LITUYA BAY ENVIRONMENTAL SURVEY

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PLANT COMMUNITY ANALYSIS

by

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Introduction

Unless otherwise noted, vegetation samples were taken in the manner described by Worley (1977, 1975, 1974) and Worley and Streveler (1974). In some instances no abundance values were ascribed, and in most cases no bryophyte data were recorded. Voucher specimens of selected plant species are deposited at the Glacier Bay National Monument Herbarium.

Numerical and graphical analysis of the vegetation data follows Worley (1977, 1975, 1974) unless otherwise stated.

The field work was accomplished primarily during 1977 by G.P. Streveler and I.A. Worley, with the most competent and necessary assistance of Robert L. Daniels, Leigh Smith, and Mary Worley; Joshua Worley was in attendance.

The initial budget, supplied by the National Park Service, was supplemented graciously by substantial assistance from the Federal Work-Study Program, and by the use of space, equipment, supplies and time from both the Vermont Agricultural Experiment Station and the Environmental Program of the University of Vermont.

Anita Mullen, Tom Savrine, Jr., and Cindy Wemple, through the Work-Study Program and the volunteering of personal time, contributed considerable numbers of hours in data reduction, entabulations, and air photo interpretation. Tom, with great care, prepared and drew the vegetation map. John Hammer provided some statistical analyses.

The Bottom Zone of the Beach Community

Introduction and General Character:

The bottom zone of the beach community (cf. Worley 1975) is the distinctive foreslope of the beach. This low zone frequently receives saltwater, and has the first few scattered vascular plants as one proceeds from sea to land. In the bottom zone, there is seldom, if ever, more than 50% ground cover by vascular plants, the species richness and diversity is always low, and the consolidation of the substrate by roots and rhizomes is never prominent. Although the bottom zone and herbaceous meadow zone freely integrate in places, it is usually not at all difficult to discern a distinctive vegetational and geo-morphological boundary between the zones. In the vicinity of Lituya Bay, *Honckenya peploides* is almost always the distinctive and prominent species of the bottom zone.

This study does not seek the boundary between the bottom zone and upper beach zones, but chooses to define it as the transition in beach vegetation that is quite clear to the eye, separating more strongly sloped forebeaches with low species diversities and frequent saltwater inundation from the more diverse and densely vegetated upper reaches of the beach that receive saltwater only during very violent storms or exceedingly high tides accompanied by storms. Samples of the bottom zone were taken on the outer coast from Topsy Creek northward as far as Justice Creek, and along the shores of Lituya Bay from near the mouth of the Bay to Cenotaph Island (Figure 1).

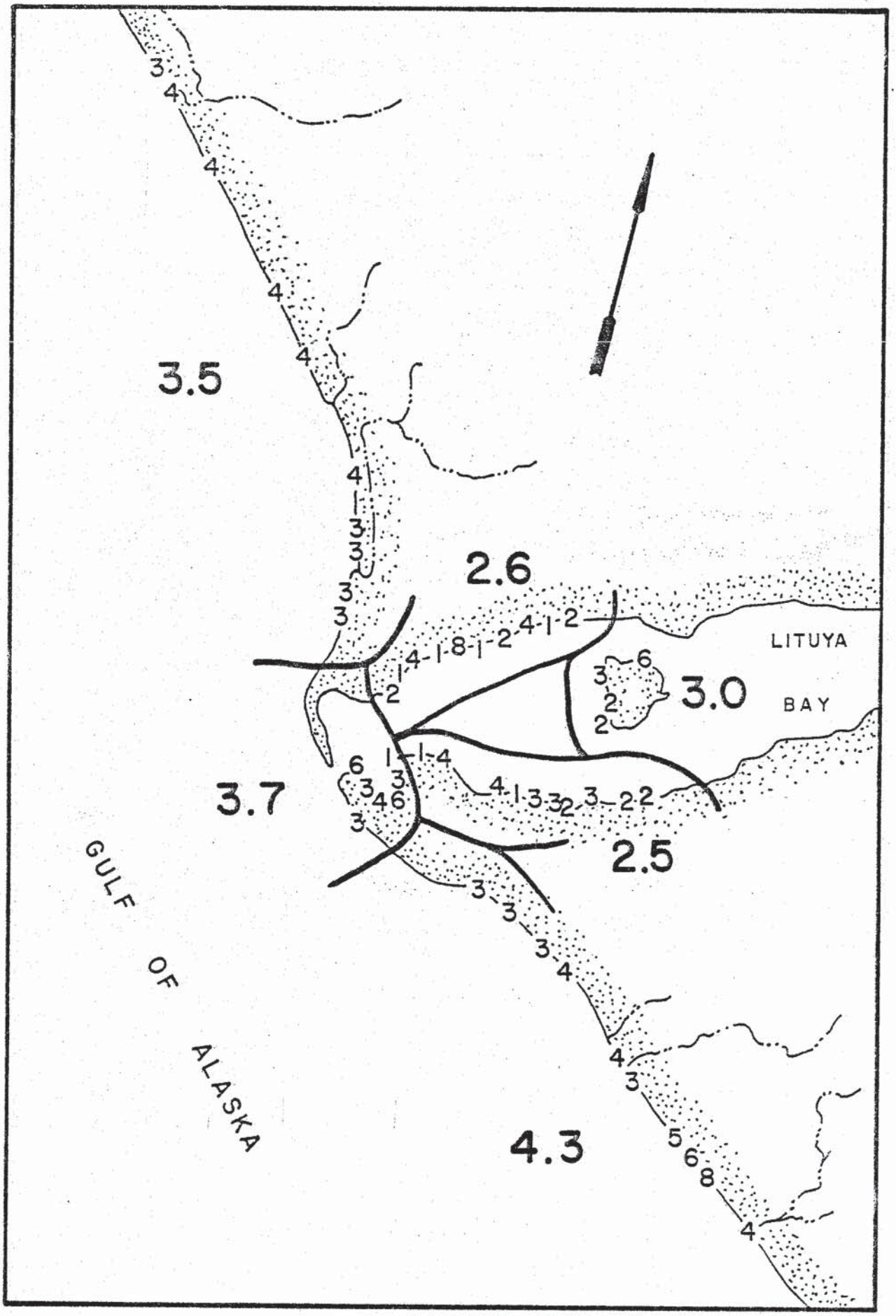
Prominent Species and Species Geography:

The distribution in the bottom zone was mapped for all species (by abundance values in most cases). Twenty-three species of vascular plants were recorded in the bottom zone, although few of these were frequent, abundant, or displayed geographical patterns of interest. Bryophytes were not systematically recorded, but only Grimmia maritima was noted in the zone, then only at very low frequencies and abundances. The bulk of the species recorded from the bottom zone with low frequency and/or low abundance are more common in the herbaceous meadows and can be considered occasional to rare colonizers on the bottom beaches. Presumably the lifespan of any such colonizer population is limited and although seeding in the bottom zone is common, the presence of saltwater denies permanent colonization of these habitats by these species.

Throughout the bottom zone samples, three species occur with high frequency and often fairly high abundance: Elymus arenarius is found at most bottom sites with the exception of the north shore of Lituya Bay where it is highly infrequent; Honckenya peploides occurs at nearly every site sampled, often with high abundance (4 or 5) and is clearly the most distinctive member of the bottom zone, whether within Lituya Bay or along the outer coast; and Lathyrus maritimus which is common all along the outer coast in the bottom zone, although scarcely ever occurring in the bottom zone within Lituya Bay. Of these three species, quite clearly Honckenya peploides is the species most capable of sustained growth well down the beaches into tidewater influence areas. Elymus does very well in the upper portion of the bottom zone as isolated individuals or small clumps, but rarely forms the dense grassland meadow of the Beach community herbaceous meadow zone. The Lathyrus seems to flourish at the intersection between the bottom zone and herbaceous meadow, doing best where it has a minimum amount of competition from other vascular plants species, but yet is relatively far removed from frequent direct tidewater wash.

Within Lituya Bay, two other species occur with moderate frequency, although never in great abundance except at highly restricted sites: the grass Puccinellia nutkaënsis grows at sub-bottom sites, apparently always in a rather flat rocky depression, perhaps where freshwater seeps out of a beach well below the limit of Honckenya peploides. Since there were no sites visited along the outer coast which provided level gravel or cobble depressions near the height of tidewater, (likely due to the intensity of the sea), it is not surprising there are no records of Puccinellia there. Similarly, the grass Hordeum brachyantherum is recorded only from the shores of Lituya Bay where it occurs with moderate frequency. Like Puccinellia, Hordeum seems to prefer substrates of gravels and rocks rather than sand. Unlike Puccinellia, the Hordeum is not restricted to flat

Figure 1. Species richness per bottom zone sample. Mean richnesses for six geographical regions of the study area are indicated with larger numerals.


3.5
2.6
3.0
3.7
2.5
4.3
LITUYA
BAY
GULF OF ALASKA

depressions or freshwater seeps that are commonly covered by tidewater.

Two species of Carex are worth comment at this point: Carex macrocephala is commonly found in areas of mobile sands, and thus is known along the outer coast and at the mouth of Lituya Bay; however, as a member of the bottom zone (perhaps as a reflection upon the person sampling rather than upon the distribution of the species) it is only known north of Lituya Bay. Another species of Carex, as yet undetermined, occurs sporadically in the bottom zone or sub-bottom zone, often with considerable density; like Puccinellia, this species forms dense herbaceous growth in the bottom or sub-bottom zones where there are flat cobble depressions.

Species Numbers Per Sample:

The mean number of species per sample (Figure 1) in the bottom zone is greater along the outer coast (3.9) than within Lituya Bay (2.6), and greatest on south beaches of the outer coast (4.3). The mean number of species per sample in the bottom zone of the beach community in all of the study area is 3.3 (range 1-8, mode 3). Since the outer coast is a high energy beach, it is surprising that there are less species within the confines of Lituya Bay. Perhaps this is because of the very sharply defined bottom zone within Lituya Bay caused by the much steeper topography, accompanied by the deleterious effects of glacial silt accumulation.

Community Structure (0.50-1.00 similarity level):

Analysis of the similarity matrix considering all similarities 0.50 or greater yields:

- one very large cluster of 48 samples,
- three samples, peripheral to the large cluster, having 2-6 similarity values between 0.50 and 0.63 associating them with the large cluster,
- a small cluster of three samples, and
- two samples having no similarities 0.50 or greater.

The large cluster consists of samples having from 1 to 6 species, averaging 3.0 species (s.d. = 1.3). All samples contain Honckenya peploides (Ave. abund. = 3.3, I.V. = 78), 73% of the samples contain Elymus arenarius (Ave. abund. = 2.0, I.V. = 53) and 54% of the samples contain Lathyrus maritimus (Ave. abund. = 1.6, I.V. = 40). This cluster is the Honckenya (Elymus-Lathyrus) sub-community. Of the other 14 species occurring in samples of the cluster, only Hordeum brachyantherum occurs in more than 10% of the samples (Freq. = 21%, Ave. Abund. = 0.5, I.V. = 15). Of the remaining species, most are commonly found in the herbaceous meadows of the sandy beaches, except for the sub-bottom species Puccinellia nutkaënsis, Plantago maritima, and Carex, sp., and Juncus arcticus, a species of freshwater seeps.

The three samples loosely associated with the Honckenya (Elymus-Lathyrus) sub-community include:

- a freshwater seep with an undercut herbaceous meadow sliding into the bottom zone, having a total of 8 species (all with abundance values of 2): Honckenya peploides, Elymus arenarius, Achillia borealis, Juncus articus, and Epilobium glandulosum. The Juncus is characteristic of wet areas, the other species (except Honckenya and Elymus) are generally restricted on the beaches to higher zones.

The full characterization of the Honckenya (Elymus-Lathyrus) sub-community is:

Species	% Freq.	Ave. Abund.	I.V.
Honckenya peploides	100	3.3	78
Elymus arenarius	73	2.0	53
Lathyrus maritimus	54	1.6	40
Hordeum brachyantherum	21	0.5	15
Carex macrocephala	10	0.3	8
Achillea borealis	8	0.2	6
Puccinellia nutkaënsis	6	0.2	5
Mertensia maritima	4	0.1	3
Agrostis exarata	4	0.1	3
Potentilla egedii	2	0.1	2
Carex spp.	2	0.04	1
Juncus arcticus	2	0.04	1
Ligusticum scoticum	2	0.04	1
Lupinus nootkatensis	2	0.04	1
Mimulus guttatus	2	0.04	1
Plantago maritima	2	0.04	1

- a small cove on the north shore of Lituya Bay with an exceptionally high diversity of graminoids: Honckenya peploides (3), Hordeum brachyantherum (3), Carex sp. (3), Deschampsia beringensis (3), Elymus arenarius (2), Agrostis exarata (2), Juncus arcticus (2), and Puccinellia nutkaënsis.
- a beach on the northeast shore of Cenotaph Island with a gentle gradation of communities from the sub-bottom beach zone to a terrestrial meadow. The species of this bottom sample seem an eclectic assemblage in the bottom zone: Honckenya peploides (4), Hordeum brachyantherum (3), Puccinellia nutkaënsis (3), Epilobium latifolium (3), Lupinus nootkatensis (2) and Deschampsia beringensis (2).

The small cluster of three samples consists of samples from sub-bottom habitats with abundant freshwater seepage. All three are dominated by the lush growth of the undetermined species of Carex, it being the sole species at one site:

Species	% Freq.	Ave. Abund.	I.V.
Carex sp.	100	5.3	94
Honckenya peploides	66	1.7	47
Puccinellia nutkaënsis	33	1.7	31
Elymus arenarius	33	1.0	25
Hordeum brachyantherum	33	0.7	22
Lathyrus maritimus	33	0.7	22

The two samples having no similarities 0.50 or greater with any other samples are from a site with two not infrequent species of the bottom/sub-bottom zone: Hordeum brachyantherum (2) and Puccinellia nutkaënsis (2); and from a site having a dense clone of Elymus arenarius as the sole species in the bottom zone, a most uncommon circumstance - this is the Elymus sub-community.

Thus, 87% of the bottom zone samples form a similar group, with the prominent variations therefrom being:

a. sub-bottom zones more saltwater influenced
b. sites with freshwater seepage
c. sites with inclusion of species from beach meadows

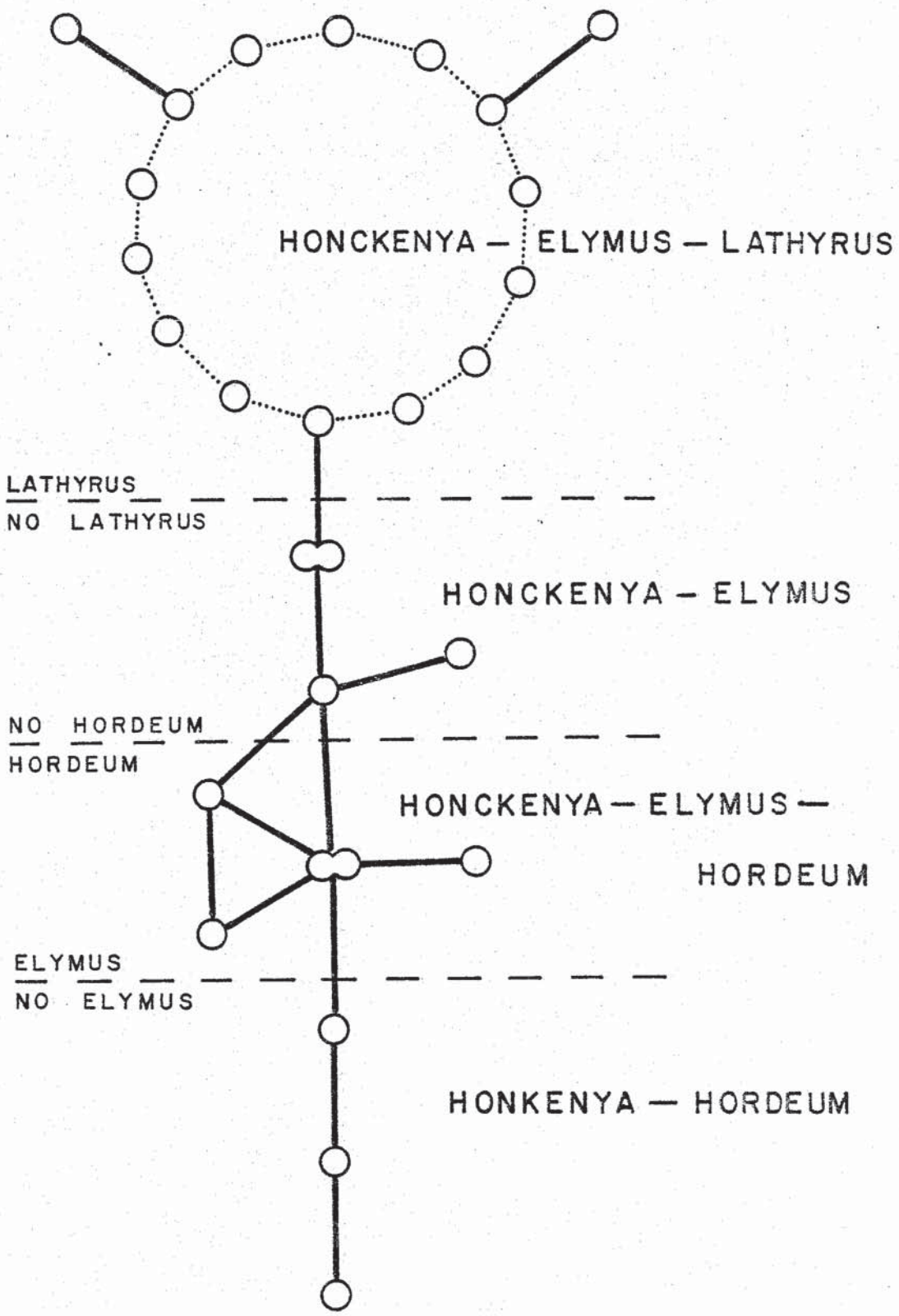
Community Structure (0.80-1.00 similarity level):

At similarity levels 0.80 or greater the large cluster of the previous discussion is subdivided extensively with 29 samples, various clusters and/or positions along a gradient in one large plexus (Figure 2); smaller plexi, containing 6, 6, and 3 species respectively, and 3 samples with no similarities 0.80 or greater (the distribution of the 8 sites not in the Honckenya (Elymus-Lathyrus) sub-community are the same at the 0.80-1.00 level as at the 0.50-1.00 level).

The large plexus basically displays the variation of the 4 most frequent and important species of the Honckenya (Elymus-Lathyrus) sub-community.

The largest group of samples (14) belongs in the top cluster of the gradient (Figure 2). It is a Honckenya-Lathyrus-Elymus sub-group with an average

Figure 2. The largest plexus of the 0.80 - 1.00 similarity level plexi of the bottom zone. The solid lines indicate similarities 0.80 or greater. The large circle of samples at the top of the plexus is very highly inter-connected at the 0.80 - 1.00 level, and the dotted lines symbolize that inter-connectedness in lieu of drawing all of the lines between the samples. The dashed lines separate portions of the plexus with or without each of three species. The double circles represent identical samples.


HONCKENYA — ELYMUS — LATHYRUS
LATHYRUS
NO LATHYRUS
HONCKENYA — ELYMUS
NO HORDEUM
HORDEUM
HONCKENYA — ELYMUS —
HORDEUM
ELYMUS
NO ELYMUS
HONKENYA — HORDEUM

richness of 3.2 species:

Species	% Freq.	Ave. Abund.	s.d.	I.V.
Honckenya peploides	100	3.1	0.7	76
Lathyrus maritimus	100	2.9	0.8	74
Elymus arenarius	100	2.7	0.6	73
Mertensia maritima	14	0.3	-	10
Festuca rubra	7	0.1	-	4

The two samples having similarities 0.80 or greater to only one sample of this cluster are but minor variations of the prevailing theme, and consist of the 3 principal species plus 2 additional, less important species.

The next sub-group along the gradient has 4 samples, with an average richness of 2.3. It is a Honckenya-Elymus sub-group:

Species	% Freq.	Ave. Abund.	s.d.	I.V.
Honckenya peploides	100	3.5	0.6	79
Elymus arenarius	100	2.3	0.5	69
Achillea borealis	25	0.5	-	17

The next sub-group along the gradient has 6 samples, with an average richness of 3.4. It is a Honckenya-Elymus-Hordeum sub-group:

Species	% Freq.	Ave. Abund.	s.d.	I.V.
Honckenya peploides	100	4.2	0.5	85
Elymus arenarius	100	2.4	0.6	70
Hordeum brachyantherum	100	2.2	0.5	68
Potentilla egedii	17	0.5	-	12
Puccinellia nutkaënsis	17	0.3	-	11
Ligusticum scoticum	17	0.3	-	11

The final sub-group along the gradient has 3 samples, with an average richness of 2.3. It is a Honckenya-Hordeum sub-group:

Species	% Freq.	Ave. Abund.	s.d.	I.V.
Honckenya peploides	100	3.3	0.6	78
Hordeum brachyantherum	100	2.3	0.6	69
Agrostis exarata	33	0.7	-	22

There are three smaller plexi, all of which are clearly similar to the main plexus just described, but at values less than 0.80.

Six samples contain Honckenya peploides, Elymus arenarius, and Lathyrus maritimus as does the principal sub-group of the main plexus, but also have Carex macrocephala. Since five of these samples did not include abundance data, the sub-group title Carex macrocephala-Honckenya is tentative:

Species	% Freq.	Ave. Abund.	s.d.	I.V.
Honckenya peploides	100	-	-	-
Elymus arenarius	100	-	-	-
Lathyrus maritimus	100	-	-	-
Carex macrocephala	100	-	-	-

Five samples are identical, containing only Honckenya peploides at an abundance of 3; one sample has Honckenya peploides at an abundance of 5. They form the Honckenya sub-group.

Three samples are identical, containing Honckenya peploides at an abundance of 4, and Lathyrus maritimus with an abundance of 2. It is a Honckenya-Lathyrus sub-group.

The remaining three samples represent further variations of the Honckenya (Elymus-Lathyrus) sub-community theme, sites having (abundance in parentheses):

- Lupinus nootkatensis (2) along with Honckenya peploides (3), a very unusual circumstance.
- Honckenya peploides (3), Elymus arenarius (3), Puccinellia nutkaënsis (3), and Plantago maritima (2), a mix of bottom and sub-bottom species.
- Honckenya peploides (2), Elymus arenarius (2), Lathyrus maritimus (2), Achillea borealis (2), Agrostis exarata (2), and Juncus articus (2), a till and shingle bedrock beach north of Topsy Creek.

