* Community.**

<b>Species</b>	<b>Ind. Value*</b>
<i>Juncus effusus</i>	99
<i>Calamagrostis canadensis</i> var. <i>canadensis</i>	82
<i>Alnus rubra</i>	61
<i>Holcus lanatus</i>	43
<i>Phleum pratense</i>	17
<i>Rubus armeniacus</i>	14
<i>Sambucus racemosa</i>	14
<i>Agrostis stolonifera</i>	10
<i>Rubus spectabilis</i>	9
<i>Vicia gigantea</i>	8
<i>Lonicera involucrata</i>	4
<i>Rosa nutkana</i>	2
<i>Sonchus arvensis</i> var. <i>arvensis</i>	2
<i>Potentilla anserina</i> ssp. <i>pacifica</i>	1

### **NOTES**

\* Indicator Value based on % of perfect indication based on combining relative abundance and relative frequency.



**Appendix 2a.** Summary of tree and shrub cover change in the study area based on 1957, 1976, and 1999 air photos. Lines indicate location of tree or shrub edge in particular years, and the amount and location of encroachment can be inferred by the distance between lines (1999 air photo base).



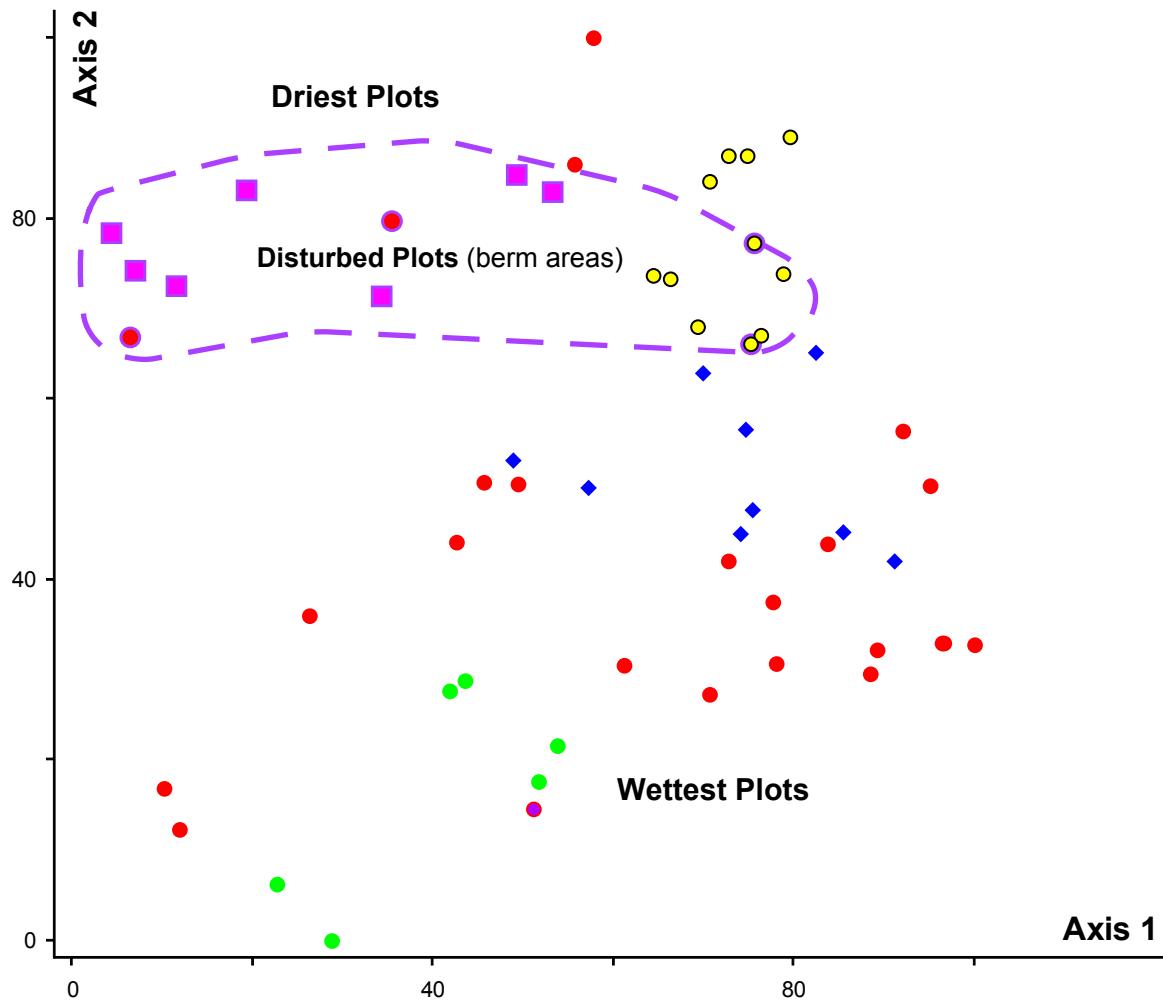
**Appendix 2b.** Vegetation and land use characteristics of the study area in 1999.



**Appendix 2c.** Vegetation and land use characteristics of the study area in 1976.



**Appendix 2d.** Vegetation and land use characteristics of the study area in 1957.



#### KEY

- *Ruppia maritima* Community
- *Carex lyngbyei* Community
- ◆ *Lathyrus palustris* - *Potentilla anserina* Community
- *Agrostis stolonifera* - *Rumex crispus* Community
- *Sonchus arvensis* - *Aster subspicatus* Community
- *Alnus rubra* / *Juncus effusus* Community

**Appendix 3.1.** NMDS ordination plot of the relationship between plots and plant communities in the Squamish Estuary study area. Plots from the wettest portions of the study area are in the lower half of the plot, while plots from drier and disturbed areas are in the upper half. Plots from sites disturbed by channel creation are circled by a purple dashed line. Analysis was undertaken using PC-ORD; the stress of the final 3-dimensional solution was 18.3; instability was 0.00769 based on 200 iterations.