Classification:

Thus, this classification evolves for the Lituya Bay study area:

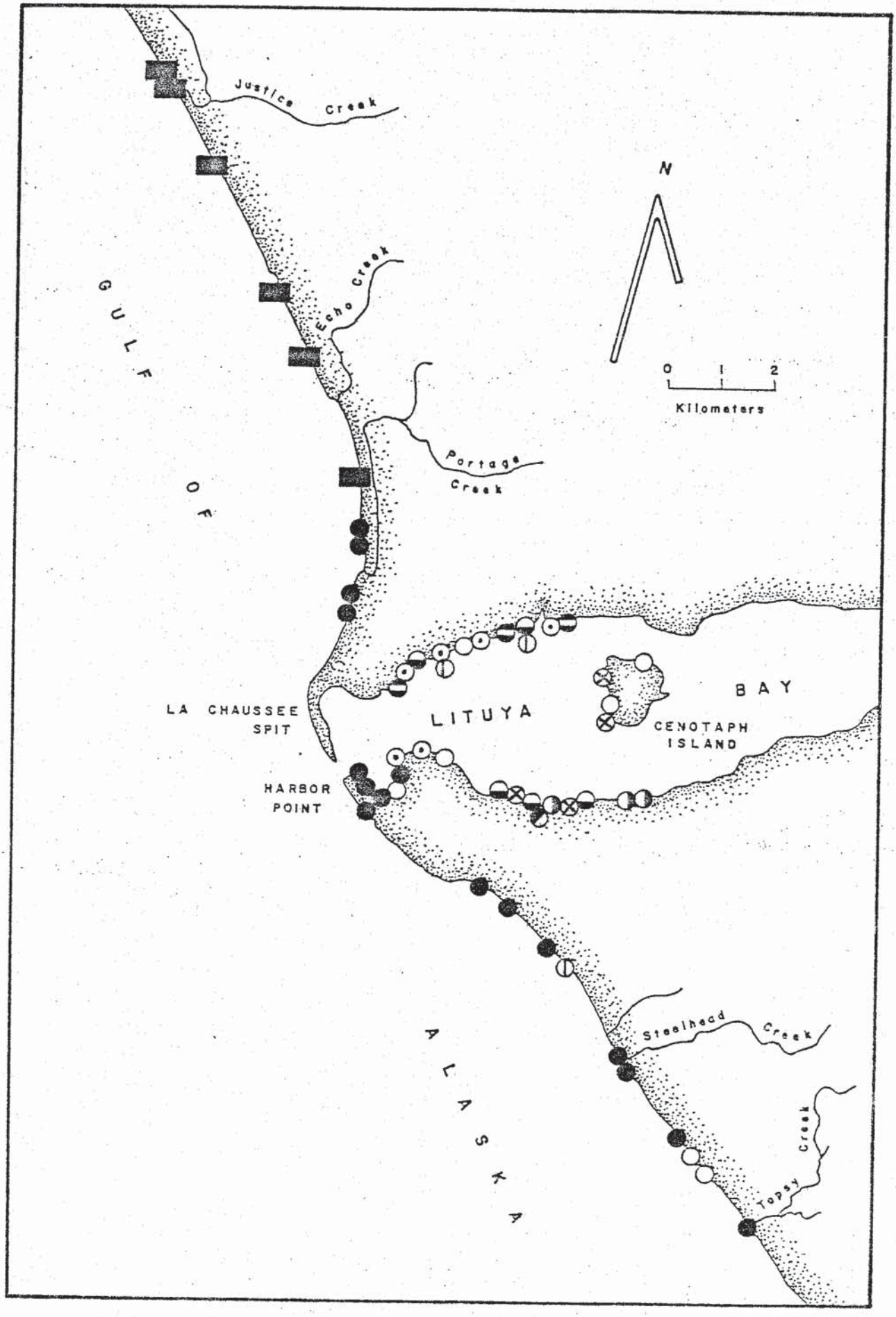
Beach Community
- Bottom Zone
  - Sub-bottom
    - Carex sp. sub-community
  - Bottom
    - Honckenya - (Elymus-Lathyrus) sub-community
      - Honckenya-Lathyrus-Elymus sub-group
      - Honckenya-Elymus sub-group
      - Honckenya-Elymus-Hordeum sub-group
      - Honckenya-Hordeum sub-group
      - Honckenya sub-group
      - Honckenya-Lathyrus sub-group
      - Carex macrocephala-Honckenya sub-group
    - Elymus sub-community

(7 samples are unclassified)

Community Geography:

Several of the sub-groups have distinctive geographical patterns (Figure 3). All 16 samples of the Honckenya-Lathyrus-Elymus sub-group are at Harbor Cove and along the outer coast, forming the dominant sub-group from Topsy Creek to Portage Creek (76% of all sampled sites in that area). The Carex macrocephala-Honckenya sub-group occurs only on the outer coast

Figure 3. Distribution of the bottom zone sub-groups and sub-communities.
The solid rectangles are the *Carex macrocephala-Honckenya* Sub-group.
The solid circles are the *Honckenya-Lathyrus-Elymus* Sub-group.
The circles with an "X" are the *Honckenya-Elymus* Sub-group.
The circles with the bottom half filled are the *Honckenya-Elymus-Hordeum* Sub-group.
The circles with the right half filled are the *Honckenya-Hordeum* Sub-group.
The circles with a dot are the *Honckenya* Sub-group.
The circles with a central white stripe are the *Honckenya-Lathyrus* Sub-group.
The circle half filled at a slant is the *Elymus* Sub-community.
The circles with a vertical line are the *Carex* sp. Sub-community of the bottom zone.
The open circles are unclassified samples.


Justice Creek
Echo Creek
Portage Creek
GULF OF
ALASKA
N
0 1 2
Kilometers
LA CHAUSSEE SPIT
LITUYA BAY
CENOTAPH ISLAND
HARBOR POINT
Steelhead Creek
Topsy Creek

north of Portage Creek, and is the exclusive sub-group reported there.

With the exception of but a single sample, all of the remaining sub-groups and sub-communities are located within Lituya Bay, displaying no outstanding geographical patterns.

Comparison with Dixon Harbor Study Area:

The 38 bottom and middle zone samples taken at the Dixon Harbor study area (Worley, 1975) provide five bottom zone sub-communities (2 to 5 samples each) and two middle zone sub-communities (8 and 11 samples each). At the Lituya Bay study area, 56 bottom zone samples comprise 3 sub-communities, one containing seven sub-groups. Comparison of the sub-communities, sub-groups, and individual samples between the study areas yields limited similarity. Between the two study areas there is but one instance of similarity at the sub-community and/or sub-group level greater than 0.36; the Honckenya (Elymus-Lathyrus) sub-community has a similarity of 0.55 with the Lathyrus-Elymus sub-community.

The beach samples of the study area can be combined into a single classification scheme by integrating the samples of two small sub-communities of the Dixon Harbor study area with sub-groups of the Lituya Bay study area.

If the four samples of the Dixon Harbor study bottom zone sub-community Elymus-Honckenya are separated, the two samples with Carex macrocephala being one group, the remaining two another, then the first two samples clearly belong with the Lituya Bay study Carex macrocephala-Honckenya sub-group, and the other two belong with the Honckenya-Lathyrus-Elymus sub-group.

If the five samples of the Dixon Harbor study bottom zone sub-community Honckenya are separated, the three samples with Galium aparine become the sub-community Honckenya-Galium, and the remaining two samples then clearly belong with the Lituya Bay study Honckenya sub-group. The new sub-group Honckenya-Galium (all samples having Honckenya at an abundance of 4 and Galium aparine at an abundance of 3 does not occur in the Lituya Bay study area although Galium aparine occurs in great abundance at some sites on the north shore of Lituya Bay above the bottom zone (in which it is not known).

In this combined classification, the Elymus-Honckenya and the Honckenya sub-communities of the Dixon Harbor study are eliminated and their samples integrated, as detailed above, into the sub-groups of the Lituya Bay study, yielding a total of 13 classification units for the bottom zone. The Elymus sub-community might be considered a sub-group of the Honckenya-(Elymus-Lathyrus) sub-community, but because of the lack of Honckenya, and all other species, due to the very vigorous growth of the beach rye grass, it seems more properly treated as a sub-community.

The combined classification of the bottom zone (Table 1) has six sub-communities with the Honckenya-(Elymus-Lathyrus) sub-community having eight sub-groups.

Of the eight unclassified sites, one from Boussole Beach and one from

Table 1. Comparison of the bottom zone sub-communities and sub-groups of the Dixon Harbor study area and Lituya Bay study area. For the Honckenya-(Elymus-Lathyrus) sub-community the summation of the values of its sub-groups are shown in parentheses.

	Number of samples in Dixon Harbor study	Number of samples in Lituya Bay study	Total number of samples	% of all samples	Mean number of species
Beach Community					
Bottom Zone					
Sub-bottom					
Carex sp. sub-community	-	3	3	4%	3.0
Puccinellia sub-community	5	-	5	6%	2.8
Bottom					
Honckenya-(*Elymus*-*Lathyrus*) sub-community	(9)	(44)	(53)	(65%)	(3.0)
Honckenya-*Lathyrus*-*Elymus* sub-group	2	16	18	22%	3.2
Honckenya-*Elymus* sub-group	-	4	4	5%	2.3
Honckenya-*Elymus*-*Hordeum* sub-group	-	6	6	7%	3.4
Honckenya-*Hordeum* sub-group	-	3	3	4%	2.3
Honckenya sub-group	2	6	8	10%	1.1
Honckenya-*Lathyrus* sub-group	-	3	3	4%	2.0
Honckenya-*Galium* sub-group	3	-	3	4%	2.0
Carex macrocephala-*Honckenya* sub-group	2	6	8	10%	4.0
Elymus sub-community	-	1	1	1%	1.0
Deschampsia sub-community	4	-	4	5%	4.3
Bottom/Middle					
Lathyrus-*Elymus* sub-community	8	-	8	10%	8.6
Unclassified	1	7	8	10%	4.9

Mean richness all samples but *Lathyrus*-*Elymus* = 3.24
Mean richness all samples = 3.76

Lituya Bay are from sub-bottom environments, the graminoid-dominated site at the cove on north shore of Lituya Bay is somewhat similar (0.51) to the Deschampsia sub-community, and the remaining five samples represent various combinations of beach species.

Thus, as the number of samples of vegetation increases from the outer coast, the number of kinds of vegetation increases. Eighty-two samples have yielded 13 classification units only one of which contains more than 10% of the samples (Table 1).

Of the 13 classification units, 46% occur only in the Lituya Bay study area, 31% only in the Dixon Harbor study area, and but 23% shared by both (Table 2). However, nearly one half (46%) of all samples classified belong to sub-groups shared by both study areas, the three most frequently encountered sub-groups in these studies.

At the Lituya Bay study area a total of only 23 species are known from the bottom zone, with an average of 3.3 species per sample. At the Dixon Harbor study area but 18 species are recorded from the botton zone, averaging 3.8 species per sample. Fourteen of the 23 Lituya Bay species (61%) are not reported from the bottom zone at Dixon Harbor, and 9 of the 18 Dixon Harbor species (50%) are not reported from the Lituya Bay study area bottom zone. Thus, only 9 of the 41 species (22%) known from the outer coast bottom zone samples occur in both study areas. These are Honckenya peploides, Elymus arenarius, Puccinellia nutkaënsis, Juncus arcticus, Lathyrus maritimus, Plantago maritima, Deschampsia beringensis, Ligusticum scoticum, and Festuca rubra.

Table 2. Comparison between the Lituya Bay and Dixon Harbor study areas of classification units (sub-groups and sub-communities) and classified samples.

	Number of class. units	% of class. units	Number of samples in the class. units	% of all classified samples
Only at Lituya Bay study area	6	46%	20	27
Only at Dixon Harbor study area	4	31%	20	27
At both study areas	3	23%	34	46

General Character of the Bottom Zone:

Most bottom zone sites have 3 species, usually with only 1 or 2 being prominent. The amount of ground cover at the upper end of the zone varies from less than 5% to greater than 80%, and is most commonly 50% or less; at the bottom of the zone, ground cover is characteristically less than 5% except in very low energy sites with sub-bottoms and/or where there are freshwater seeps - in these sites cover may approach 100% in places.

For the most part, the dominant species of the bottom zones of both study areas are the same, with Honckenya peploides, Elymus arenarius, Lathyrus maritimus, and occasionally Carex macrocephala the most distinctive species. Other distinctive species are Deschampsia beringensis at the head of the west arm of Torch Bay, Puccinellia nutkaënsis at sub-bottom sites in the Dixon Harbor study area and sporadically at Lituya Bay, Hordeum brachyantherum common at Lituya Bay, and a species of Carex which forms lush sub-bottom stands at Lituya Bay. Plantago maritima also may occur in the sub-bottom zone.

Freshwater seeps are indicated by higher species numbers, Carex spp., Juncus spp. (including J. arcticus), and sometimes additional grass species.

The most prominent similarity between study areas are the sand beaches of the Lituya Bay outer coast and the sand beaches of the Dixon Harbor study area: Boussole, Astrolabe, and Inner Point. There is also similarity among sites where Honckenya peploides dominates or is the exclusive species. Finally, there is isolated similarity wherever a sub-bottom habitat favors the growth of Puccinellia nutkaënsis.

Afterword:

Although the total number of species recorded in the bottom zones of both study areas is low, the samples segregate into a large number of sub-groups and sub-communities. By and large, these sub-units consist of various combinations of a few quite frequent and often dominant species. Thus, it would seem that the bottom zone of the beach community as now known from Torch Bay to Justice Creek consists of a variety of habitats suitable for the dominance of one or two species each and that each species acts quite independently from any other species. The only inter-specific competition that is apparent in the bottom zone of the beach community occurs when large graminoids (usually Carex spp. and/or Elymus arenarius) grow in sub-bottom sites so tall and densely that they prohibit further colonization by other plant species.

Thus, it appears to be more valuable to know and understand the habitat requirements of the individual bottom zone species than it is to be concerned with the recognition of sub-groups and sub-communities. One should think of species as indicators of habitat types rather than sub-groups and sub-communities as habitat indicators, recognizing that the combined presence of several species at a site better defines the nature of the habitat.

The Supra-tidal Meadow Zone of the Beach Community

Introduction and General Character:

The supra-tidal meadow zone of the beach community (cf. Worley 1975) is the most prominent vegetated beach zone in the Lituya Bay study area. Along the outer coast the lush meadows extend almost unbroken for kilometers at a time, often several tens of meters wide.

This zone consists of the portion of the beach that lies above the normal high tide line, but does not have a closed canopy of woody vegetation. The zone often intergrades with the bottom zone, especially within Lituya Bay; however, along the outer coast, an erosion scarp often clearly separates the two. Along the outer coast colonization of the supra-tidal meadows by spruces is commonplace. Within Lituya Bay, only 19 years (at the time of data collection) have elapsed since beaches and adjacent lowlands were scoured by the last great wave; nonethless, vegetation boundaries seem well established, with forest colonization at most sites down to, or even somewhat upon, the uppermost active storm beaches.

Samples of the supra-tidal zone were taken on the outer coast from Topsy Creek northward as far as Justice Creek, and along the shores of Lituya Bay from the mouth of the bay to Cenotaph Island (cf. Figure 4). Most samples came from sites also having bottom zone samples. Samples from north of Echo Creek were restricted to present-absence data. No bryophytes at any of the sites were recorded in the data.

In most instances, the sample included the full breadth of the supra-tidal zone, a zone varying from less than a meter to over 120 m in extent. Thus, some obvious vegetation variation is masked; for example, Fragaria-dominated, short herb "sub-communities" (which never occupy the total breadth of a beach) are always merged in the data with an Elymus or umbelliferous assemblage.

Prominent Species and Species Geography:

One hundred nine species of vascular plants were recorded. The distribution of occurrence in the supra-tidal zone was mapped for all species. The majority of the species displayed distinctive geographical patterning (unlike the bottom zone species which show little geographical patterning).

The study area was divided into several geographical zones (Figure 5) for the ease of comparison among different species distribution. These geographical regions coincide with certain environmental characteristics. For example, sand substrates are essentially absent within Lituya Bay, and rocky beaches are uncommon throughout most of the outer coast sites.

Except for species of infrequent occurrence, all species could be classified into one of these groups:

Predominantly Outer Coast:

Includes species recorded only along the outer coast, and a few species found only at sites on the outer coast and at Harbor Cove (15 species in total).

Figure 4. Species richness per supra-tidal meadow sample. Mean richness for six geographical regions of the study area are indicated with larger numerals. (next page)

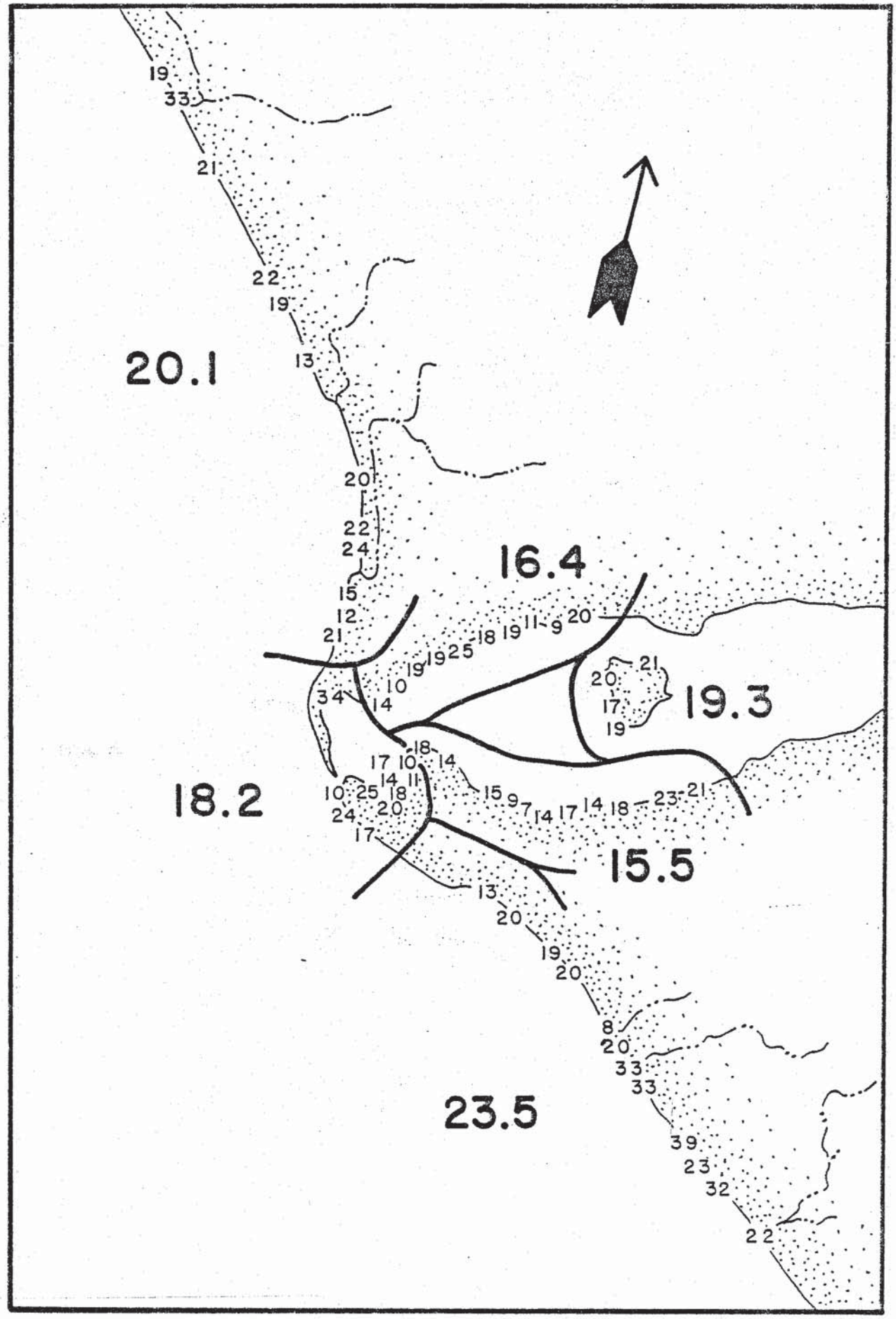
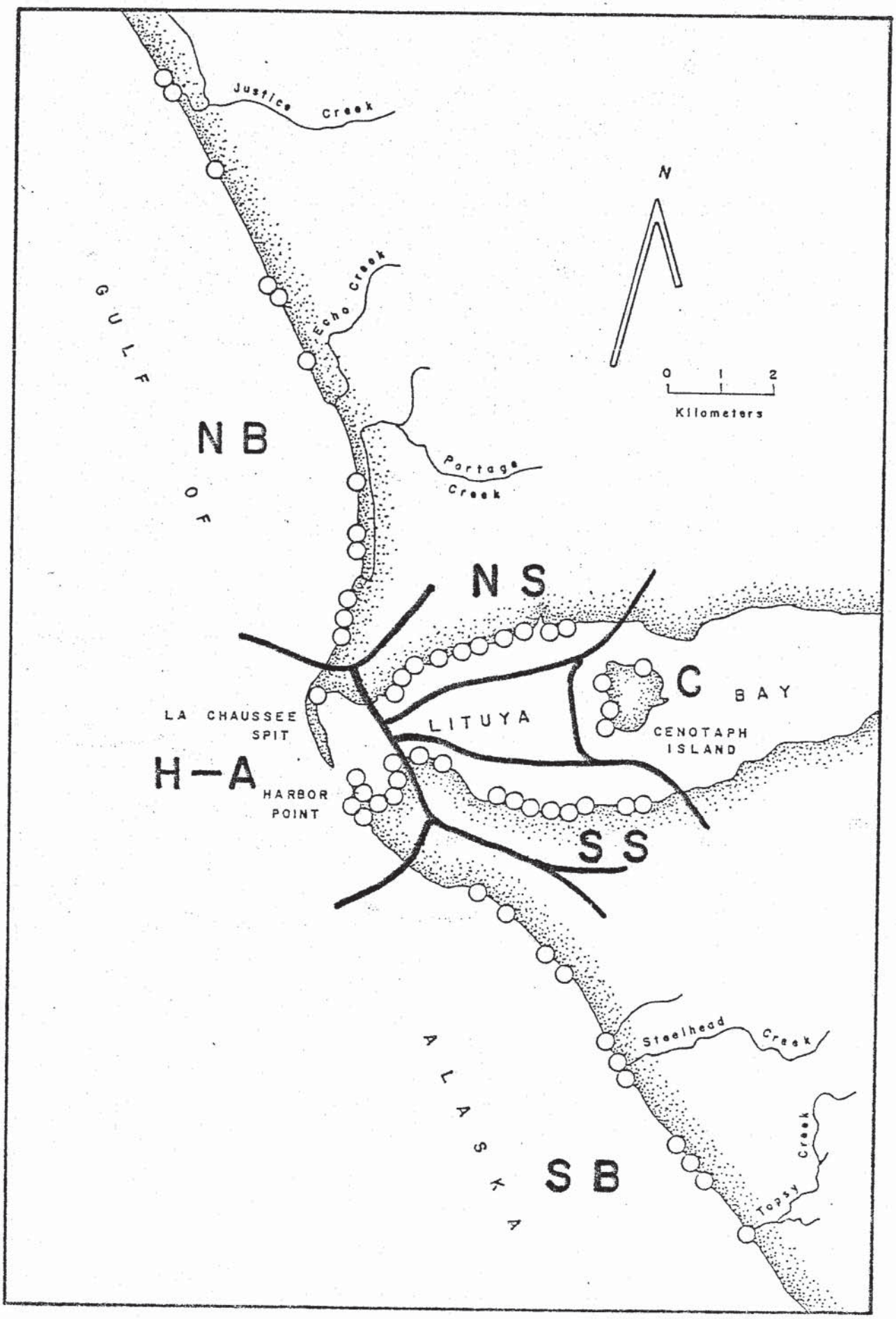

20.1
16.4
19.3
18.2
15.5
23.5

Figure 5. Geographical regions of the Lituya Bay study area beaches. NB = North Beaches; SB = South Beaches; NS = North Shore Lituya Bay; SS = South Shore Lituya Bay; C = Cenotaph Island; H-A = Harbor and Anchorage Coves. (next page)


Justice Creek
Echo Creek
Portage Creek
N
0 1 2
Kilometers
GULF OF ALASKA
NB
NS
SS
SB
C BAY
LITUYA
CENOTAPH ISLAND
LA CHAUSSEE SPIT
H-A
HARBOR POINT
Steelhead Creek
Topsy Creek

Predominantly Lituya Bay:

- Includes species recorded only within Lituya Bay, and a very few species with rare records on the outer coast; some species occur on only the north shore or south shore of the bay (17 species in total).

Throughout:

- Includes 19 species that are recorded from all geographical areas, though sometimes more frequently in certain of the areas.

Lituya Bay and South Beaches:

- Includes seven species recorded predominantly or exclusively from Lituya Bay and the beaches south of Harbor Point.

Harbor Cove:

- Includes one species recorded exclusively from Harbor Cove.

Fifty species occurred with frequencies sufficiently low that classification was meaningless.

Of the Predominantly Outer Coast species, four occur all along the outer coast including the mouth of Lituya Bay: Maianthemum dilatatum, Carex macrocephala (Figure 6a)*, Castilleja unalaschcensis (Figure 6b), and Platanthera dilatata. Six inhabit exclusively outer coast locations, from 5 to 19 sites respectively: Botrychium lunaria, Geum macrophyllum, Rubus arcticus, Moehringia lateriflora, Alnus oregona, Tsuga heterophylla, Trientalis europaea (Figure 6c), and Fritillaria camschatcensis (Figure 6d). Castilleja chrymactis is recorded along the outer coast and from a single sample on Cenotaph Island. Athyrium filix-femina grows on beaches principally south of Lituya Bay, and Glehnia littoralis is recorded in the supra-tidal zone from but three sandy sites south of Lituya Bay (Streveler has seen Glehnia at the mouth of Echo Creek).

The two tree species found sporadically as seedlings at outer coast sites, but not in any of the Lituya Bay sites, do grow, however, with expected frequencies and abundances in the successional forest sites throughout Lituya Bay. Three additional species, Athyrium filix-femina, Maianthemum dilitatum, and Trientalis europaea, are commonly associated with meadows closest to forest stands. Seven of the species are characteristic of shores, especially those of fine substrates, such as sands or silts, while the remaining species have no distinctive habitat preferences.

Seventeen species are categorized as Predominantly Lituya Bay species. Galium trifidum is known from six sites, all on the north shore of the Bay. Poa vivipara, Juncus arcticus, Epilobium sp. and Carex gmelini were found only on the south shore of the Bay, ranging from 3 to 5 samples respectively. Six species are recorded in beach samples only from within Lituya Bay: Populus trichocarpa (only at Cenotaph Island), Equisetum

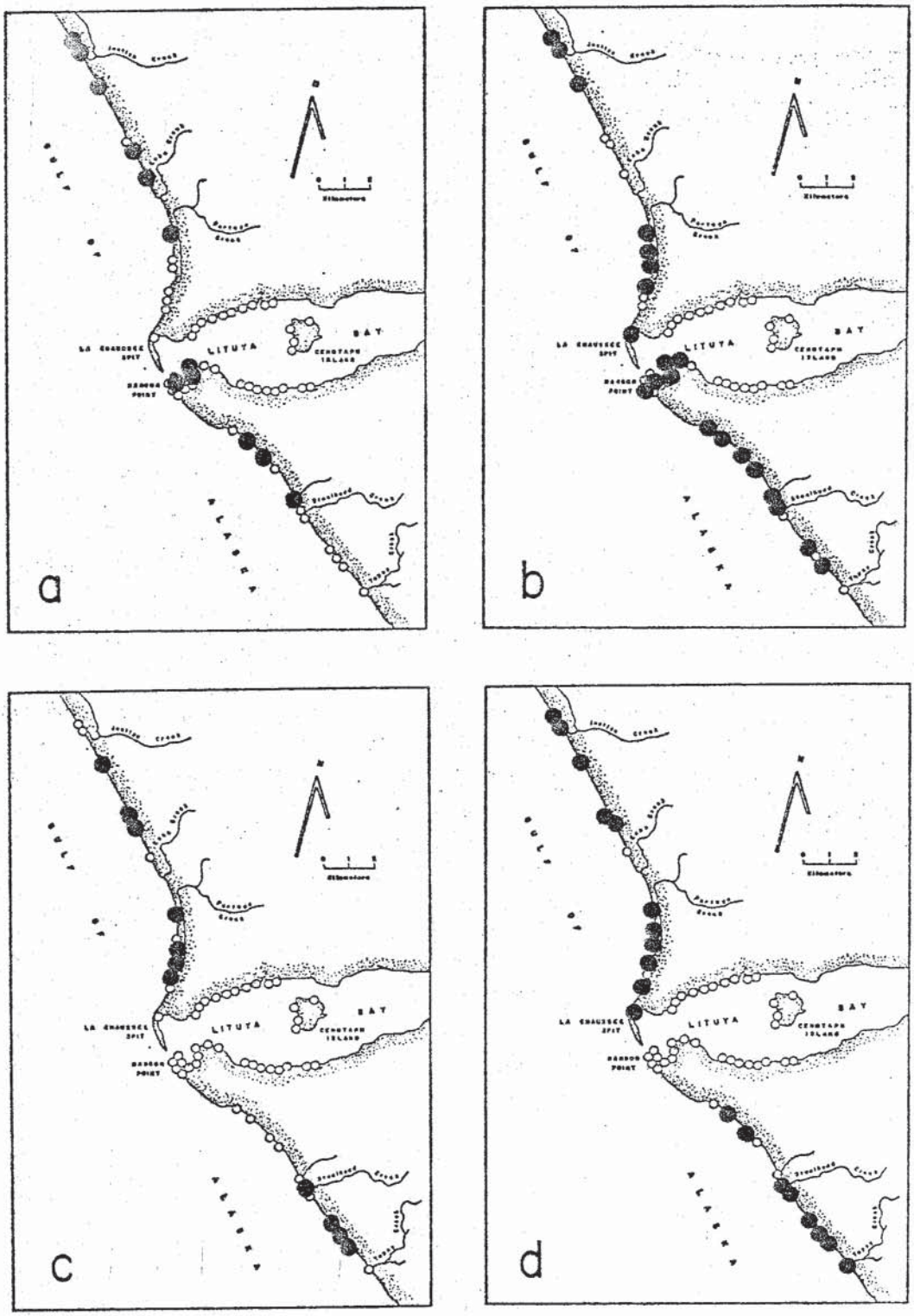
* In this discussion selected, representative species distributions are illustrated.

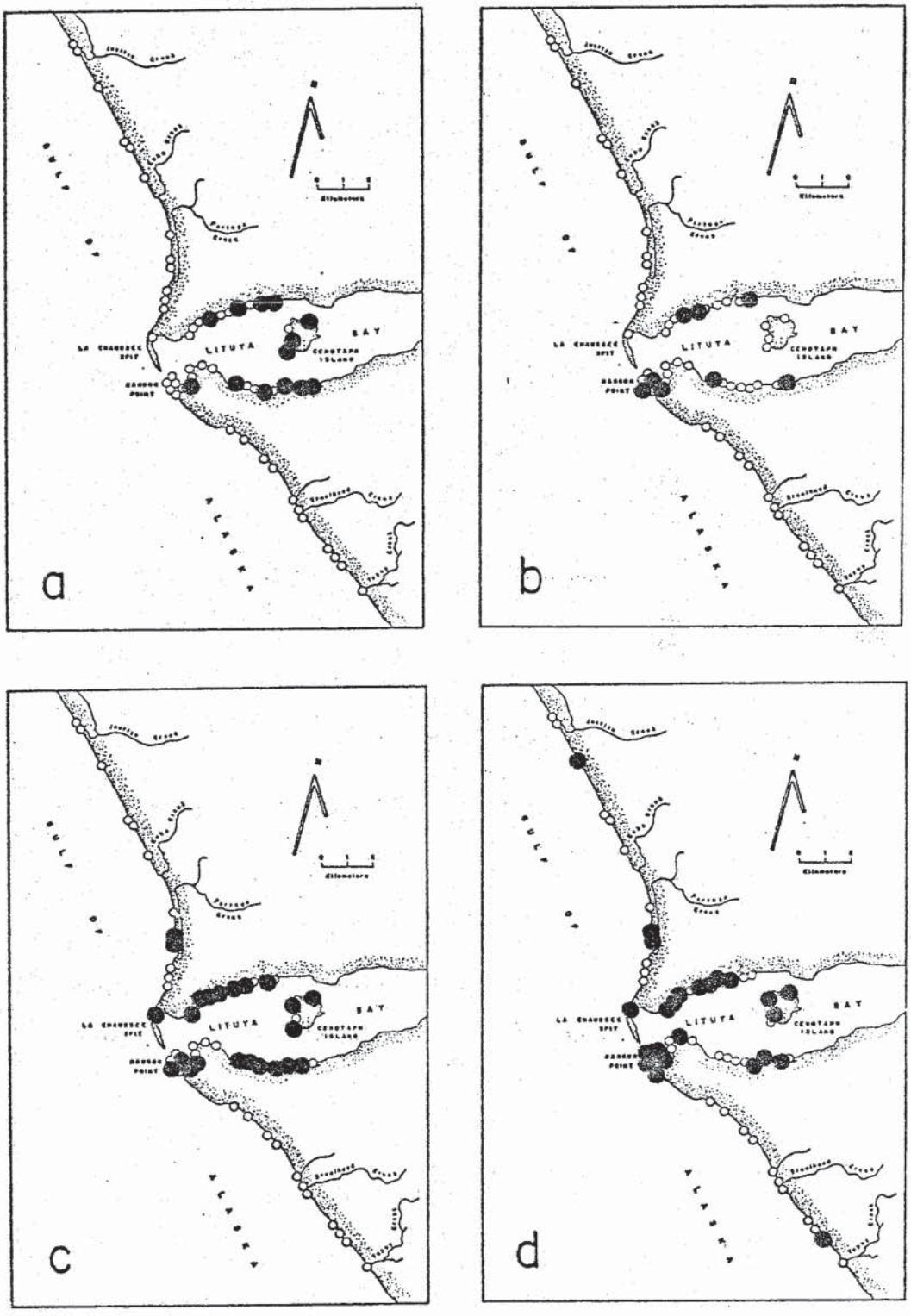
Figure 6. Distribution of selected Predominantly Outer Coast species of the supra-tidal zone: a) Carex macrocephala, b) Castilleja unalaschcensis, c) Trientalis europaea, d) Fritillaria camschatcensis.

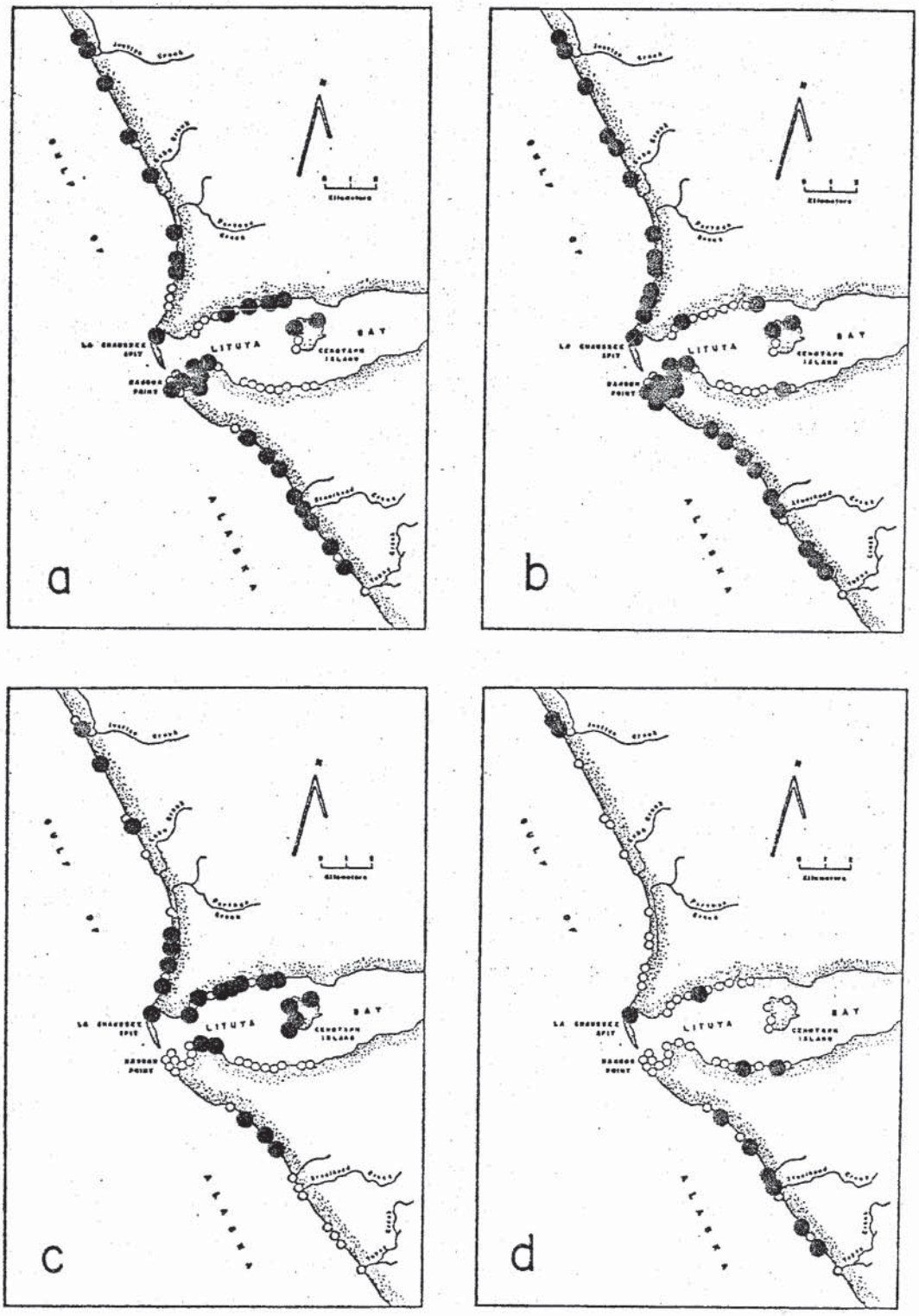
Figure 7. Distribution of selected Predominantly Lituya Bay species of the supra-tidal zone: a) Epilobium latifolium, b) Anaphalis margaritacea, c) Rubus spectabilis, d) Epilobium angustifolium.

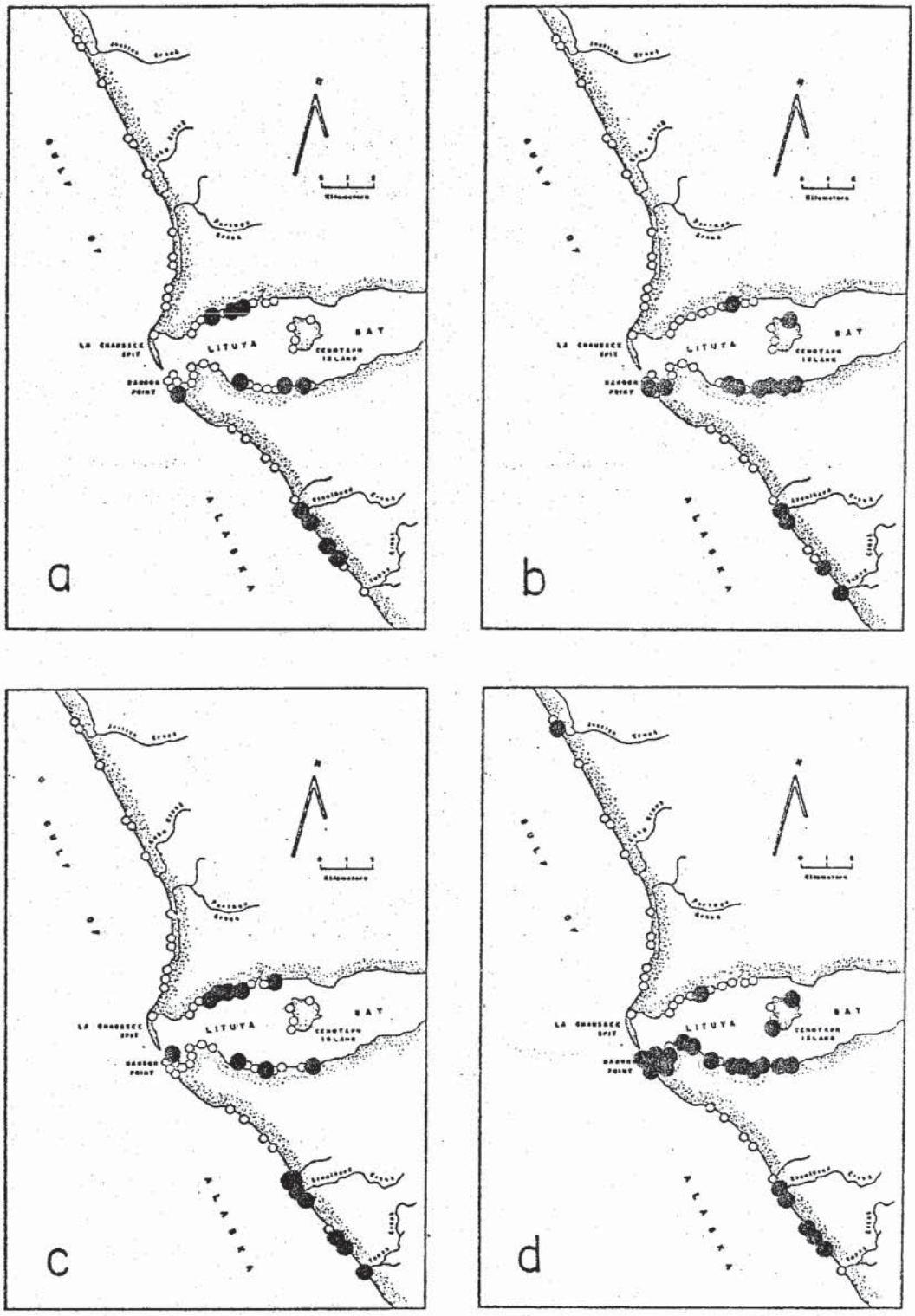
Figure 8. Distribution of selected Throughout species of the supra-tidal zone: a) Rhinanthus minor, b) Fragaria chiloensis, c) Lupinus nootkatensis, d) Luzula multiflora.

Figure 9. Distribution of selected Lituya Bay and South Beaches species of the supra-tidal zone: a) Calamagrostis canadensis, b) Galium aparine, c) Equisetum arvense, d) Agrostis spp.


a
b
c
d
LITUYA
BAY
CENOTAPH ISLAND
LA CHAUSSEE SPIT
HARBOR POINT
Kilometers


a
b
c
d
LITUTA
BAY
Kilometers


a
b
c
d
LITUTA
BAY
Kilometers


a
b
c
d
LITUYA
BAY
GULF OF ALASKA

variegatum (only from the central bay), Salix sitchensis, Aruncus sylvester, Epilobium latifolium (Figure 7a), and Anaphalis margaritacea (Figure 7b). Six species have distributions predominantly within Lituya Bay, but with scarce outer coast reports: Poa sp., Deschampsia beringensis, Stellaria crispa, Hordeum brachyantherum, Rubus spectabilis (Figure 7c), and Epilobium angustifolium (Figure 7d).

The two tree species are successional trees of Lituya Bay not common along the outer coast; they are generally scarce within the beach community. Seven of the species grow at fresh water seeps or streams. Thus, they belong to this geographical classification principally because of the limitation of this habitat to sites within Lituya Bay. Five of the species are most abundant on cobble beaches, a phenomenon rare to nonexistent on the outer coast.

Nineteen species are categorized as Throughout species. These species vary in frequency of occurrence from 14% to 96% (Table 3), and sometimes are more prevalent in particular portions of the study area. For example, Rhinanthus minor (Figure 8a) occurs at 70% of the outer coast sites but only 29% of the Lituya Bay sites, being essentially absent on the south shore of the Bay. Similarly, Fragaria chiloensis (Figure 8b) occurs at 91% of all outer coast sites and at but 17% of Lituya Bay sites. Seldom does the opposite trend prevail, but Lupinus nootkatensis (Figure 8c) is more frequent (especially on Cenotaph Island and the north shore) in the Bay (54%) than along the outer coast (43%). Luzula multiflora (Figure 8d) is typical of the many species found throughout the study area but at low frequencies (it occurs in only 21% of all samples).

Six species are known at frequencies 70 or above from both Lituya Bay and the outer coast; whereas five species have frequencies 70 or greater along the outer coast but frequencies less than 60 within Lituya Bay. Thus, eleven species are known with frequencies of 70 or above from within Lituya Bay.

Seven species (nearly all graminoids) have the curious distribution Lituya Bay and South Beaches. Four graminoids, Luzula parviflora, Calamagrostis canadensis (Figure 9a), Agrostis borealis, and Juncus arcticus, are reported at low frequencies, and are slightly less frequent within the Bay than along the outer coast beaches south of the Bay. Galium aparine (Figure 9b) and Equisetum arvense (Figure 9c) have the same distribution, but at greater frequencies. The genus Agrostis (Figure 9d) has this distribution, but is reported once in the study area north of Lituya Bay. These species may reflect the presence of bedrock and boulders in some beaches south of Steelhead Creek.

Consequently, the bulk of the species in the supra-tidal meadows in the study area occur in one of three distributions: Predominantly Outer Coast, Predominantly Lituya Bay, and Throughout. Thus, one may conclude that there are basically two kinds of species occupying the beaches: a) those species generally found throughout regardless of the general character of the substrate, and b) those species whose distributions are restricted either to sand or to gravel/cobble substrates. The remaining distributional trend are of such minor importance that no distinctive geographical or ecological patterns are evident at this point.

Table 3. Percent frequency of occurrence of the supra-tidal meadow species classified by geographical area as Throughout. The total number of sites in each area appears in parentheses. The addition of distribution records from the bottom zone at the corresponding sites alters the table insignificantly, except for Honckenya peploides (see elsewhere in this report for data concerning this species).

	NB (12)	SB (11)	NS (10)	SS (10)	C (4)	H-A (9)	OC (23)	L (24)	TOTAL (56)
Lathyrus maritimus	100	100	100	90	100	89	100	96	96
Achillea borealis	100	100	90	90	100	89	100	92	95
Elymus arenarius	100	100	90	90	75	100	100	88	95
Festuca rubra	83	100	50	90	50	100	95	70	82
Angelica lucida	92	64	80	60	75	89	78	71	77
Conioselinum chinense	100	82	70	30	100	78	91	58	75
Heracleum lanatum	92	82	70	40	50	78	87	54	71
Stellaria sitchana	58	82	50	80	100	78	70	71	71
Honckenya peploides	42	36	70	100	100	89	39	88	68
Fragaria chiloensis	100	82	20	20	50	100	91	17	63
Ligusticum scoticum	67	73	60	20	50	78	70	42	59
Rhinanthus minor	67	73	40	10	50	67	70	29	52
Lupinus nootkatensis	58	27	70	20	100	11	43	54	43
Alnus crispa	17	18	20	40	100	78	17	42	38
Epilobium glandulosum	25	64	20	30	75	33	43	25	38
Ranunculus bongardi	17	55	20	30	0	22	35	21	27
Luzula multiflora	17	55	10	20	0	11	35	13	21
Mimulus guttatus	0	18	10	30	25	11	9	21	14
Potentilla egedii	17	0	40	20	0	0	9	25	14

NB = North Beaches; SB = South Beaches; NS = North Shore Lituya Bay; SS = South Shore Lituya Bay; C = Cenotaph Island; H-A = Harbor Cove and Anchorage Cove; OC = NB + SB; L = NS + SS + C; TOTAL = H-A + OC + L (see Figure 2).

One species is reported only at the mouth of Lituya Bay. Arabis hirsuta is known from three samples at Harbor Cove.

Species Numbers per Sample:

The mean number of species per sample (Figure 4) is greater on the outer coast than within Lituya Bay, there being an average of 23.5 species per sample along the beaches of the outer coast south of Lituya Bay and 20.1 per sample north of the Bay; whereas the sites average only 16.4 species on the north shore of the Bay and 15.5 species along the south shore of the Bay (the four sites at Cenotaph Island contain an average of 19.3 species per site). The mean for all samples is 22.7 species.

The difference in the number of species may be attributable to a variety of causes, the most obvious parameters being the age of the terrain and the size of the beach at any one sample site. It is clear that the supra-tidal meadows in Lituya Bay are only 19 years old, whereas those along the outer coast are older, at least 30 having elapsed since the last major disturbance. Furthermore, the average width of a sample site in Lituya Bay is considerably narrower than the average width along the outer coast. Finally, the substrate of sites in Lituya Bay often consists of gravels or cobbles whereas the substrate of the supra-tidal meadows along the outer coast is most commonly well sorted sand.

Community Structure:

The similarity matrix shows a remarkably narrow range of similarity values in which clustering and patterning appear. Only six similarity values exceed 0.75, and all samples form a single cluster when values 0.50 or greater are used. A smaller, single cluster, with a prominent gradient occurs with similarity values 0.60-1.00 (Figure 10).

There are recognized but two sub-communities, one with three samples, the other including all remaining samples but two. The latter sub-community contains three sub-groups. The sub-community distinction is derived from the 0.50-1.00 similarities, and the sub-group distinctions arise from the 0.60-1.00 similarities. Based upon all species with importance values 0.50 or greater in a sub-community or sub-group, the similarity between the two sub-communities is 0.16, and the similarities among the sub-groups are 0.54, 0.61, and 0.63.

Thus, this classification evolves for the Lituya Bay study area supra-tidal meadows:

Beach Community
- Supra-tidal Meadow Zone
  - Lathyrus-Lupinus Sub-community
  - Lathyrus-Elymus-Achillea Sub-community
    - Lathyrus-Achillea-Elymus Sub-group
    - Elymus-Lathyrus Sub-group
    - Elymus-Heracleum Sub-group

Because the similarity variation is so narrow, the sub-groups are characterized utilizing the samples that participate in the 0.60-1.00 plexus, but for the purposes of mapping the location of the sub-groups all samples except seven (see Figure 11) are mapped with the sub-group or sub-community

Figure 10. Plexus mapping of the supra-tidal meadow samples at similarity values 0.60-1.00. The broad lines represent similarity values in excess of 0.75, the narrow lines represent similarity values from 0.60 to 0.75. In order to display the Lathyrus-Lupinus Sub-community, dotted lines representing the 0.50 to 0.54 similarity level are included. The two sites discussed in the text as including more than the supra-tidal meadow zone appear as a separate pair at the bottom of the figure.
L-L = Lathyrus-Lupinus Sub-community
L-A-E = Lathyrus-Achillea-Elymus Sub-group
E-L = Elymus-Lathyrus Sub-group
E-H = Elymus-Heracleum Sub-group

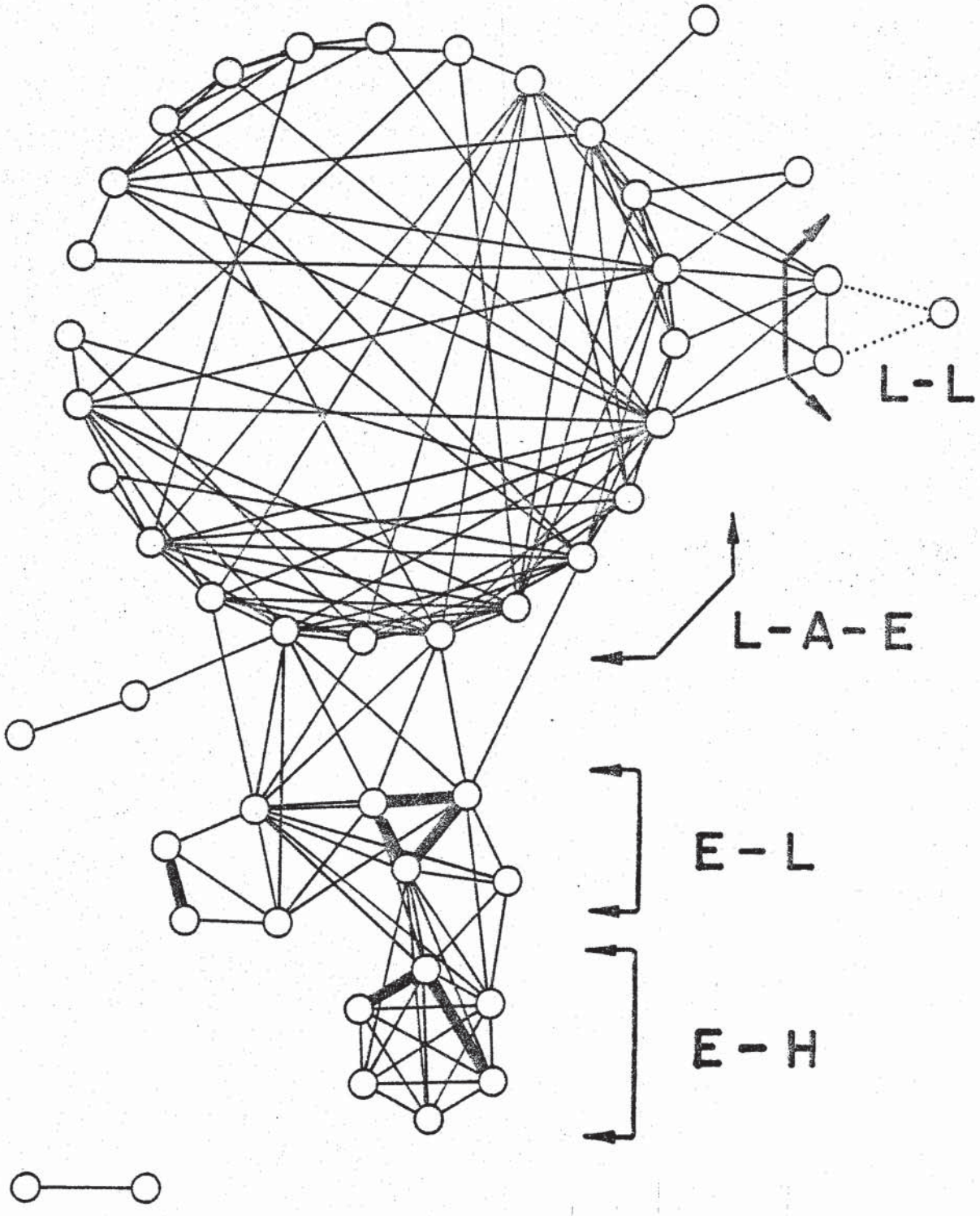
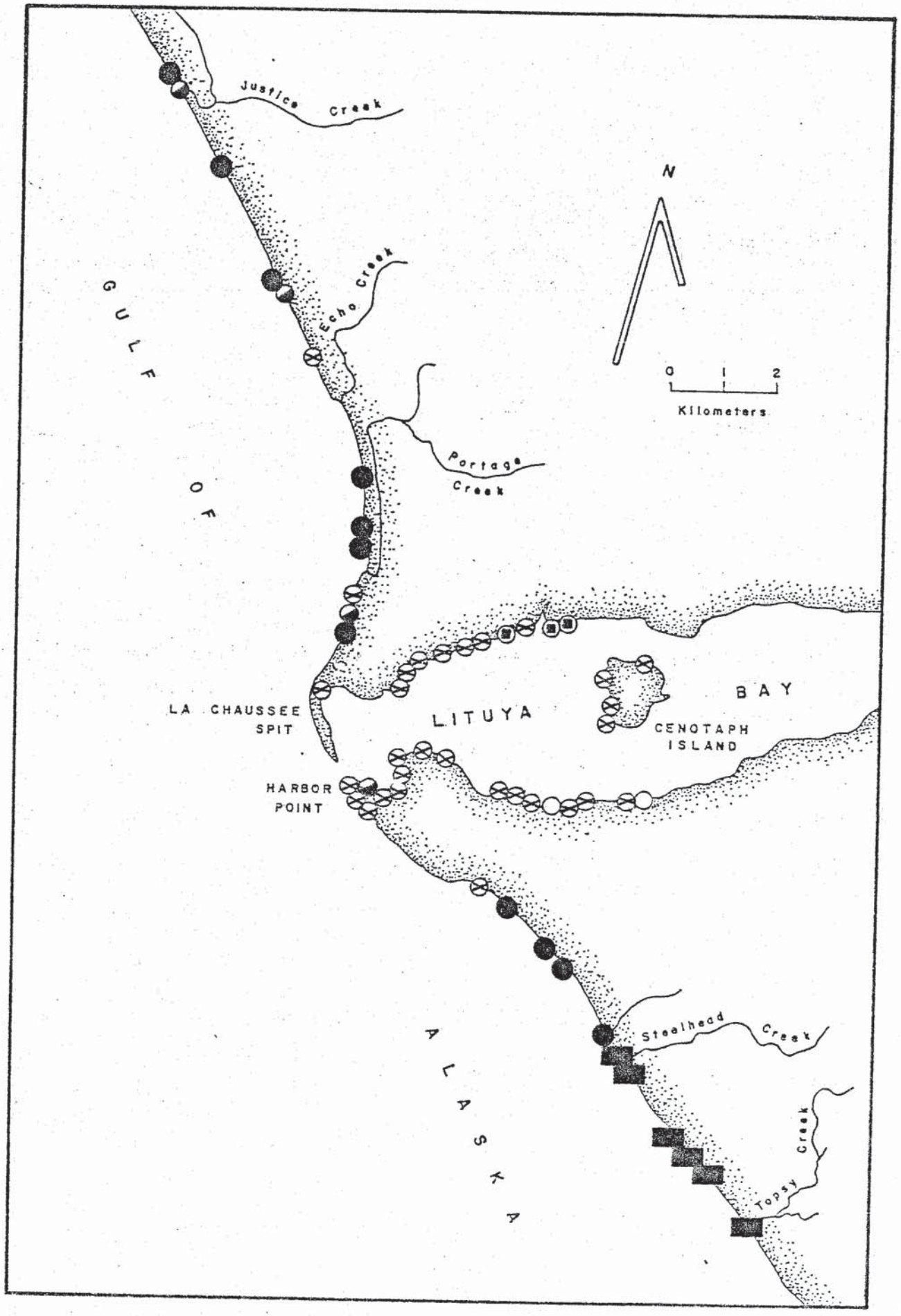

L-L
L-A-E
E-L
E-H

Figure 11. Geographical distribution of the sub-communities and sub-groups of the supra-tidal meadows of the Lituya Bay study area.

Closed circle	=	*Elymus-Lathyrus* Sub-group
Closed rectangle	=	*Elymus-Heracleum* Sub-group
Circle with "X"	=	*Lathyrus-Achillea-Elymus* Sub-group
Circle with enclosed square	=	*Lathyrus-Lupinus* Sub-community
Half closed circle	=	Classifiable equally well as *Lathyrus-Achillea-Elymus* Sub-group or *Elymus-Lathyrus* Sub-group
Open circle	=	Not classified


Justice Creek
Echo Creek
Portage Creek
GULF OF
ALASKA
N
0 1 2
Kilometers
LA CHAUSSEE SPIT
LITUYA BAY
CENOTAPH ISLAND
HARBOR POINT
Steelhead Creek
Topsy Creek

to which they are most closely related.

Sub-community distinction is granted three sites, with 15 species each, on the north shore of Lituya Bay, sites in an area where post-1958 wave succession has been very retarded, slowed perhaps by a combination of exposed landscape (to sea and storm) and very well drained substrate (my recollection is that the site is on relatively coarse outwash or till). The prominence of Lupinus nootkatensis and Epilobium latifolium, along with Equisetum arvense, E. variegatum, and Epilobium angustifolium are especially reminescent of the early successional stages throughout the Bay following the last great wave. The sub-community is titled Lathyrus-Lupinus; in addition to the two prominent legumes (I.V. = 84 and 78) five other species occur at all three sites and have importance values greater than 50: Epilobium latifolium (I.V. = 75), Galium trifidum (I.V. = 75), Rhinanthus minor (I.V. = 73), Honckenya peploides (I.V. = 70), and Hordeum brachyantherum (I.V. = 70).

The Lathyrus-Elymus-Achillea sub-community occurs throughout the study area and is best characterized by its three sub-groups (see below). A few samples are equally similar between two sub-groups. Forty-eight samples were used to characterize this sub-community. Three species predominate: beneath the physiognomically dominant Elymus arenarius (I.V. = 75) are tangles of Lathyrus maritimus (I.V. = 78) and the omnipresent (90% frequency) Achillea borealis (I.V. = 68). The average sample contains 15.5 additional species, most commonly including Festuca rubra (I.V. = 59), Angelica lucida (I.V. = 52), Conioselinum chinense (I.V. = 50), Stellaria sitchana (I.V. = 49), and Heracleum lanatum (I.V. = 1), Botrychium lunaria (two sites, I.V. = 3), and Malaxis monophylla (one site, I.V. = 1). In striking contrast with the beaches of the Dixon Harbor study area, Circaea alpina was recorded at but a single site.

The Lathyrus-Achillea-Elymus sub-group of the Lathyrus-Elymus-Achillea sub-community is the dominant sub-group on rocky substrates, and occupies 85% of the sites sampled within and at the mouth of Lituya Bay. Typically, the sites are on beaches with rather steep tidal slopes, narrow supratidal meadows, and well defined, but narrow, storm beaches - the last often being colonized by forest trees and understory plants. The youthful, nutrient poor substrates are advantageous to the legume Lathyrus maritimus (I.V. = 82), whose often vigorous growth is always prominent beneath the overstory of Elymus arenarius (I.V. = 72) and Festuca rubra (I.V. = 63). Achillea borealis (I.V. = 77) is everywhere. Other important species include Honckenya peploides (I.V. = 64; always most abundant in the lower parts of the beach, especially where not shaded), several umbellifers - Angelica lucida (I.V. = 57), Conioselinum chinense (I.V. = 55), Ligusticum scoticum (I.V. = 49), and Heracleum lanatum (I.V. = 40), as well as Epilobium angustifolium (I.V. = 50; in 68% of the samples, but seldom especially abundant and showy), and the whispy Stellaria sitchana (I.V. = 50). The samples average 17.3 species, a fairly large number for the limited breadth of the beaches. However, of the 56 species recorded from the 22 samples, a remarkable 71% occur in less than 33% of the samples. This reflects, I suggest, that youthfulness of the sites, and the opportunist abilities of many of the species of beach meadow plants.

The Elymus-Lathyrus sub-group of the Lathyrus-Elymus-Achillea sub-community is wide-spread and common on the sandy beaches of the outer coast, occupying

at least 71% of the sandy beach sites north of Steelhead Creek. Elymus arenarius (I.V. = 86) is always present, and often dense and vigorous (its average abundance is 4.25). Nearly equal in importance, often forming a solid understory, is Lathyrus maritimus (I.V. = 84). Achillea borealis (I.V. = 77), Festuca rubra (I.V. = 76), and Fragaria chiloensis (I.V. = 75) are likewise always present, the last most abundant at the back part of the beach on well drained sands. Isolated seedlings and saplings, and occasional copses, of Picea sitchensis (I.V. = 66) are always present. Fifteen additional herb species occur at the average site (mean richness is 20.9 species). Of the 44 species recorded at the sites of this sub-group, 43% occur at less than 1/3 of the sites.

The Elymus-Heracleum sub-group of the Lathyrus-Elymus-Achillea sub-community is not well named, for three additional species are nearly as important as the Heracleum. This sub-group is reported only from between Steelhead and Topsy Creeks, occupying all 6 sites sampled there. The mean number of species per sample is exceptionally high, 30.4. Only 24% of the 54 species recorded from the sites occur in less than 1/3 of the samples.

Elymus arenarius (I.V. = 92) is exceptionally vigorous (mean abundance is 5.0), as is Heracleum lanatum (I.V. = 79; mean abundance is 3.5). Ten additional species grow in every sample: Achillea borealis (I.V. = 77), Festuca rubra (I.V. = 77), Lathyrus maritimus (I.V. = 75), Conioselinum chinense (I.V. = 68), Stellaria sitchana (I.V. = 68), Epilobium glandulosum (I.V. = 67), Fritillaria camschatcensis (I.V. = 67), Ligusticum scoticum (I.V. = 67), Platanthera dilatata (I.V. = 67), and Ranunculus bongardi (I.V. = 67). These species, plus the additional 18 species (almost exclusively herbs) at each site, provide a rich, and often colorful understory to the tall beach rye grass.

I cannot hypothesize the environmental factors causing the differences between these last two sub-groups, both of which are developed on sandy beaches of the outer coast.

The principal differences between the three sub-groups are:

a) Rocky sites have fewer species (17.3 vs. 20.9 and 30.4),
b) Rocky sites have fewer important (I.V. greater than 50) species (7 vs. 14 and 17),
c) Honckenya peploides is important at rocky sites (I.V. = 64), but not sandy sites (I.V. = 29 and 22) of the supra-tidal meadow zone,
d) The forest species Picea sitchensis and Maianthemum dilatatum are important only at sandy sites,
e) Six other species of diverse morphology are significantly more important at sandy sites than at rocky sites,
f) Elymus arenarius, one of the three most important species, is much less abundant at rocky sites than at sandy sites (2.95 vs. 4.25 and 5.0), and
g) The other two most important species are roughly equivalent in abundance at rocky and sandy sites (Lathyrus maritimus - 3.18 vs. 3.25 and 3.17).

One additional sub-group could be recognized, consisting of two samples from the south shore of Lituya Bay. Seven species have importance values exceeding 70: Epilobium latifolium (I.V. = 75), Equisetum arvense (I.V.

= 75), Honckenya peploides (I.V. = 75), Hordeum brachyantherum (I.V. = 75), Argostis exarata (I.V. = 71), Mimulus guttatus (I.V. = 71), and Lathyrus maritimus (I.V. = 71). Both samples had 19 species. At both sites the supra-tidal meadow zone was essentially non-existent due to geomorphological configuration. Vigorous forest growth from the uplands abutted almost directly upon tide influenced shore; at both sites there was a minor erosion scarp rather than a depositional beach at the elevation normally occupied by supra-tidal meadows. Thus, perhaps due to imprecise reading of the geomorphology by the sampler, the samples contain bottom and meadow zone species along with upland species such as Salix sitchensis and Alnus crispa. Notable records at these sites are Elymus hirsutus and "Poa vivipara." These sites are not included as a sub-group in the classification of the supra-tidal meadows, for they apparently include data from more than just the meadow zone.

Geography of Sub-groups and Sub-communities:

The sub-groups of the supra-tidal meadow are strongly geographically patterned (Figure 11).

The Lathyrus-Lupinus sub-community occurs only on the north shore of Lituya Bay at three sites in close proximity. Vegetationally, the sites are among the most youthful along the Bay within the area sampled.

The Elymus-Heracleum sub-group is known only from Steelhead Creek to Topsy Creek, it being the only sub-group sampled along that 5 km stretch of beach.

The Elymus-Lathyrus sub-group, which is closely related to the Elymus-Heracleum sub-group, is likewise restricted to outer coast beaches, almost exclusively on sandy substrates. This sub-group extends from Steelhead Creek to Justice Creek, though essentially absent from beaches of morainic origin near the mouth of Lituya Bay.

Nearly all samples from within Lituya Bay belong to the sub-group Lathyrus-Achillea-Elymus, as do samples from Harbor Point, and samples from Lituya Bay moraine or outwash deposits on the outer coast.

Several samples are equally classified as Lathyrus-Achillea-Elymus or Elymus-Lathyrus. These are five outer coast samples, scattered from Harbor Point north to Justice Creek.

Thus, there is clear distinction between the supra-tidal meadows on sandy substrates (restricted to the outer coast) and those on rocky substrates (within Lituya Bay, and on the outer coast on moraines and outwash). Likewise, on sandy substrates south of Lituya Bay there are only Elymus-Lathyrus and Elymus-Heracleum sub-groups, with the most distinctive (Elymus-Heracleum) being the farthest from the Bay. However, on beaches north of Lituya Bay there is a mixture of Elymus-Lathyrus (mostly) and Lathyrus-Achillea-Elymus (some). This mixture is not readily explainable.

Comparison with Dixon Harbor Study Area:

The supra-tidal meadows of this study area may be compared with the Middle

and Top Zones of the Beach Community determined for the Dixon Harbor study area (Worley 1975).

In this study two sub-communities have been recognized, one with three sub-groups. At the Dixon Harbor study area four sub-communities, two in each zone, were recognized. A similarity matrix (Table 4) utilizing all nine of the sub-communities and sub-groups was generated based upon the importance values of the eight most important vascular plant species in each assemblage. Thus, each sub-community or sub-group was considered to contain but eight species, the remaining species were ignored; in all cases, except when a sub-group or sub-community had but a very few constituent samples, this procedure incorporated all vascular plant species with importance values above 0.50.

Inspection of the matrix shows that the mean similarity among the four sub-communities of the Dixon Harbor study area is 0.27, and the similarity between the Lituya Bay sub-communities is 0.16. However, the mean similarity among the three sub-groups of the Lituya Bay study area is 0.59, with the greatest being 0.63. The maximum sub-group similarity with its sub-community is 0.78. Consequently, if any of the sub-communities of the sub-communities of the Dixon Harbor study area are to be considered congruent with any of the sub-groups or sub-communities of the Lituya Bay study area (and conversely), then the similarity should exceed 0.60 (preferably 0.80 or greater), otherwise each sub-group or sub-community should retain its identity.

Since such high similarities do not exist; since none of the similarities are sufficiently great to designate any of the sub-communities of the Dixon Harbor area as a sub-unit of any Lituya Bay category, or conversely; and since none of the inter-sample similarities is great enough to permit regrouping as was feasible in the Bottom Zone classification, the following combined classification scheme for the supra-tidal meadows from Torch Bay to the Fairweather Glacier is proposed:

Beach Community
- Supra-tidal Meadows
  - Lathyrus-Lupinus Sub-community
  - Lathyrus-Elymus-Achillea Sub-community
    - Lathyrus-Achillea-Elymus Sub-group
    - Elymus-Lathyrus Sub-group
    - Elymus-Heracleum Sub-group
  - Lathyrus-Elymus Sub-community
  - Elymus-Galium Sub-community
  - Elymus-Calamagrostis Sub-community
  - Heracleum-Circaea-Calamagrostis-Rhytidiadelphus Sub-community

The highest similarities between the study areas are between EC* and EH (0.62, see Table 4) and EC and LEA (0.57, see Table 4). The most significant difference between EC and the others is that it has fewer species per sample (13.8 vs. 30.4 and 18.5), and the prominent grass Calamagrostis canadensis (I.V. = 90) is notably scarce or absent in the Lituya Bay study area, replaced by Festuca rubra (I.V. = 77 and 59 respectively). Because the prominence of Calamagrostis, and other important species occurring in

* Sub-group and sub-community abbreviations are explained in Table 4.

	LEA	LL	LAE	EH	EL	HCCR	EC	EG
LL	.16							
LAE	.76	.38						
EH	.78	.25	.61					
EL	.62	.33	.54	.63				
HCCR	.30	.12	.16	.29	.11			
EC	.57	.12	.44	.62	.49	.27		
EG	.31	0	.27	.33	.19	.17	.27	
LE	.51	.32	.51	.44	.40	0	.36	.52

LEA = Lathyrus-Elymus-Achillea Sub-community

LL = Lathyrus-Lupinus Sub-community

LAE = Lathyrus-Achillea-Elymus Sub-group

EH = Elymus-Heracleum Sub-group

EL = Elymus-Lathyrus Sub-group

HCCR = Heracleum-Circaea-Calamagrostis-Rhytidiadelphus Sub-community

EC = Elymus-Calamagrostis Sub-community

EG = Elymus-Galium Sub-community

LE = Lathyrus-Elymus Sub-community

Table 4. Similarity matrix of the sub-groups and sub-communities of the supra-tidal meadows of the Dixon Harbor study area and the Lituya Bay study area. The dashed lines separate the two study areas and sub-groups from sub-communities.

only one of the sub-units, and because of the vast difference in richness (120% greater at EH sites), EH and EC are not combined, albeit their similarity is unmistakeable. For similar reasons it is not appropriate to combine EC and LEA.

The EC sub-community occurs on and behind the high dunes of Astrolabe Beach (Worley 1975), a habitat not at all dissimilar with the sites of the EH sub-group (which occur, at least, between Steelhead and Topsy Creeks) in substrate, beach breadth, exposure to the sea, and elevation. Since a broader portion of the beach is included in the EH samples, it is reasonable to combine the Middle and Top zone sub-communities from Astrolabe Beach for comparison with EH. Doing so does not enhance the similarity.

Physiognomically, EC and EH are quite similar, with the tall graminoid dominance of Elymus and Calamagrostis or Festuca broken by the coarse Heracleum lanatum, and a thick understory of Achillea borealis, Conioselinum chinense, tangles of Lathyrus maritimus, and a variety of broad-leaf herbs. The colorful flowers of Epilobium angustifolium in EC are paralleled by a variety of richly flowered herbs in EH, especially Fritillaria camschatcensis, Platanthera dilitata, along with Epilobium glandulosum, Ranunculus bongardi and others.

The other similarity of note is between EC and LEA. Both sub-communities have as particularly important species Elymus arenarius, Lathyrus maritimus, and Achillea borealis; however, there is the notable prominence of Calamagrostis canadensis in EC (only somewhat approximated by Festuca rubra in LEA), as well as Heracleum lanatum and other species.

Since LEA is the generalized sub-community at the Lituya Bay study area, incorporating sites both from within the Bay and along the outer coast, one can draw little from the similarity between EC and LEA (as well as the 0.51 similarity between LE and LEA) except to again emphasize the need for smaller sample plot sizes and/or additional zonal differentiation at the Lituya Bay study area.

The sub-communities HCCR and LL are clearly individually distinct, especially because of their lack of Elymus arenarius, and the respective physiognomic prominence of Calamagrostis canadensis and Athyrium filix-femina (for HCCR) and Lupinus nootkatensis, Epilobium latifolium, and Potentilla egedii (in LL).

By contrast, the three sub-groups of the Lituya Bay area and the three other sub-communities of the Dixon Harbor area have prominent Elymus arenarius. In four of the six assemblages Elymus is the most important plant (I.V.'s from 86 to 99), once it is second in importance (I.V. = 80), and once third (I.V. = 72).

LE and EG are distinguished by very low richness, being in the middle zone (cf. Worley 1975), and being principally dominated by but two species, Lathyrus maritimus and Elymus arenarius for LE, Elymus arenarius and Galium aparine for EG.

EC, EH, LAE, and EL have greater richness (13.8, 30.4, 17.3, and 20.9 respectively), include the upper reaches of the supra-tidal meadows (and

sometimes the entire supra-tidal area), and all have as important and visually prominent species Elymus arenarius, Lathyrus maritimus, and Achillea borealis. EC is quickly identified by the prominence of Calamagrostis canadensis, which is absent or scarce in the others, and by the absences of Festuca rubra as well as the high frequency of Trientalis europaea. LAE only infrequently has prominent Heracleum lanatum, and has a firly high frequency 86% of Honckenya peploides. EH and EL are quite similar (0.63), differing primarily in their smaller plants. EL seems to occupy drier sites, and has notable abundances of Fragaria chiloensis, Rhinanthus minor, and Castilleja unalaschcensis, whereas the understory of EH contains some 10 more species per site, many of which are larger and more coarse.

A comparison among the eight most important species of a sub-group or sub-community (a total of 33 species in all) yields (particularly notable species are identified by an asterisk):

a) eight supra-tidal meadow species notably scarce or absent at the Lituya Bay study area, but diagnostically important and/or abundant at the Dixon Harbor study area:
   - Calamagrostis canadensis*
   - Trientalis europaea
   - Circaea alpina*
   - Deschampsia beringensis*
   - Rorippa islandica
   - Galium aparine
   - Athyrium filix-femina
   - Juncus arcticus

b) at least nine supra-tidal meadow species notably scarce or absent at the Dixon Harbor study area, but diagnostically important and/or abundant at the Lituya Bay study area:
   - Festuca rubra*
   - Rhinanthus minor
   - Fragaria chiloensis*
   - Castilleja unalaschcensis
   - Epilobium glandulosum
   - Platanthera dilatata
   - Ranunculus bongardi
   - Lupinus nootkatensis*
   - Epilobium latifolium*

c) and eleven supra-tidal meadow species diagnostically important and/or abundant at both study areas:
   - Elymus arenarius*
   - Lathyrus maritimus*
   - Achillea borealis*
   - Heracleum lanatum
   - Honckenya peploides
   - Angelica lucida
   - Conioselinum chinense
   - Epilobium angustifolium
   - Fritillaria camschatcensis
   - Stellaria sitchana
   - Ligusticum scoticum

The most significant of these are the differences in the sub-dominant grasses, Festuca rubra vs. Calamagrostis canadensis and Deschampsia

beringensis. The appearance of "forest proximity" species (e.g. Trientalis europaea, Athyrium filix-femina, and perhaps Circaea alpina) in the Dixon area reflect more mature and enclosed sites than the species of stable sandy substrates (such as Fragaria chiloensis, Castilleja unalaschcensis, and perhaps others) along the outer coast near Lituya Bay.

Except for the differences in sub-dominant grasses this comparison of important species supports the viewpoint that there is overall similarity among the supra-tidal meadows rather than strong distinctive differentiation. Likewise, one must conclude that generalist species are more important biologically in the supra-tidal meadows than specialists.

The supra-tidal meadow sub-communities at the heads of Thistle Cove and Torch Bay (HCCR and EG) are not at all similar with any sub-community or sub-group at the Lituya Bay study area. The mean similarity between HCCR and EG vs. LLG, EH, EL, and LAE is only 0.18. This decided dissimilarity, even with sites within Lituya Bay where there are very similar substrates, is likely due to the youthfulness of the Lituya Bay beaches and the more enclosed climatic settings at Torch Bay and Thistle Cove.

The sandy substrate beach sub-communities (EC and LE) from Boussole Beach, Astrolabe Beach, and Dixon Harbor are reasonably similar with the sub-groups (EL and EH) from the outer coast in the Lituya Bay area (mean similarity is 0.49).

Curiously, the sub-group from rocky substrates within Lituya Bay and at Harbor Point (LAE) has nearly as high a similarity with EC and LE, 0.48. Three factors may contribute to this similarity of habitat:

a) both habitats are youthful, the Lituya Bay sites because of the denuding wave of 1958, the sandy sites because of rejuvenation due to sand mobility as a result of depositional activity and/or shoreline uplift;
b) there may be a similarity of climatic setting; and
c) there may be a similarity with respect to sea vigor.

Factor Analysis:

As a class project in the Geography Department of the University of Vermont John Hammer performed bivariate correlations, factor analysis, and multiple regression analysis among five species (Elymus arenarius, Honckenya peploides, Lathyrus maritimus, Achillea borealis, Fragaria chiloensis) and four factors (species richness, beach width, latitude, and longitude) for the supra-tidal meadows of the Beach Community. Data for the species consisted of abundance values; thus the 6 most northwesterly sites sampled (those northwestward of Echo Creek) were not included in this analysis as they lacked abundance data. Beach width estimates included field measurements and recollections; the estimates are accurate within 20 - 30%.

Bivariate correlation analysis among all nine variables provided six weak, but biologically reasonable correlations (latitude and longitude have been combined here into northwestness and southeastness):

	Correlation Coefficient
Wider beaches have more species	.51
Species numbers decrease to the northwest	.45
Beach width decreases to the northwest	.42

Lathyrus abundance is proportional with Achillea abundance	.40
Honckenya abundance is negatively proportional with both Elymus and Fragaria abundance	.37
Fragaria is more abundant on wider beaches	.35

All the above statements correspond with our impressions concerning the beaches (recalling that the Honckenya as included here refers only to supra-tidal meadows, and does not include the bottom zone -- thus, the more distinctive the meadow (i.e. the more Elymus, or the more the Fragaria habitat) the less terrain available for Honckenya).

Together, the first three correlations lead to ambiguity. However, considering the relatively short biogeographical distance from the most SE site to the most NW site, it appears more likely that increased species richness is caused by the larger available space and more diverse habitats in wider beaches than by some NW - SE biogeographical factor. The Fragaria habitat seems relatively specialized, and seems to involve a combination of well drained sandy substrates, at a distance from the active beach, where there is little tree colonization. Thus, it is not surprising that Fragaria is more abundant in wider beaches.

Lathyrus, as mentioned elsewhere in this report, seems most abundant and frequent in the transition between the bottom zone and the supra-tidal meadows. This analysis shows that Achillea is most abundant frequently in that same transitional location. It is possible, therefore, that there is indeed a "Middle Zone" between the bottom zone and the supra-tidal meadows at the Lituya Bay study area just as was reported for the Dixon Harbor study area. If a real feature of the beach community within the Lituya Bay study area, the middle zone apparently is not distinctive and/or extensive.

Factor analysis (utilizing multiple correlation coefficients and orthogonal rotation) of the nine variables yielded three principal factors which account for 53% of the total variance. Factor 1, (which accounts for 28% of the total variance) consists of the variables latitude, longitude, species richness and beach width, Elymus arenarius, Honckenya peploides and Fragaria chiloensis. Factor 3 (8% of the total variance) has but two variables, Lathyrus maritimus and Achillea borealis.

Therefore, 53% of the variation in data contributed by nine variables at 51 sites can be accounted for by three factors in the multi-dimensional factor space. Factor 1 states that among the variables considered the combination of geographical position, beach width and number of species provides the most distinctive characteristics of the supra-tidal meadows of the beach

community. (The geographical location is strongly, but not exclusively, weighted by the relative position of Lituya Bay and the outer coast).

The next most prominent factor characterizing the meadows consists of the combination of beach width and three species. This factor highlights a gradient among the sites (a mapping of which shows no significant geographical patterning) from narrow beaches with little Elymus arenarius and Fragaria chiloensis, but relatively significant amounts of Honckenya peploides in the supra-tidal meadows to wide beaches with large amounts of Elymus and Fragaria and essentially no Honckenya.

The third most prominent character of the meadows is the combined abundances of Lathyrus maritimus and Achillea borealis. This, as noted elsewhere in the report, may indicate the presence of a Middle Zone of the Beach Community, a zone unsampled in this study.

The third analysis completed was a multiple regression of all variables, considering species richness per site as the dependent variable. F test (a weak test of significance) permitted a four-step multiple regression, but the substantially more selective t test allowed only a two-step regression. The two statistically significant variables, beach width and longitude, account for only 37% of the species richness variation. The regression equation is:

$$\#\text{ of species} = 0.09\,(\text{beach width in meters}) + 1.76\,(\text{longitude}) + 9.87$$

As a predictive model, this equation is not very satisfying. The value of the equation rests in the indication that there are other significant variables accounting for the variation which have not been treated. The most likely variables of significance excluded from these analyses are beach substrate composition, beach fresh water hydrology (presence or absence of streams or seeps, and/or drainage characteristics of substrate), and age of site.

Afterword:

In the Dixon Harbor study area, beaches were for the most part very narrow, with well defined vertical zonation; wheras in the Lituya Bay study area the outer coast beaches were often very broad, with vertical zonation masked in our data, often by their breadth, and in places by the erosion caused by the exposure to the open ocean of the recently uplifted sand sediments.

A more precise understanding of species and community variation in the Lituya Bay study area would require smaller sampling units, recording distance from and height above the sea (perhaps annotated with respect to severity of the sea), substrate composition, and age of terrain.

One could also determine the complete similarity matrix of all individual samples already recorded from both study areas, rather than comparing subgroups and sub-communities, as done here. In addition to requiring time and facilities not currently available, this methodology would not overcome the masking of community variation, and the concomitant result of poorly defined clusters within the similarity matrix, caused by the large sample plot size in the Lituya Bay study area.

The Beach Community

Zonal Comparisons:

Comparison between the sub-community/sub-group distinctions and geography of the bottom and supra-tidal meadow zones of the beach community in the Lituya Bay study area reveals three general conclusions:

a) at various levels of similarity both zones show broad scale differentiation between Lituya Bay shores and outer coast shores;
b) near the mouth of Lituya Bay the bottom zone vegetation is like the outer coast bottom zone vegetation, whereas the supra-tidal meadows correspond with Lituya Bay meadows; and
c) there is no apparent site-by-site correlation between bottom zone sub-communities and/or sub-groups.

Factors affecting a) must include salinity, suspended load of sea and bay water, wave strength, substrate type, and age of site. However, in order to account for b) one can hypothesize that the bottom zone at the mouth of Lituya Bay has wave conditions akin to the outer coast, being very vigorous during storms, whereas the supra-tidal meadow zone has the same rocky substrate as do sites elsewhere within the Bay.

Conclusion c) demonstrates that at each site there is apparently little interaction among the vegetation, and perhaps the respective ecosystems as well, of the two zones; each zone responding to separate predominant environmental factors. Thus, the zonal distinctions are justified, demarking separate, though adjacent, ecological entities.

Beach Dominants:

Three vascular plant species, Honckenya peploides, Lathyrus maritimus, and Elymus arenarius, dominate the zones of the beach community in the study area by:

a) often contributing considerable biomass in one or both zones,
b) often demarking zones, and
c) often being physiognomically prominent.

One or more of the three species is in the title of all but one (a sub-bottom sub-community) of the sub-communities and sub-groups.

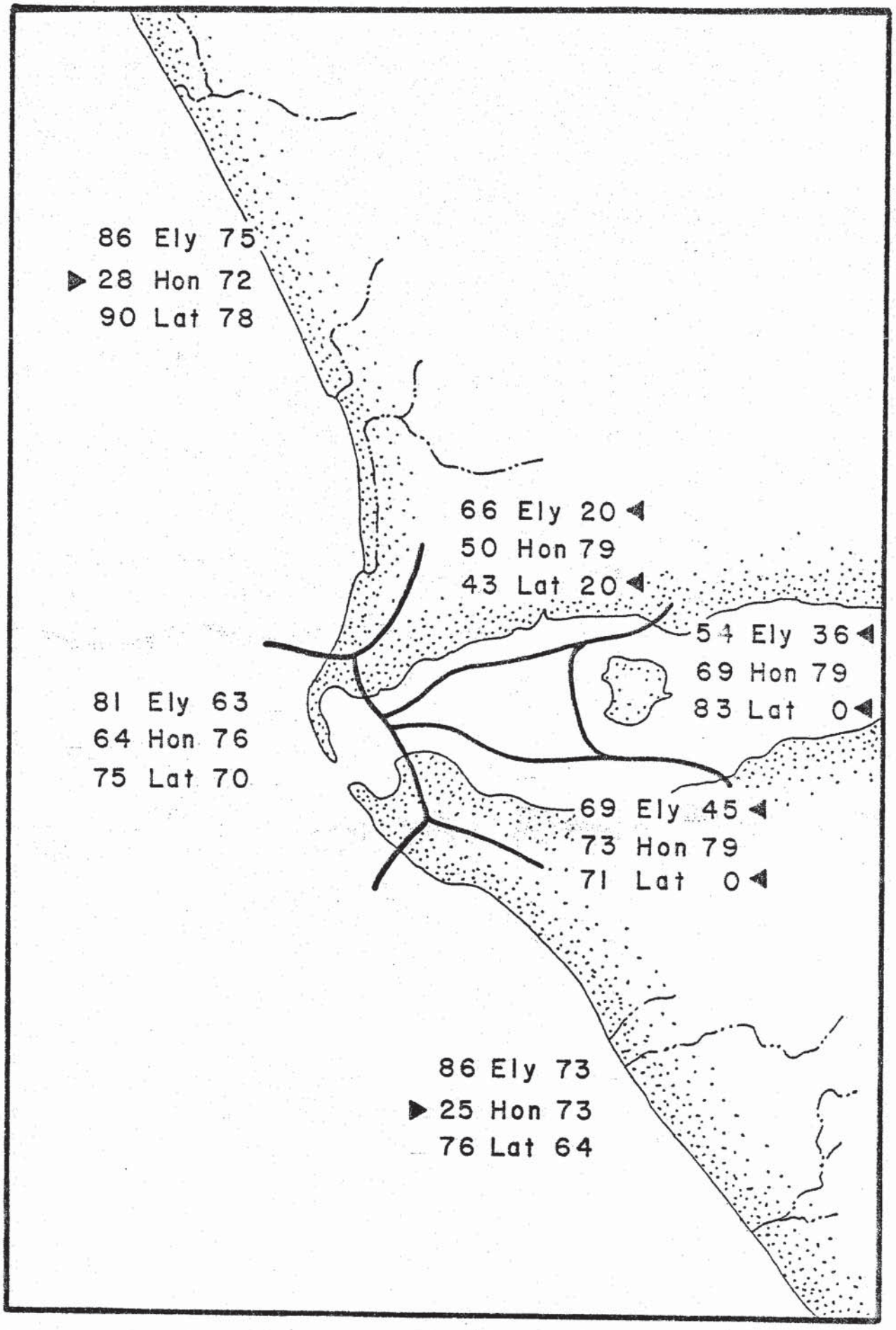
A comparison of the distribution and abundance of these three species in both zones (Table 5) provides distinctive patterns (Figure 12). Along the outer coast, including the mouth of Lituya Bay, all three species are important in the bottom zone; however, within Lituya Bay only Honckenya has high importance values in the bottom zone. Within Lituya Bay and at the mouth of the Bay, all three species are important in the supra-tidal meadows; however, along the outer coast (exclusive of the mouth of the Bay) Honckenya has low importance values while both Elymus and Lathyrus have high values.

One interpretation of these data is that when sampling along the outer coast the samplers designated the division between the bottom zone and the supra-tidal meadow zone to the upper limit of Honckenya, whereas within Lituya Bay the zonal division was distinguished at the lower limit of Elymus and Lathyrus. Since Worley did most of the sampling within the Bay, and Streveler and Daniels did most of the sampling along the outer coast, such

Table 5. Frequency, abundance and importance of Elymus arenarius, Honckenya peploides, and Lathyrus maritimus in the supra-tidal meadow zone (STM) and the bottom zone (BZ) for various geographical regions (see Table 3 for explanation of symbols) of the study area. "Sites" is number of samples including the zone per geographical region. (next page)

		NB	SB	NS	SS	C	H-A	OC	L	TOTAL
Sites	STM	12	11	10	10	4	9	23	24	56
Sites	BZ	10	10	10	10	4	7	20	24	51
					% Frequency					
Elymus	STM	100	100	90	90	75	100	100	88	95
Elymus	BZ	100	100	30	60	50	86	100	46	73
Honckenya	STM	42	36	70	100	100	89	39	88	68
Honckenya	BZ	90	100	100	100	100	100	95	100	98
Lathyrus	STM	100	100	100	90	100	89	100	96	96
Lathyrus	BZ	100	90	30	0	0	86	95	13	55
					Mean Abundance					
Elymus	STM	4.3	4.3	2.5	2.9	2.0	3.7	4.3	2.6	3.5
Elymus	BZ	3.0	2.8	0.6	1.8	1.3	2.4	2.9	1.2	1.9
Honckenya	STM	0.8	0.8	1.8	2.8	2.3	2.3	0.8	2.3	1.7
Honckenya	BZ	3.2	2.7	3.5	3.5	3.5	3.1	3.0	3.5	3.3
Lathyrus	STM	4.8	3.1	3.4	3.1	4.0	3.6	4.0	3.4	3.7
Lathyrus	BZ	3.4	2.3	0.6	0	0	3.2	2.9	0.3	1.7
					Importance Value					
Elymus	STM	86	86	66	69	54	81	86	66	77
Elymus	BZ	75	73	20	45	36	63	74	33	52
Honckenya	STM	28	25	50	73	69	64	26	63	48
Honckenya	BZ	72	73	79	79	79	76	73	79	77
Lathyrus	STM	90	76	43	71	83	75	83	76	79
Lathyrus	BZ	78	64	20	0	0	70	72	9	42

Figure 12. Importance values of Elymus arenarius (Ely), Honckenya peploides (Hon), and Lathyrus maritimus (Lat) in different geographical regions of the study area for the supra-tidal meadows (numbers on left) and bottom zone (numbers on right) of the beach community. Certain key values (see text) are highlighted. (next page)


86 Ely 75
28 Hon 72
90 Lat 78
66 Ely 20
50 Hon 79
43 Lat 20
54 Ely 36
69 Hon 79
83 Lat 0
81 Ely 63
64 Hon 76
75 Lat 70
69 Ely 45
73 Hon 79
71 Lat 0
86 Ely 73
25 Hon 73
76 Lat 64

a bias is possible.

Overall, for both zones, Elymus and Lathyrus have high importance values (mean I.V.'s of 78 and 76 respectively) along the outer coast including the mouth of Lituya Bay, but much lower importance values within the Bay (mean I.V.'s of 48 and 37 respectively). Honckenya, on the other hand has greater importance within Lituya Bay and the mouth of the Bay, than along the outer coast away from the Bay (mean I.V.'s of 71 and 50 respectively).

I suggest that substrate, age of terrain, successional secuence, and sea vigor play important roles here. Within Lituya Bay depositional shores are limited in extent, often thin veneers, and usually fairly steep; similarly, the wave and tide eroded shores of moraine materials are typically fairly steep. Also, storm beaches are youthful and small, having had but 19 years for development following the last wave. Consequently, beach zones tend to be quite narrow. Furthermore, circumstances are such that aggressive woody plant growth, especially by deciduous trees, extends to, and sometimes on, the storm beaches. By contrast, the outer coast beaches commonly include elevated sand deposits that are essentially level and often very broad. The height of the vegetated surface is sufficiently low to have direct sea influence, but sufficiently high to become ultimately forested. For undetermined reasons the forestation on these deposits is very much slower than in the wave denuded zone of Lituya Bay, and does not include deciduous trees - the initial colonization being solely by Picea sitchensis. It would appear that the fortuitous height of the beach deposits of the outer coast, in concert with the slow succession by woody plants, provides an abnormally favorable setting for supra-tidal meadow development - hence the prominence of Elymus and Lathyrus (and the many, less important species). Within the Bay, on the other hand, there has been little time for depositional beaches to replace the steep shores, thus restricting the development of extensive meadows.

Conversely, Honckenya on the sandy beaches of the outer coast must contend with very active substrates, both depositional and erosional. The more stable bottom zone within the Bay thus permits more vigorous Honckenya growth.

Lituya Bay Forest "Face"

Introduction:

Forest succession at Lituya Bay following denudation by the 1958 wave has been exceedingly rapid (cf. Lawrence 1976). Except for an area on the north shore north of Cenotaph Island, and isolated patches here and there, most of the low elevation, wave scoured terrain east of the neck of the Bay (the "neck" of Lituya Bay as used here is determined by the points of land demarking the easternmost extent of Anchorage and Harbor Coves), in the 19 years since the wave, has attained closed, or nearly closed, canopy woodlands of tall shrubs and/or trees ranging from 1.5 to 12 meters in height.

No vegetation samples were taken from within these woodlands, but in the course of sampling the Beach Community between the woodlands and the sea, the character of the face of the forest was documented. This documentation provides a partial characterization of the forest/beach interface, an

ecotone likely of major ecological significance, and an initial look at sea-margin forest edge succession in an environmental and historical setting other than isostatic-eustatic adjustments and depositional-erosional dynamics.

The forest face was defined to be the edge of the woodland community (denoted by trees or tall shrubs, at least 1.5 meters in height) as it abuts the landward edge of the herbaceous meadow of the Beach Community. In most locations there was a very distinctive interface between the herbaceous and woody plant communities, but occasionally the trees were scattered or clustered with open areas among them. Where the trees were scattered, or where one could see well back into the wooded plant community, only those trees which bordered the landward side of the herbaceous beach community were included in the data.

At each station, the abundance of each woody species as it contributed to the face of the woody plant community was determined *a la* Worley (1975).

Heights of the trees of the forest face were recorded by noting the tallest and shortest canopy trees. Thus, a height record might be 4-11 meters, indicating the canopy varied in height from 4-11 meters. Heights were estimated to the nearest meter with a presumed accuracy of 10-15%.

Ten samples on the northwestward shore, eleven samples on the southwestward shore, and two on Cenotaph Island comprise the sampling (Figure 13). Note that no samples were taken east of Cenotaph Island and there are no samples from Anchorage Cove or Harbor Cove, there being no well defined forest face behind the beach at those coves.

Species Richness:

A total of six tall woody plant species occur in the forest face: *Alnus crispa*, *Alnus oregona*, *Picea sitchensis*, *Populus trichocarpa*, *Salix sitchensis*, and *Tsuga heterophylla*. No sites had all six species at the forest face; however, three sites had five species. Figure 13a shows the geographical variation in species richness; the south shore of Lituya Bay contains 19% more species on the average than the north shore - 3.8 species per sample vs. 3.2 species per sample. The two samples from Cenotaph Island both had four species. The westernmost five samples, three on the north side, and two on the south side, have fewer species (2.6) than do the remaining sites in Lituya Bay, which average 3.8 species per site (46% more). Thus, in the main body of Lituya Bay, including Cenotaph Island, there is an average of about four tree species per site, only slightly lower on the north shore; whereas approaching the neck of Lituya Bay, the number of tree species reduces to less than three per site (this trend is opposite that of the Beach Community).

Distribution of Individual Species:

Alnus crispa is found at nearly all stations except those at the neck of Lituya Bay (Figure 13b). On the north shore of Lituya Bay, it has an abundance value averaging 2.2, whereas on the south shore of Lituya Bay the abundance value averages 2.7. Similarly there is a tendency for the abundance of *Alnus crispa* to increase with distance from the mouth of the Bay.

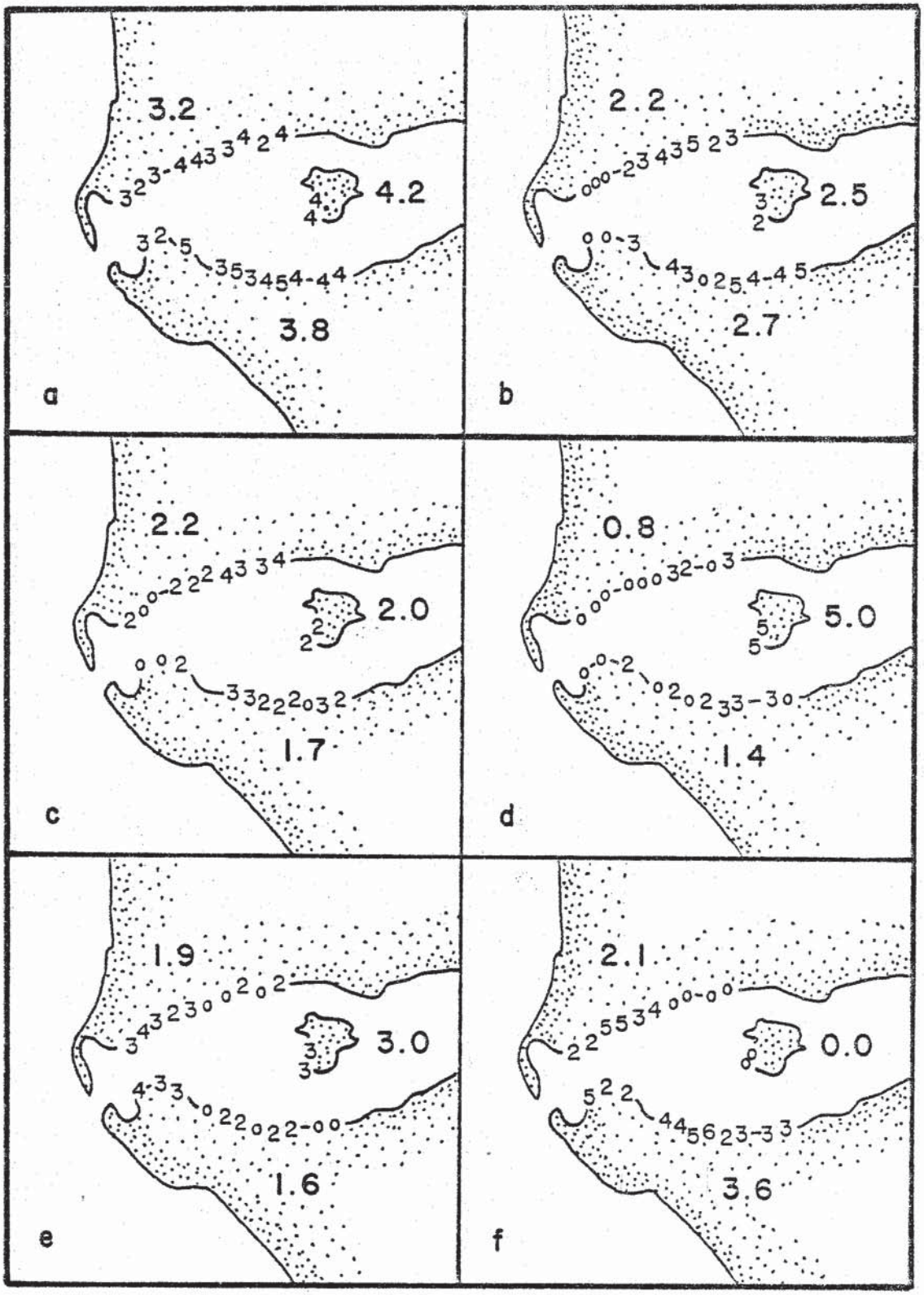
Figure 13. Richness and species abundance of "forest face" trees at Lituya Bay. The larger numerals are averages for the north shore samples, the Cenotaph Island samples, and the south shore samples respectively.

a) The small numerals are the number of tree species recorded in the forest face per sample.

b) - f) The small numerals are the abundance value (see text) for each species at each sample:

b) Alnus crispa
c) Salix sitchensis
d) Populus trichocarpa
e) Picea sitchensis
f) Alnus oregona

(next page)


3.2
4.2
3.8
a
2.2
2.5
2.7
b
2.2
2.0
1.7
c
0.8
5.0
1.4
d
1.9
3.0
1.6
e
2.1
0.0
3.6
f

Salix sitchensis, like Alnus crispa, is least common near the mouth of Lituya Bay (Figure 13c). But, unlike Alnus crispa, it is more abundant on the north shore, having a mean of abundance of 2.2 versus the south shore mean abundance of only 1.7. Both species are present at low abundances on Cenotaph Island, at the two sites sampled.

Populus trichocarpa is clearly a species of the middle bay (Figure 13d). Of the sampled sites, it occurs in greatest abundance on Cenotaph Island; and it is most frequent and abundant at the sample sites farthest from the neck of the Bay. It has a greater average abundance on the south shore than the north.

Picea sitchensis has a pattern noticeably different from the preceding species (Figure 13e). Its highest abundances are near the neck of the Bay, and it occurs with low abundance and sporadic occurrence in the forest face at sites farthest from the neck of the Bay. At the westernmost sites, spruce has its highest abundances, in part because of the nearness of mature forest which was not eradicated by the 1958 wave. Spruce occurs with similar frequencies and abundances on both shores of Lituya Bay.

Like spruce, Alnus oregona appears to be more frequent near the neck of the Bay, at least on the north shore of Lituya Bay (Figure 13f). The species is clearly more frequent on the south shore where it has greater stature, and is a much more impressive component of the forest face. It has a mean abundance value of 3.6 along the south shore, but only 2.1 on the north shore.

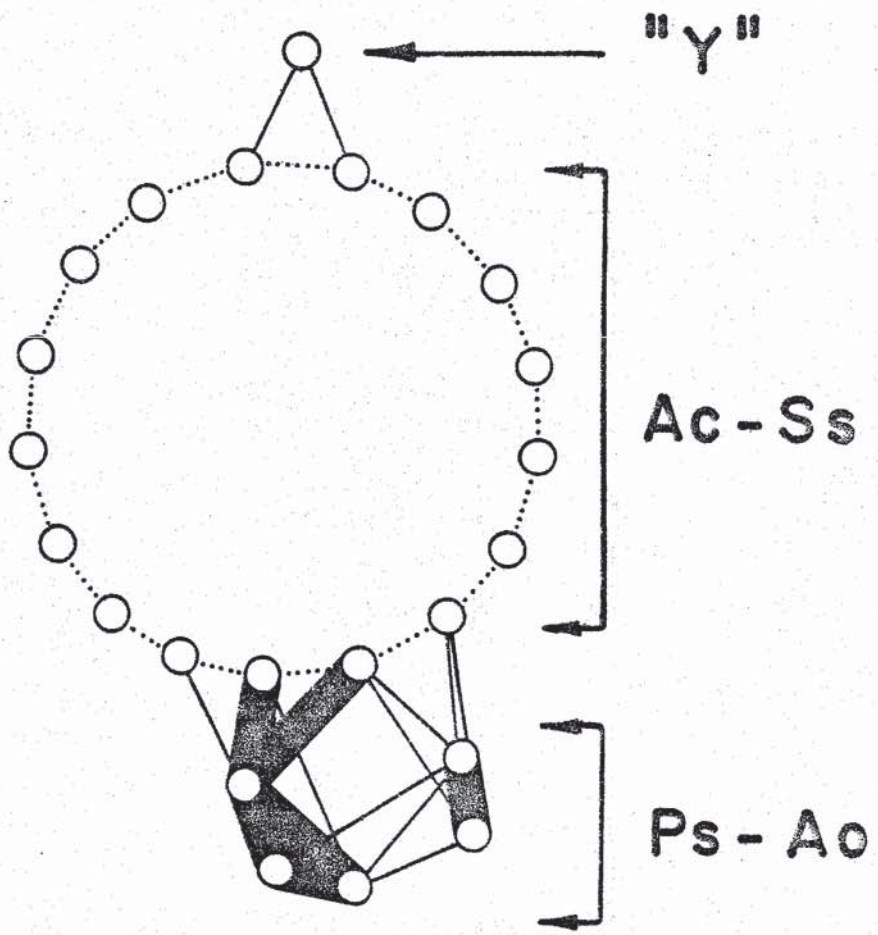
Thus, it can be generalized that there are fewer species of trees in the forest face near the mouth of Lituya Bay, and there are fewer tree species per site along the north shore. Picea sitchensis and possibly Alnus oregona are most frequent and abundant near the neck of Lituya Bay whereas Populus trichocarpa, Salix sitchensis and Alnus crispa are clearly more frequent and abundant at a distance from the neck of Lituya Bay. The last three species are species of successional deciduous woodlands in the general study area along the outer coast; whereas both Picea sitchensis and Alnus oregona are species of more mature forests.

It should be noted that Tsuga heterophylla appeared at only four sites, which is not unexpected during early successional stages, it being a tree of shaded forest sites. I can suggest no significance in the fact that spruce and willow have their greatest average abundances on the north shore and the two alders and cottonwood have their greatest average abundances on the south shore.

Species Composition and Community Structure:

The plexus of sites (Figure 14), based upon species composition and abundance, segregates the sites into three sub-groups, one containing but a single sample ("Y"). Sample "Y" is on the north shore and is the only site where succession appears to still be in a very youthful phase. At this site is the Lathyrus-Lupinus beach meadow sub-community. Woody plants are low, often less than 2 meters tall and well scattered. The only two species of woody plants at the site which could be considered to be part of a forest phase were small scattered Salix sitchensis and Alnus crispa.

Figure 14. Plexus of forest face samples from Lituya Bay. The broad lines indicate similarity values 0.75-1.00; the narrow lines indicate similarity values 0.60-0.74; the dotted lines symbolize the very high degree of similarity among all the samples of the large circle of the plexus. Sample "Y" is discussed in the text. Ac-Ss is the *Alnus crispa-Salix sitchensis* sub-group.


"Y"
Ac - Ss
Ps - Ao

The two principal clusters are best considered sub-groups of a gradient (Worley, 1977). The larger sub-group consisting of 17 samples is highly integrated. The mean number of similarities with which any single point is tied in with other points which are equal to or greater than 0.60 is 10.5, 66% of all possible. Furthermore, the mean number of similarities equal to or greater than 0.50 is 14.5, or 85% of all possible. The mean of all similarities among all members of the large cluster is 0.62, thus noting a highly cohesive unit. If one considers only the 5 samples of the smaller cluster which are not included in the larger cluster, then 100% of all possible similarities among those 5 sites are equal to or greater than 0.50, the mean being 0.73. If one considers all 8 samples of the smaller cluster, 96% of all similarities are equal to or greater than 0.50 and the mean of all similarities is 0.67. Finally, if one considers the percentage of all possible similarities between the samples of the smaller clusters and the samples of the larger clusters, when shared sites are not included, 90% of all possible similarities are less than 50. Therefore, it is certainly legitimate to separate the two clusters as sub-groups along a gradient.

The sub-group of the forest face community which is represented by the larger cluster (excluding the 3 shared sites) is characterized by high species richness of woody plants (4.0) with the three successional species Alnus crispa, Salix sitchensis, and Populus trichocarpa being the most important (Table 6). The three samples which are included in both clusters have a lower richness intermediate between the clusters of 3.7. These three samples have similar species to that of the principal cluster with the exception of the absence of Populus trichocarpa, but the species are in reverse order of importance with Alnus oregona and Picea sitchensis being the principal species (Table 6). The smaller cluster completes the transition of species composition with Picea sitchensis the most abundant and frequent species followed closely by Alnus oregona, there being a complete absence of Populus trichocarpa and Alnus crispa. Note that in the transition sites Alnus oregona is the most important species, whereas in these sites it is almost equally important to Picea sitchensis.

It is therefore possible to consider the gradient which begins at sample "Y" and ends with the smaller cluster as being akin to the successional sequence of tall woody plants at Lituya Bay. The early woody species are Salix sitchensis and Alnus crispa, followed by Populus trichocarpa, then Alnus oregona, and Picea sitchensis. As time passes, Alnus oregona becomes most dominant with high importance of Picea sitchensis and Salix sitchensis; by this time Alnus crispa has begun to be shaded out in many places. Ultimately, Picea sitchensis along with Alnus oregona form a tall woody canopy later succeeded by a spruce forest containing some Alnus and seedling hemlocks. The high percentages of Alnus oregona at places in Lituya Bay do not appear to be mirrored further down the coast along the beaches. However, a similar successional pattern may be the case in the sloughs or fluvial deltas behind the beaches north of Lituya Bay.

The forest face at Lituya Bay as it abuts the herbaceous beach community is clearly successional. It is not the same forest face that one finds abutting tidewater beach communities elsewhere along the outer coast (Worley and Streveler 1974, Worley 1976, also this study) where spruce abuts the meadows or spruce with a zone of Alnus crispa form a marginal woody plant community. Thus it would seem that the marginal fringe of Alnus

Table 6. Tall woody plant composition of the forest face sub-groups.

Site "Y":

	Abund. Value
Salix sitchensis	3
Alnus crispa	2

Alnus crispa-Salix sitchensis sub-group (excludes sites in transition with the following sub-group):

	Ave. Abund.	% Freq.	I.V.
Alnus crispa	3.4	100	78
Salix sitchensis	2.4	93	67
Populus trichocarpa	2.4	79	59
Alnus oregona	2.2	64	50
Picea sitchensis	1.4	57	40
Tsuga heterophylla	0.1	7	5

Picea sitchensis-Alnus oregona sub-group (excludes sites in transition with the previous sub-group):

Picea sitchensis	3.4	100	78
Alnus oregona	3.2	100	77
Tsuga heterophylla	0.8	40	27
Salix sitchensis	0.4	20	13

Composition of transition between preceeding two sub-groups:

Alnus oregona	4.3	100	86
Picea sitchensis	2.3	100	69
Salix sitchensis	2.0	100	67
Alnus crispa	1.7	67	47

crispa so common between spruce or spruce-hemlock forests and the tide-water interface in southeastern Alaska must arrive as a secondary effect of succession and is not necessarily established with initial colonization by Alnus crispa. It would be interesting to know why or how Alnus crispa functions quite distinctly as a colonizer of terrain, and as an opportunist between the spruce forest and herbaceous meadow. Noting that Alnus crispa does not form a fringe between spruce forest and extensive beach meadows where the substrate is sand, as is seen along the outer coast, one wonders if the presence of the band of Alnus crispa along rocky coasts may indicate succession which is occurring either because of isostatic or tectonic uplift.

The distribution of the subgroups along the shores of Lituya Bay shows that the Picea sitchensis-Alnus oregona sub-group occurs only at the neck of Lituya Bay; that the three transitional sites are generally close to the neck of Lituya Bay; and that the Alnus crispa-Salix sitchensis sub-group occupies the remainder of the Bay at least as far as Cenotaph Island. The one site still in an early successional stage was sampled on the north shore of Lituya Bay northwest of Cenotaph Island.

Tree Heights:

The south shore of the Bay had the tallest canopy trees, averaging 34% taller than those of the north shore. The tallest trees along the south shore averaged 9.20 m tall per site in contrast with an average of 6.85 m on the north shore.

Sixty percent of the south shore sites had maximum canopy heights 9 m or more, whereas 70% of the north shore sites had maximum canopy heights of 8 m or less (Table 7).

Maximum tree heights were little patterned with respect to distance from the mouth of the Bay except that the shortest maximum heights occur on the north shore near the cove to the northwest of Cenotaph Island.

Mean canopy height was calculated by averaging the two heights recorded for each site (see above). As with maximum heights, the south shore had a greater average canopy height, 6.4 m compared with 4.7 m for the north shore. Site for site, west to east, and north shore versus south shore, the westernmost three sites have the same average canopy heights, whereas for the remainder of the sites, farther from the mouth of the Bay, the mean canopy heights on the south shore average 2.9 m taller (61.5% taller).

Canopy height variability was calculated per site as the difference in height between the tallest and shortest canopy heights. The south shore average greater variability, 5.2 m vs. 3.85 m for the north shore, partly because of the taller canopies. The greatest variability on the north shore occurred in the central sites, whereas the converse was true for the south shore sites. Percent variability (maximum height minus minimum height, divided by maximum height times 100) averaged the same for north and south shores (55.6% vs. 57.6%), with the site by site variation exhibiting the same patterns as the absolute variation.

Thus, the south shore has taller trees (34% taller), taller average canopy (36% taller), and greater variability in canopy height per site

Table 7. Tree heights and distribution of tree heights of the forest face.

Height of tallest canopy tree (m)	% of North Shore Sites	% of South Shore Sites
11-12	0	20
9-10	30	40
7-8	30	30
5-6	10	10
3-4	20	0
less than 3	10	0

(35% greater). Near the neck of the Bay the canopies on north and south shores were equivalent in height, but farther from the neck the south shore canopies are 61.5% taller than their north shore counterparts.

The greater vigor of the south shore woody vegetation seems most likely due to its more protected setting from storms, which are predominantly from the south during the growing season.

Summary:

The edge of the successional woodlands at Lituya Bay typically consists of about 3.5 tree species averaging about 5.5 m tall. The south shore trees are more diversified (19% more species per site than the north), have taller trees (34% taller) and a taller canopy (36% taller), than does the north shore, whose woody plant succession is somewhat, to considerably, retarded.

Alnus crispa, Salix sitchensis, Populus trichocarpa and Alnus oregona are common constituents of both shores, all but S. sitchensis most abundant on the south shore.

The portion of the Bay east of the neck has 46% more species per site than at the neck, with Alnus crispa, Salix sitchensis and Populus trichocarpa in greatest abundance. At sites near the neck Picea sitchensis and Alnus oregona are the prominent species.

Consequently, the overall pattern is one of successional, deciduous plant species predominating except at the neck of the Bay; the most vigorous growth along the south shore; and the most retarded growth at sites on the north shore and behind the coves near the mouth of the Bay. These differences are most likely attributable to protection (or lack thereof) from storms, availability of seed source, and (unknown) substrate differences.

Other Plant Communities

Forests:

Twenty-eight vegetation samples of forested sites were taken in the study area from the vicinity of Topsy Creek northwestward to Justice Creek. Nineteen of the sites are on beach deposits, seven on moraines, and two

on bedrock; all are within a few hundred meters of the Gulf of Alaska.

Each sample consisted of a complete listing of all vascular plants present in an area 20 to 40 meters in diameter (Streveler et al, 1974); the most abundant species were specially noted. No abundance values were determined, nor were bryophytes recorded.

From the presence-absence data, a similarity matrix was generated for all samples. Plexus diagrams provided displays of cluster patterns.

At no levels of similarity is there distinctive cluster segregation. At the 0.70-1.00 level five samples with mature forests form a tightly-knit plexus, separate from three related samples of younger forests, and a third group, of only two samples, both immediately adjacent to the sea.

Twenty-two samples compose the only plexus (Figure 15a) at the 0.60-1.00 similarity level. The plexus has a central core with a number of peripheral samples. The ten, highly similar core samples are characterized vegetationally below.

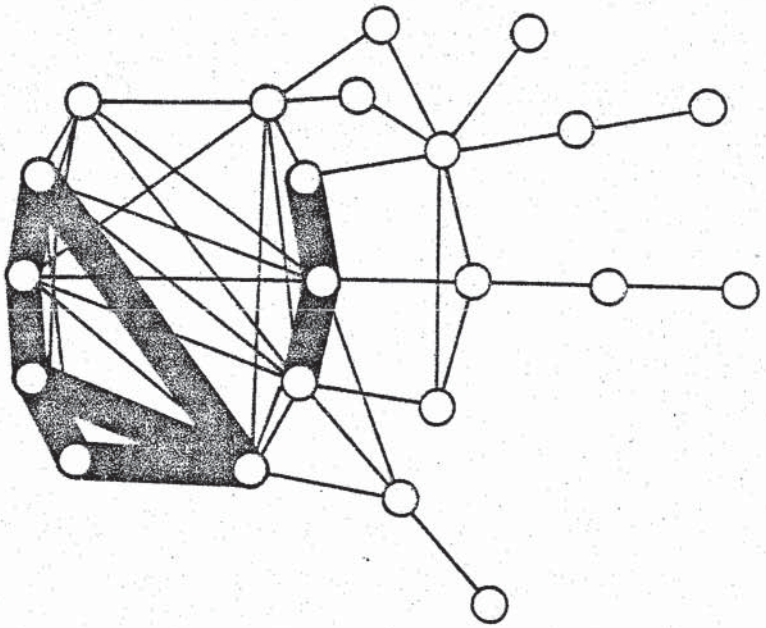
At the 0.50-1.00 similarity level all samples participate in a single plexus (Figure 15b), with a highly interrelated core of 20 samples which is characterized below.

The clustering of samples provided by these data and the use of the similarity index does not conform to one's expectations based upon vegetation physiognomy, forest age, distance from the sea, substrate, or geographical location. Three of 15 samples of youthful forests and five of seven samples of mature (not including parkland samples) forests cluster at the 0.76-1.00 similarity level. However, at the 0.60-1.00 similarity level, the principal cluster includes samples of all ages; and at the 0.50-1.00 similarity level all samples belong to a plexus in which sample age plays no role in determining the strength of association or gradients within the plexus. At no similarity level do distance from sea, substrate, or geography correlate with clusters or gradients of samples. Therefore, qualitative sampling of only vascular plants is inadequate to separete forest types according to their age, substrate, distance from the sea, geography, or other parameters. Since the biotic structure of the forests sample has considerable variation to even the untrained eye, further forest analysis and characterization is recommended. In addition to variation correlative with the four parameters mentioned before, there clearly is variation in biomass, productivity, stature, dominance, diversity, strata, bryophytes, successional status, groundwater regime, and topography.

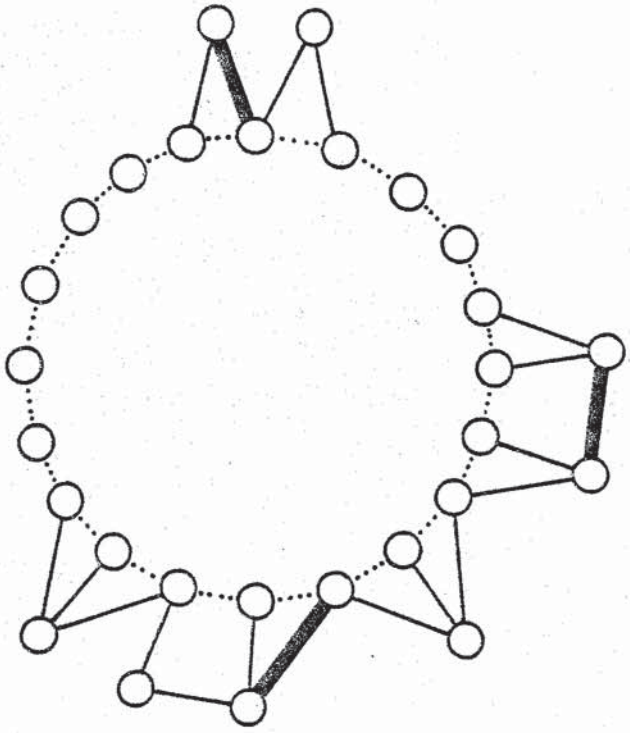
Thus, high degrees of similarity among forest samples based upon species composition is known for both the Dixon Harbor and Lituya Bay study areas. Air photos demonstrate that gradients dominate the lowland forests of the Lituya Bay area; gradients of height, density, size of individual trees, darkness of canopy, and species composition are the most prominent.

Worley (1977) determined and characterized the forests of the Dixon Harbor area. Not surprisingly the principal assemblage of forest samples of the Lituya Bay area is most similar with the "Spruce Dominated Forest" of the Dixon Harbor area (because of the limited data for the Lituya Bay forests, the comparison was based upon the eight most important or most frequent

Figure 15. Plexus mappings of the forest samples. The broad lines indicate similarity values 0.75-1.00; the narrow lines indicate similarity values 0.60-0.74; the dotted lines symbolize the very high degree of similarity among all the samples of the large circle of the plexus (b). Figure "a" is the 0.60-1.00 plexus; the ten samples used to characterize the core of the plexus (see text) are the leftmost ten samples. Figure "b" is the 0.50-1.00 plexus. (next page)



a



b

vascular plant species, yielding a presence-absence similarity of 0.88). The "Spruce Dominated Forest" was represented by sites "near sea atop cliffs, by beaches, or on stream deltas . . . (with) . . . other sites on youthful outwashes and floodplains. . . . (The) majority of the sites are clearly successional . . . and associated with beach or outwash systems." Thus, the habitats of the Dixon Harbor "Spruce Dominated Forest" are comparable with the Lituya sites. It seems reasonable to extend the name "Spruce Dominated Forests" to both the principal clusters of sites, that containing similarities 0.60-1.00 along with the one with similarities 0.50 or more.

The ten samples belonging to the 0.60-1.00 cluster are characterized by abundant spruce and high frequencies (90-100) of hemlock (often as seedlings and saplings), devil's club, Vaccinium ovalifolium, Rubus pedatus, Cornus canadensis, Maianthemum dilatatum, and Dryopteris dilatata. Eight additional species occur in half or more of the samples: Menziesia ferruginea, Vaccinium parvifolium, Streptopus amplexifolius, Vaccinium alaskensis, Gymnocarpium dryopteris, Alnus oregona, Listera cordata, and Moneses uniflora.

The cluster of forest samples at the 0.50-1.00 level has a species composition little different from that just described. Seven of the eight most frequent species are the same, with Streptopus amplexifolius replacing Dryopteris dilatata as the principal large herb. Only five additional species occur in at least ten of the 20 samples: Alnus oregona, Rubus spectabilis, Vaccinium parvifolium, Dryopteris dilatata and Moneses uniflora.

Although unsampled in the Lituya Bay study area, the prominent moss understory of these forests appears similar to that described (Worley, 1977) for the Spruce Dominated Forests at the Dixon Harbor Study Area.

For the most part, the forests represented by these samples are closed canopy spruce forests of various ages, with lush moss carpets over soil and deadfall. Herbaceous, sub-shrub, and shrub understories are often sparse, though occasionally dense and rich in species. At some sites seedling and sapling hemlocks combine with Vaccinum ovalifolium (or V. parvifolium) to form a dense tall shrub sub-canopy.

Parklands:

Four parkland samples located on the sea-facing moraine slopes south of Harbor Point, included in the analysis above, have a mean inter-sample similarity of 0.50, compared with 0.43 for the Dixon Harbor study area parkland samples (Worley, 1975). Two vascular plant species dominate the physiognomy and biomass, providing the parkland character in the absence of numerous shrubs and/or tall herbs: Picea sitchensis and Calamagrostis canadensis. The low, broadleaf plants Maianthemum dilitatum and Cornus canadensis are frequent and abundant among various mosses within the dense Calamagrostis. Vaccinium ovalifolium and V. parvifolium, the herbs Conioselinium chinese, Polypodium vulgaris, and Streptopus amplexifolius, and occasionally other herbs occur in small amounts here and there in the parkland sites.

Among the most frequent and more important species shared between the Lituya Bay and Dixon Harbor parklands are Picea sitchensis, Calamagrostis

canadensis, Maianthemum dilatatum and Vaccinium ovalifolium. For the most part there is little similarity in species composition between the two areas. Notable by their absence at the Lituya sites are Carex macrochaeta, Dryopteris dilatata, and the moss Trachycystis flagellaris (sought but never found in the Lituya Bay study area).

Parklands in the study area appear common on the moraine slopes at the sea at Lituya Bay, and presumably occur at similar settings at Fairweather and La Perouse glaciers. They are not known currently from other locations.

Forest Fringe by Wetlands:

Adjacent to the sloughs and wetlands north of Lituya Bay, on the landward fringe of the forested bar is a zone of dense vegetation with a prominent deciduous canopy. Two sites were sampled near Justice Creek. Both sites had abundant Alnus oregona, Picea sitchensis, and Rubus spectabilis, along with Echinopanax horridum, and either Populus trichocarpa or Sambucus racemosa contributing considerable woody biomass at all levels of the sites. These well-lighted sites also have rich herbaceous understories including Athyrium filix-feminia, Osmorrhiza sp., Actaea rubra, Dryopteris dilatata, Streptopus amplexifolius, Maianthemum dilatatum, and at least five additional herbs.

Marshes:

From the marshes north of Lituya Bay but three vegetation samples (vascular plants only) were taken, all at the Justice Creek Marsh. That marsh is a complex of three prevalent physiognomically distinctive vegetation types, whose location appears directly correlated with the degree of paludification. A willow dominated carr (shrub wetland), which was not sampled, is the other major non-forested vegetation type of the wetland.

In standing water is a sub-community of the marsh community, the Eleocharis-Equisetum sub-community (this title is tentative, being based upon a single vegetation sample). Three emergent species dominate: Eleocharis palustris, Equisetum fluviatile, and Equisetum palustre. Scattered here and there are individuals or clusters of Carex cf. aquatilis, Cicuta Douglasii, Lysichiton americanum, Caltha palustris and Hippuris vulgaris. This assemblage of low, narrow leafed and stemmed plants, with occasional broad-leafed individuals, in shallow water is similar to sites in the basin of the former North Deception Lobe Lake and the Dixon River marsh (Worley and Streveler, 1974), and sites in the wetlands of the Gustavus outwash (M. Worley and I. Worley, unpublished data).

At sites somewhat less wet, species richness increases markedly (in our samples from 8 species to 22 species), primarily through the addition of broadleaf herbs and low shrubs. The sedge Carex cf. aquatilis dominates physiognomically. Consequently, in the field this vegetation type is seen as a sedge meadow. Because of the visual (and perhaps biomass) dominance of Carex cf. aquatilis, and the abundance of four species of Equisetum (E. arvense, E. fluviatile, E. palustre, E. variegatum) this vegetation type is tentatively titled the Carex cf. aquatilis-Equisetum spp. sub-community of the marsh community. In our sample, Cicuta Douglasii and Caltha palustris were also abundant. Other uncommon or scarce species at the site included the woody plants Picea sitchensis, Salix barclayi, and

Myrica gale, the tall herbs Angelica genuflexa, Iris setosa, Deschampsia cf. beringensis, and Rumex fenestratus, and the shorter herbs Lysichiton americanum, Scirpus microcarpus, Epilobium glandulosum, Hippuris vulgaris, Parnassia palustris, Platanthera dilatata, and Potentilla palustris.

At less wet marsh sites, adjacent to the bordering fringe of forest, there is a lush vegetation type, predominantly marsh, but in part a transition (in character, not necessarily in location) with low carr. Physiognomically prominent is the tall and often dense Scirpus microcarpus. Also abundant are low (i.e., generally less that 1.5 m in height) shrubs of Salix barclayi, and S. sitchensis, and the low herbs Caltha palustris and Oenanthe sarmentosa. The tentative sub-community name is Scirpus microcarpus-Salix spp. sub-community of the marsh community.

Containing four more species than the preceding sub-community, this tall, dense vegetation assemblage adds to the list of woody species Alnus oregona, Rubus spectabilis, and Viburnum edule. Added to the list of tall herbs are Athyrium filix-femina, Calamagrostis canadensis, Elymus arenarius, and Sanguisorba stipulata (two dominants of the preceding site, Carex cf. aquatilis and Cicuta douglassii, are absent in this sub-community). The low herb composition changes markedly between the two sub-communities; these species are present in the last-mentioned sub-community: Ranunculus pacificus, Achillea borealis, Epilobium glandulosum, Equisetum arvense, E. palustre, E. variegatum, Plantanthera dilatata and Potentilla egedii.

The Scirpus-Salix sub-community contains many species commonly associated with beach locations. In fact, if one were to exclude the prominent genera (Oenanthe, Salix, Scirpus and Caltha) the remaining 21 species provide a species composition not unlike beach sites along a stream mouth or other fresh-water source.

For the purpose of discussion, consider the samples as A, B, and C, in the order described above.

One hundred percent of the species in A are found in B, whereas 47% of the species of B are found in C (25% of A species are in C). The only two species occurring in all three sub-communities are Equisetum palustre and Caltha palustris, both abundant in two of the sub-communities. None of the species occurs only in A; 2 of 30 species (7%) occur only in B (Parnassia palustris and Potentilla palustris); whereas 12 of 31 species (39%) of C are unique to it, including two of the abundant species (Oenanthe sarmentosa and Salix sitchensis).

The three marsh sub-communities consist of a gradient of species composition change, wherein the physiognomically dominant species provide the sub-community distinctions.

The extension of these sub-communities to other marsh sites north of Lituya Bay is untested by sampling, but casual observation confirms general similarity throughout the marsh complexes at the level of gross physiognomy.

A Grassy Meadow:

A grassy meadow occupying the former channel of Portage Creek was sampled. This channel was abandoned by the creek around 1920 and has subsequently

been used by prospectors and other persons. Vegetation within the channel was bull-dozed 10-20 years ago. Very high seas often invade the channel from the southeast, perhaps forcing saltwater as far as the sampled site 1/4 - 1/2 mile northwest of the present Portage Creek mouth. The sample contains a remarkable 41 species including 26 short herbs, 10 tall herbs, 3 shrubs, and young trees of Alnus oregona and Picea sitchensis. Most of the species are typically found on the study area beaches; a few are most commonly foun in drier portions of freshwater marshes; none of the species was recorded to be especially abundant.

A Peatland Sample:

A single large sample of peatland vegetation was made at a pine dominated site on the 122 m (400 ft.) elevation terrace 1/2 mile north of Topsy Creek. The vascular plant species list contains 37 species, far more than the mean of 20 reported by Worley (1977) for peatlands in the Dixon Harbor study area. The sample is most like the Slope Peatland Sub-community (Worley, 1977) with the most abundant species being Pinus contorta with a graminoid understory of Carex cf. pauciflorus, Trichophorum caespitosum, and 5 other, less abundant species, but is noticeably rich in woody plant species (15) and broadleafed herbs (14 species). The number of species and their composition are very much different from the peatland on Pleasant Island at the mouth of Glacier Bay (Reiners, et al., 1971); also, there is low similarity with the peatlands described southward in southeastern Alaska by Neiland (1971).

Three Wet Sites:

Vascular plant species lists were compiled at three various wet sites north of Topsy Creek: an alder-skunk cabbage dominated slough in a silty flat through which a low gradient stream meanders, and which is separated from the beach by an alder shrub fringe; an emergent aquatic dominated edge of a marshy pond 150 meters distant from the beach; and the Calamagrostis canadensis dominated pond shore. No similar sites have been sampled at Dixon Harbor(Worley and Streveler 1974, Worley 1974, 1975, 1977) or, to our knowledge, elsewhere in Southeastern Alaska.

Two Alder Thickets:

Two alder thickets (Deciduous Shrublands, Worley 1977) of very different origin were sampled: a wind-shorn alder-salmonberry thicket at the south margin of the mouth of Steelhead Creek, and an alder thicket of the wave scoured area just behind the beach meadow along the southwest shore of Harbor Cove. The vascular plant species compositions of the two samples are quite different, neither highly similar with any of the Deciduous Shrublands reported from the Dixon Harbor study area (Worley 1977). The thicket at the mouth of Steelhead Creek bears resemblance to the Shrub-Margin Zone of the Beach Community at the Dixon Harbor Study Area (Worley 1975), but similarity indicies with any of the Sub-communities are very low. Many of the understory species are typically found at sites in the Lituya Bay study area where freshwater is available at a marine beach.

The Harbor Cove thicket is essentially a successional site with a canopy of Alnus crispa over seedling Picea sitchensis, Tsuga heterophylla and seven common beach herbs.

Vegetation Transects

Introduction:

Transects of the vegetation and geomorphology at two beach sites were made during the summer of 1977. The following comments are meant to clarify aspects of the diagrammatic representation of these transects (Figure 16 and Figures 17 and 18; latter two are in rear pocket).

At the bottom of the illustrations are noted distances in meters. These distances begin at arbitrary points and the numbers are used solely to assist the reader in locating stations along the transect. Also indicated are the sampling stations (eg. SC-4) used by other investigators in this study, for example during bird and soil observations. The ground surface was surveyed using tape and hand-held inclinometer. The inclinometer had a precision of approximately one-half degree. Survey points are marked by ticks between which straight lines are drawn. Mean sea level relationships were determined by reference to the figures of Molnia (this volume). The ground surface vertical exaggeration is 3x. The vegetation vertical exaggeration is 2/3x. Thus, the ground surface is 4.5x the vegetation. Vegetation heights are somewhat exaggerated for low vegetation. Similarly, boulders, driftwood, stumps, and fallen timbers are somewhat exaggerated in height. The illustrations represent the vegetation and topographic conditions along the transects in generalized form, occasionally synthesizing information adjacent to, but not along, the specific transects. Species composition, branching patterns, surface materials, and bryophyte locations are shown. The illustrations do not accurately represent tree densities, due to the scale exaggerations. Also, understory density and diversity is sometimes under-portrayed.

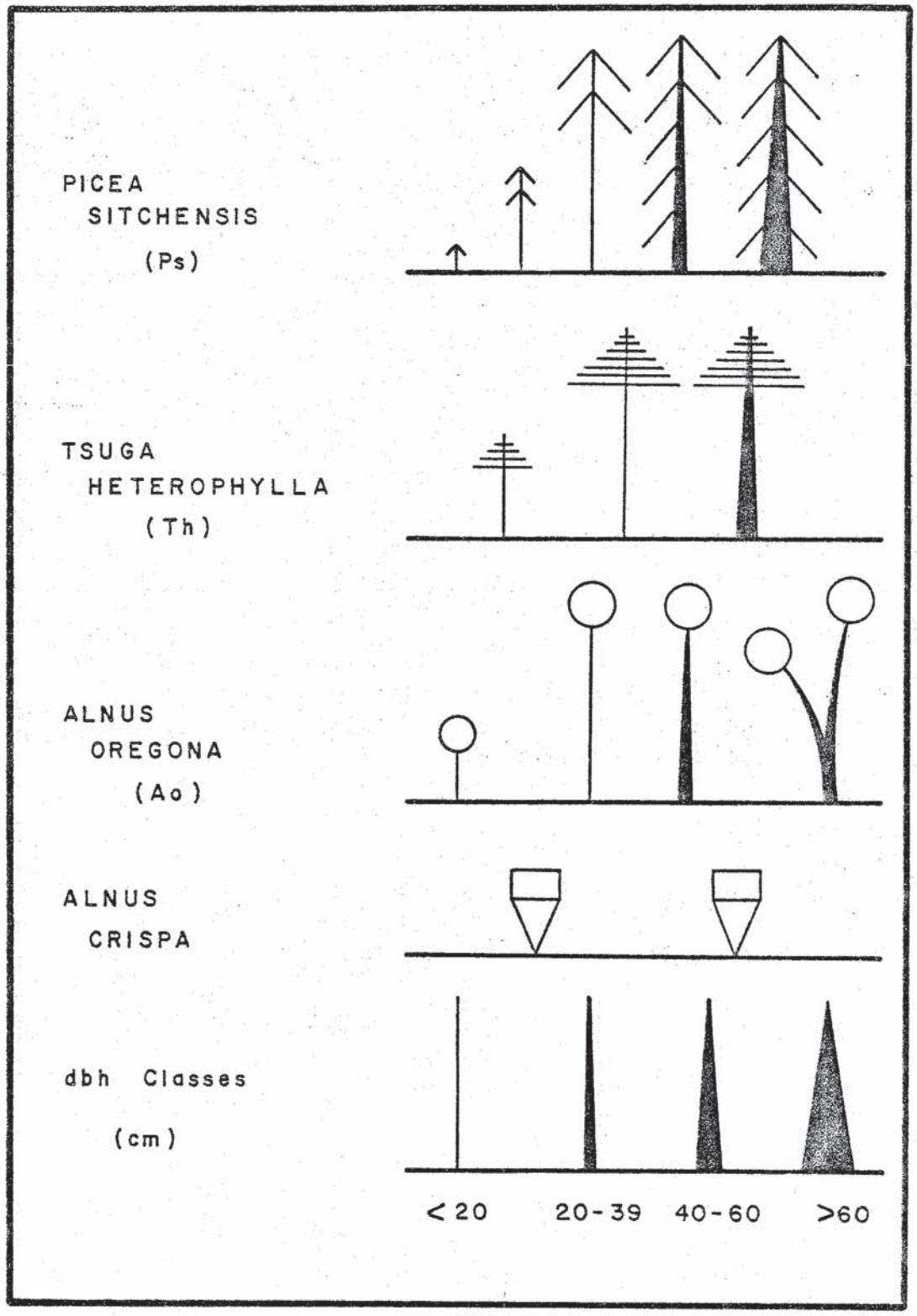
Unless otherwise indicated, those trees for which cores were extracted are the largest trees of that species at the site. In the text, the term sapling is used for individuals taller than 1 m with a dbh less than 5 cm. Seedlings are individuals of tree species less than 1 m tall and less than 5 ($\pm$) years old. Only live trees are shown in the illustrations; wherever pole stands are indicated, there are usually numerous dead and dying individuals not figured. Note that for trees a diagram indicates species, height, thickness of canopy, pattern of branching, dbh, and germination substrate.

dbh Dating Compensation:

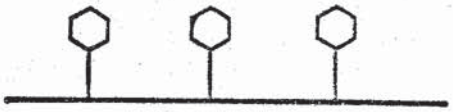
In order to determine approximately how many years pass in the growth of a tree before it reaches dbh height (1.4 m), ten young spruce from open meadows were dated via whorl counts and/or coring at the root/stem transition zone. The strong positive correlation ($r=0.90$, Figure 19) between age and height allows compensation for growth to dbh height when determining the age of older trees. The intersection of the regression line by dbh height is 6.0 years.

Thus, for all trees in this study, including hemlock and red alder, 6 years has been added to ages determined by corings at dbh height. It may be that 6 is too large for red alder, and perhaps hemlock as well; however, in the absence of actual sampling, I have chosen to add 6 years to all three species.

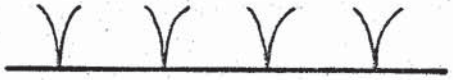
Figure 16. Key to vegetation transect symbols.
(Figures 17 and 18, rear pocket)


PICEA
SITCHENSIS
(Ps)
TSUGA
HETEROPHYLLA
(Th)
ALNUS
OREGONA
(Ao)
ALNUS
CRISPA
dbh Classes
(cm)
< 20
20-39
40-60
>60

Tall Shrubs



Tall Herbs

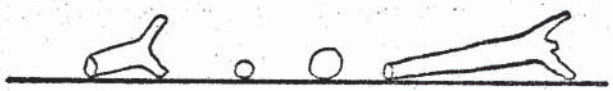


Short Shrubs and Herbs

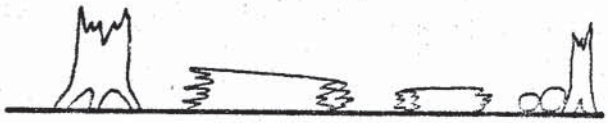


Bryophytes

Driftwood



Fallen Timbers and Stumps



Tree Age and Diameter

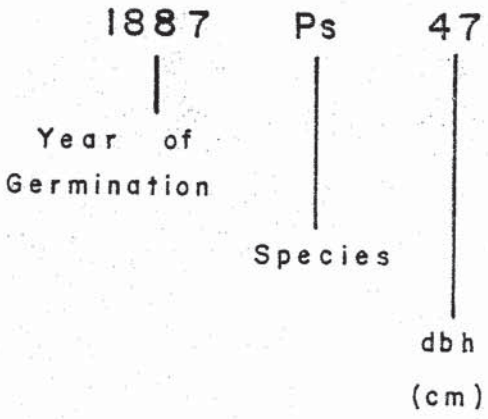
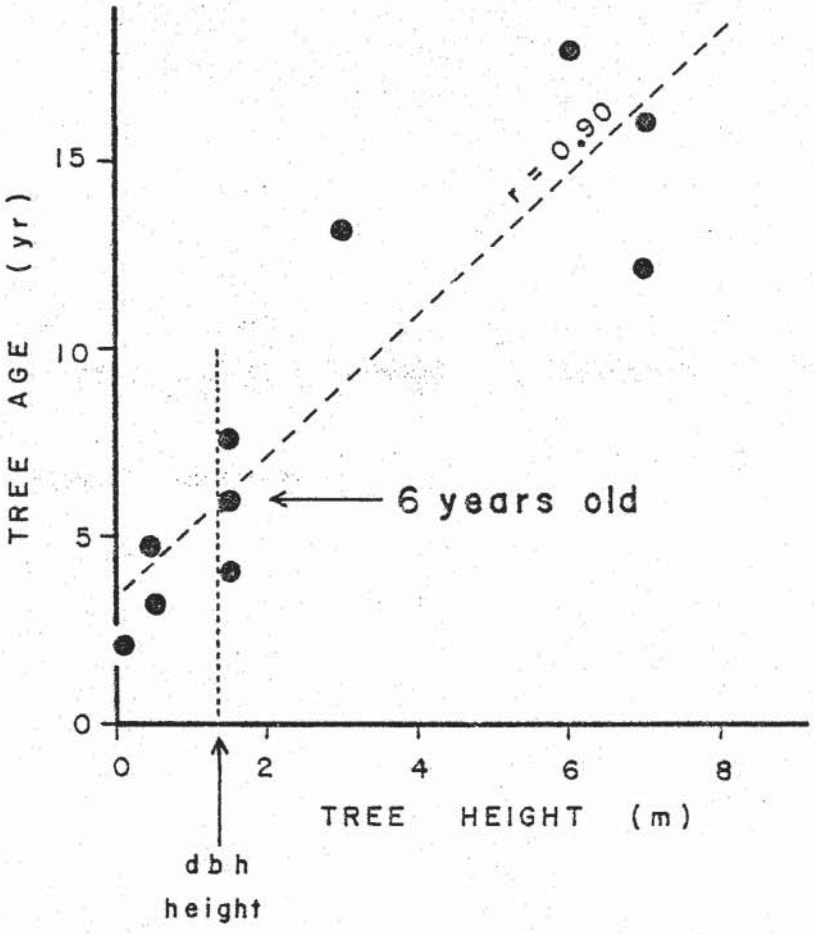


Figure 19. Age versus height for young Sitka spruce in the supra-tidal meadows near Steelhead and Portage Creek transects. (next page)


TREE AGE (yr)
15
10
5
0
r = 0.90
6 years old
0
2
4
6
8
TREE HEIGHT (m)
dbh
height

Portage Creek Transect - Description:

This transect (Figure 17) is the "PC" transect of Weisbrod (this volume), and begins very near the southern limit of beach meadows north of Portage Creek. Because of the length and sometimes gentle slopes of this transect, it is possible that the ground surface survey is in error by some degree. The most likely sources of error are miscalculation of minor slopes, as the precision of measurement was 0.5°.

The two stream associated, Alnus oregona stands (28-38, 55-62)* are very similar with prominent, 3 m tall Rubus spectabilis thicket understories. The alders are generally unbranched to 10 m or so, and provide a closed canopy. Along the banks of the former stream channel (perhaps a flood course) are occasional Salix sp. (not illustrated). The dense sedges and forb s occupy the herbaceous community of the channel.

On the former stream bottom (64-73) there are branched and unbranched, large, very old red alders; large open grown spruce; seedling and sapling spruce; and a characteristic forest understory of mosses, herbs, Rubus spectabilis and Echinopanax horridum.

The large spruce at 73-81 are branched to streamside; there are many hemlock samplings beneath.

The surfaces and slopes from 28 to 143 have no erosion runnels, indicative of the rapid infiltration of rainwaters through the sands.

No driftwood remains were located by a cursory search on the slope 78-130, although remnants can be expected in the 78-93 section, especially beneath the oldest spruce. These spruce have characteristic cones of litter (occasionally burrowed by red squirrels) around their bases. This region is clearly the site of forest initiation, and is first generation.

Throughout the pole stand (93-130) there is extensive natural thinning of spruce due to shading, with many sub-canopy snags and stumps (generally 10-25 cm in diameter). Their litter is abundant, and relatively undecayed. The absence of large stumps or ancient litter further indicates first generation forest growth. A typical bryophyte carpet provides nearly 100% ground cover, with most of the larger litter lying atop the bryophytes. Shrubs (Vaccinium uliginosum, Echinopanax horridum) and herbs (Coptis, Streptopus) are very sparse.

It appears that the spruce first to establish (as evidenced by swollen bases) in this pole stand area are now sub-canopy and dead or dying, being overtopped and shaded by later arrivals. The size of trees diminishes from meter 95 to meter 130. Hemlocks arrived much later, and if the scattered saplings and seedlings all live they will ultimately provide 70% or more of the forest canopy. The hemlock are rooted in the bryophyte covered forest floor and in the litter cones at the base of spruce trees. In this zone red alder are very sparse, unbranched, with diameters 15-30 cm.

The former forest margin (131-136) is well marked by a line of large old spruce with straight boles and seaward branching. The boles do not broaden

* Indicates position on transect, see Figure 17.

dramatically at the base as is the case with open grown individuals. It is not clear whether they germinated on driftwood or not; but some smaller individuals clearly did, although the driftwood is well disguised by decay and bryophyte growth.

Smaller spruce (20 cm or more dbh) are sub-canopy and are frequently dead or dying. As throughout the spruce forests on this slope (78-144) there are no seedling or sapling spruce. The largest hemlocks are 20 cm dbh and quite uncommon; however, hemlock saplings are common.

The frequent red alder along this former forest margin may be 50-60 cm dbh; they have no low branching and reach the forest canopy. Characteristically, they lean seaward and occur exactly on the line of the forest margin.

The ridge crest (144) has little breadth; old drift logs lie about, especially to the landward with the trunks perpendicular to the ridge and the root bases to seaward. Well decayed and hidden by bryophytes, the driftwood characteristically has spruce rooted in it.

The outstanding features of this site are the remains of Alnus crispa and the tall canopy hemlock that germinated in their shade. Numerous, the hemlocks range from large canopy trees to saplings to seedlings. The Sitka alder remains are well rotted, with a few standing snags (the depicted alder at meter 145 is dead).

Spruces along the ridge (135-148) display little branching, and do not exceed 30-50 cm dbh. Some groups of spruce cluster tightly on a single piece of drift; their dbh's are 15-30 cm. Most sub-canopy spruce suffer from shading and many are dead or dying.

The slope 144-158 appears to be an erosional surface. However, similar tree ages on both sides of the ridge crest and this slope indicate that the erosion was a minor event and that the 78-144 slope did not extend significantly higher and more seaward.

Along this erosional slope, discontinuous open grown outlier trees with heavy lower branches and very wide bases, and similar copses, form a canopy with other spruce, hemlock and red alder. Some of the big spruce clearly germinated on driftwood, others may have, but it was not possible to so determine. All big spruce have litter cones at their bases, composed primarily of branches and needles. A vigorous hemlock sapling canopy at 3-8 m overtops additional hemlock saplings and seedlings. Dead or dying trees of any species are scarce. The understory contains the typical bryophyte carpet with sparse herbs and blueberries.

The surface from 157 to 202 appears to have a similar history. Driftwood up to 1.3 m in diameter occurs throughout, though more abundant from 163 to 183. Somewhat decayed and soft, the bryophyte covered driftwood is easily to hardly discernible. All, or nearly all, pieces of driftwood are occupied by spruce trees; thus, the spruce often occur in rows or clusters. Commonly, the driftwood lies at right angles to the shoreline.

Probably a former gallery, the low area (157-163) supports mostly tall trees with no more than small branches. From 163 to 183 some spruce display occasional branching, being something of a transition with the complex of

open grown and copse spruce, multi-boled red alder, and former galleries from 183 to 197.

From 157 to 202 spruce dominate the canopy; the scarce red alder are old, large and reach the canopy, whereas tall hemlocks are exceedingly uncommon. The numbers of trees and the extent of natural thinning increase through the region to the seaward. Pole stand spruce that are dead or dying range from 20 to 55 cm dbh. Many of these spruce did not germinate on driftwood. As the thinning is limited to branches and smaller individuals, the forest litter is not prominent. Abundant hemlock saplings and seedlings join Vaccinium spp. and Echinopanax horridum to form a distinctive shrub subcanopy. Herbs and short shrubs sparsely adorn the continuous bryophyte ground cover.

A large mammal trail crosses the transect parallel to the beach at 182-184. I felt that the path was also used with frequency by humans, but I was not able quickly to verify this suspicion.

The former forest margin (199-202), originally very densely forested with all sizes of heavily branched spruce, is now sufficiently thinned to permit relatively easy passage, as most lower branches and some of the smaller trees have died from shading from trees on the escarpment below. At one time there was a solid wall of dense spruce trees and branching right down to the top of the escarpment, typical of some forest margins presently north of Echo Creek. The closed canopy is now 10 m. All trees are spruce, with dbh's from 20-64 cm. Germination on driftwood is rare or lacking.

The escarpment (202-215) was eroded by the former stream (the previous outlet stream of Portage Creek), perhaps assisted by tidal or storm floods up the stream from the sea, or even direct overwash of the seaward sands by storm waves. Because of the straightness of the stream channel, one must presume that the amount of landward erosion by the stream was limited, and thus the berm at 199-202 is at or near the most seaward extent of surface 157 to 202, at least since that surface has been forested.

The lip of the escarpment has about 1.5 m of exposed vertical sand and/or undercut root systems. On the steepest parts of the slop large spruce (to 60 cm dbh) and red alder (to 43 cm dbh) form a canopy beginning 17-25 m high. Many of these trees, especially on the upper slope, are highly bent due to undercutting of their roots and/or downward soil creep. Further down the slope (204-208) begins a salmonberry thicket. The lowest part of the slope is youthfully vegetated with red alders (dbh to 21 cm) and active spruce saplings (dbh 5-15 cm).

The old streambed, which contains chains and other refuse from former prospector passage, is occupied by a graminoid and forb community (see elsewhere in this report for one quantitative sample) that is slowly being replaced by Salix sp., Alnus crispa, and spruce (usually encroaching from adjacent banks).

The seaward streamback (230-239) appears to have younger vegetation, and supports the only active Alnus crispa on the transect.

Seaward of the streamback (239-255) there are open grown and copse spruce (25-63 cm dbh) and many pole spruce forming a closed canopy. Surprisingly,

but similar with the forest at 73-81, there is no distinctive border of branched spruce or alder facing the channel. However, occasional spruce near the edge have branching toward that lighter place, and there are some multi-branched red alders (usually near or on the stream bank). The initial spruce germinated on driftwood, some of which remains clearly intact and incompletely bryophyte covered, although most is well cloaked. The root bases are 25-70 cm above the ground surface. Note that the litter cones about the bases of the initial spruce at meters 73-81 are 50-70+ cm tall, thus perhaps disguising driftwood germination not observed by our cursory inspection.

The entire slope from 239 to 274 is dominated by pole spruce, which become progressively younger, smaller and more dense. Open grown individuals are rare. The trees seem to have germinated quite uniformly, but seldom on driftwood (which is scattered sparsely here and there through the zone). Considerable thinning has taken place and continues, although the dead poles (10-20 cm dbh) have not yet fallen; thus, twig litter predominates. Hemlock seedlings are scattered throughout in the carpet of bryophytes (almost solely mosses); herbs and shrubs are very sparse. There are occasional, dead, mostly collapsed, bare-branched alders (presumably A. crispa). They occur as individuals, not thickets.

At the seaward end of this zone (270-274) tree density is very great, most trees are 10-18 cm in diameter, thinning has yet to begin, litter is scarce (just fallen twigs), and the closed canopy noticeably is brighter. Herbs are scarce, and Rhytidiadelphus loreus and Hylocomium splendens form a complete forest carpet.

At the height of the slope (275-295), there are some drift logs, many lying with their roots to the sea, boles to the land. Many of these are without spruce germination.

The former gallery (275-285) has a generally closed canopy. In the adjacent pole stand (285-293) trees become increasingly more dense, with dbh's of 2-25 cm. Thinning is restricted to the numerous saplings (2-8 cm dbh). Most trees in this vicinity did not germinate on driftwood. The relatively abundant drift logs and stumps, although moss covered and often lined with blueberries, are still quite solid (they jar the foot that kicks them). Red alder seedlings to 1 m in height are common in this pole stand and the adjacent former forest margins, but hemlocks are absent except for very sparse seedlings. The dense mat of mosses (Hylocomium splendens, Rhytidiadelphus loreus and Dicranum majus) contains very sparse herbs and scarce blueberries.

The former forest margin (292-298) did not initiate primarily on driftwood. The driftwood present includes materials both pre-dating and post-dating the trees. Amongst the row of marginal trees lie some 30 cm diameter boulders.

The rapidly closing gallery at 298-317 is in a zone of old open grown spruce, copse spruce, and galleries. Where open canopy prevails, a continuous mat of Hylocomium splendens and Rhytidiadelphus loreus contains scattered Fragaria chiloensis, some depauperate Lupinus nootkatensis, scarce non-flowering Fritillaria kamchatensis, and a very few Rubus pedatus, sparse Cornus canadensis, and scattered Trientalis europea. The total herb

cover in the openings is less than 5 percent. Bear trails, diggings, and droppings are abundant.

In the galleries there is considerable spruce generation, from 1 year old seedlings to 10 m tall trees. All are of the essentially branchless pole habit. Also present are frequent red alder seedlings and some rather straight boled saplings 5 m tall and 6.5 cm dbh. In the shade of branches where litter fall is not great, hemlock seedlings survive. Most of the open grown and copse spruce germinated on old driftwood. This and unoccupied driftwood in this area is more highly decayed, and (thus) appears older than some of the driftwood at 292-298.

The contemporary forest margin (317-324) presents a very dense and vigorous spruce forest face to the sea of leafy branches to the ground surface. Within this zone there is extensive driftwood, apparently the result of a lost log raft 30+ years ago. Some of the logs are 1.5 m or more in diameter. About the same time, perhaps amidst the jumbled logs, spruce germinated, not on that driftwood, but either in sand or on older driftwood. The older trees are at the back edge of the driftwood and perhaps denote the earliest the log raft could have washed ashore (about 1927). Only recently has there been germination on the now more decayed wood. All trees are spruce, there are no other woody plants or spruce seedlings. Heavy litter fall of needles and some twigs, and dense shade prohibit even the customary bryophyte carpet.

The low meadow just in front of the forest margin has been used sporadically in recent decades by prospectors and other passers-by.

The meadow contains two distinctive zones along this transect. From 324 to 372 spruce germination is common, always upon or beneath driftwood. The abundant driftwood, including some saw timber, is generally well-covered with full meadow growth, or well festooned with bryophytes. From 372 to 399 are concentrated logs from the 1958 Lituya Bay wave and recent driftwood, often lying perpendicular to the shoreline with root bases seaward. There is very scarce spruce germination here. Most of the driftwood lies above the meadow plants, and, like smaller driftwood more hidden, has few to no bryophytes.

Portage Creek Transect - History:

The oldest tree dated, a spruce, germinated in 1808 at the farthest distance from the sea. Since there is no evidence of earlier forest on these deposits it may be that the sands from meter 78 to 144 (or 202) represent either a spit or elevated bar that ceased to be overrun by the sea in the mid- to late 1700's (the contemporary beaches show a lag time of at least 20 years for spruce initiation after the permanent establishment of supra-tidal meadows). At this time most of the lowlands between Lituya Bay and Cape Fairweather drained southwestward through Portage Creek, perhaps occupying the entire channel width from 0 to 52, 62, or 73. Quite possibly at this time there was no stream channel at meter 222 or extensive supra-tidal sands seaward of 222.

From 1808 to 1850 one may presume that a supra-tidal meadow occupied the exposed sands (78-144 or 202), with driftwood being deposited especially at the ridge crest (144) and the lowlands in front. Probably during the

later part of this period an alder (A. crispa) thicket developed along the ridge.

During the next 50 years or so scattered spruce germinated (eg. 1851, 1872, 1873 near meter 92, 1852 at meter 171, 1874 at meter 188 and 1876 at meter 201). Perhaps many of the pole spruce from meter 93 to 133 germinated then too.

As these trees became outliers and copses in the meadow, a surge of spruce germination from 1894 - 1905 (1913) began at the ridge (later to become outliers, copses, and forest margins) and the escarpment lip (202). About the same time (1885, 1907, 1911) hemlock and red alder germinated in the alder (A. crispa) thicket at the ridge crest.

Nearly all of these early germinating trees grew rapidly for their first 3-5 decades. Trees near meter 93 attained significantly retarded growth by 1910. Since about 1930 trees near the ridge have had slowed growth. However, trees from the base of the ridge (158) to the escarpment (202) slowed in growth about 1910.

Consequently, it would seem that by 1910 most or all meadow was gone, replaced by a closed canopy, a canopy that merged with the ridge canopy about 20 years later. The opening and alder thicket at the ridge had the last canopy closure by trees. The principal hemlock initiation beneath this canopy did not begin until or after about 1925.

Thus, the successional sequence here indicated is:

a) establishment of meadow upon sands; driftwood accumulation
b) about 20+ years later spruce germination is successful on or beneath driftwood; additional driftwood may accumulate
c) period of open grown spruce and copse spruce in meadows
d) continued growth and initiation of additional copse and open grown spruce, the coalescence of which begin to form galleries (25-50 years)
e) the abundant seeding of spruce
f) the development of pole stands
g) the closure of the spruce canopy (50-100 years following the initial germination, 30-50 years after the first abundant establishment of open grown and copse spruce)
h) hemlock germination may initiate as early as 25 years following canopy closure.

This sequence, at least its early stages, is repeated on the sands seaward of the former stream course (215-230).

At the lip of the escarpment (202), the two largest spruce demonstrate very similar growth patterns. Both trees, after some years of rapid growth, had 22 years of very subdued growth followed by renewed vigor. The retarded growth began in 1909 for one tree and 1917 for the other. Because of the very narrow rings, there may have been some counting errors. Thus, some time between 1909 and 1917, until 1931 and 1939, growing conditions were very unfavorable. Since other spruce along the transect do not show a similar period of retardation, the conditions must have been unique at this site. Note, additionally, that a spruce that germinated at that site in 1913 grew rapidly during the period of retardation of the

older trees. Presumably, the beginning of the period of subdued growth marks the last erosional events of the stream before the abandonment of the channel, with the trees' root systems being partially undercut and/or protective trees being washed away. After the shock was overcome, some 22 years later, the trees resumed vigorous growth. Furthermore, the alder that seeded in 1920 on the escarpment slope (a similar, smaller alder on the opposite bank germinated in 1928) must have seeded after the escarpment became established. Consequently, sometime before 1920, the stream very likely abandoned this channel (as a new mouth was exposed near the present mouth of Portage Creek), or the stream became much smaller (as Echo Creek, and perhaps Justice Creek and some smaller streams developed their own sea mouths) prior to a later abandonment. Thus, the abandonment of the channel, or any other severe alteration of water flow occurred prior to 1920, but after some time between 1909 and 1917.

These phenomena of the second decade of this century were certainly caused by changes in the relationship between the sea and the long sand beaches, perhaps alteration of currents, uplift of the sands, or variations in sediment loads. This marine/land event (or events) was likely also responsible for the initiation of forest seaward of the old stream course at the same time (two spruce at 240-253 germinated on driftwood in 1910 and 1916). These copse and open grown trees grew vigorously until about 1947. Nearby pole trees that germinated in 1923 and 1933 likewise grew actively until 1947. Pole trees further seaward that germinated in 1927 and 1928 grew rapidly until about 1953. Thus, the open meadows contained some copses and open grown trees by the early 1920's, persisting as meadows until at the latter part of the decade, notably 1927-28, extensive spruce germination occurred (establishment was slightly later further up the slope). By 1947 on the lower slope and 1953 on the upper slope, the spruce canopy closed.

The next sequence of events began in the mid-1930's, with tree germination at the former forest margin and the establishment of outliers and copses in the meadows seaward of that margin. Presumably much of the "recent" driftwood in that region was deposited just before or about the same time. By the mid-1940's there had been sufficient growth and coalescense of the copses and outliers that the present forest margin formed, perhaps in conjunction with the grounding of the log raft and other driftwood (which may have taken place during WW II, perhaps as late as 1945). The galleries behind the present forest margin are incompletely grown in, but a closed canopy may be only a decade away (50 years from the first tree germination at those sites, compared with some 30 years for closure behind the former forest margin - spans comparable with closure durations noted in the older forest on the first part of the transect).

In the meadows within 10-30 meters of the contemporary forest margin outliers and copse trees initiated about 1950 (three trees were dated at 1949, 1951, 1952). However, most germination has been within the 1970's. No dead spruce were seen anywhere in the meadows.

Thus, forest colonization of the beach deposits has been progressive, beginning at the farthest distances from the sea and moving seaward. Colonization is by the establishment of copses and individuals, usually intimately associated with driftwood, and then the subsequent coalescence of the copses and outliers followed by the growth of pole stands. Forest

margins do not migrate seaward, likely because the extensive needle and twig fall in the margins, along with the deep shade, prohibit successful germination. Furthermore, since the forest margins are always essentially parallel with the sea, there must be some elevation and/or distance relationship between the margin and the sea at the time of margin formation.

Important dates for this transect that may relate to geomorphological events:

Mid- to late 1700's - Meadow colonization of the sands in the vicinity of meter 93.
Early 1800's (eg. 1808) - First tree germination, vicinity of meter 93.
Mid-1800's - Scattered spruce germination in meadows on sands from 89-202.
1910's - Changes and/or abandonment of stream course at meter 215-230. Also, germination of first spruce seaward of the stream course.
Late 1920's - Active spruce germination and forest margin formation (at 294).
Mid-1930's - New cycle of driftwood, and copse and outlier germination begins.
Mid-1940's - Establishment of present forest margin.
Early 1950's - Some outlier and copse germination.
1970's - Active outlier and copse type spruce germination in meadows.

Note that the sea margin appears to have been landward of the transect prior to 1800, perhaps as late as sometime in the 1700's. The margin may have been near the former stream course sometime in the 1800's, then seaward of present shoreline in the late 1800's (?) and early 1900's. At some point landward progression of this shore began (most significantly near the present mouth of Portage Creek), yielding the present retreating shoreline through erosion.

Steelhead Creek Transect - Description:

The profile of the Steelhead Creek Transect (Figure 18) is relatively simple and agrees in form with the shore features as described by Derksen (1974). The beach deposits consist of about 160 meters of sand with occasional boulder or outcrop exposures topped by vegetation less than 110+ years old. These beach deposits abut a steep escarpment that is presumably cut into bedrock. The lower part of the escarpment and the beach sands post-date Derksen's event "A_1". The upper part of the escarpment apparently represents Derksen's "A_1" sea cliff. The upper surface figured is Derksen's "B" terrace. At the base of the escarpment, there are large (up to 5 meters in diameter) boulders (some of which are cavernously weathered) and some bedrock outcrops. The larger boulders are much exposed. At meter 141-146, there is a row of boulders 2-4 meters in diameter aligned parallel with the shoreline; these boulders are 75-85% buried and generally covered with bryophytes. At meter 171, there are several nearly covered, cavernously weathered boulders of undetermined size.

The forest on terrace "B" is clearly several generations old. The forest floor is a mass of decaying timbers in various states of decay from recent to almost unrecognizable. The site contains a superb example of a multi-generation forest with mixed age trees, openings due to the toppling of trees dead from old age, seeding spruce and hemlock, deep litter, and dead-falls of all ages, with most trees rooted well above the ground

surface on old fallen logs or upon stumps. Most spruce are 30 to 120 cm in diameter, with one of the larger spruce measuring 166 cm at 2 m above the ground surface. Fallen spruce festoon the forest floor. Seedling spruce are scarce except for along some rotting logs at sites with broken canopies. There are slightly more hemlock trees than spruce trees, but hemlocks occur in all sizes from seedlings to canopy trees 60 cm or so in diameter. One large hemlock measured 172 cm in diameter 2.3 m above the ground surface. Older hemlock trees show decay and rot with snags of all size classes present. There are no alders. The understory is a typical spruce-hemlock forest understory with abundant shrubs, herbs, and bryophytes. Most tree root bases begin about 1-1.5 m above the ground surface.

At the lip of the escarpment (44), there is nothing to indicate age transition with the escarpment slope, such as open grown trees. However, the escarpment forest is clearly different.

The escarpment slope is not as uniform as depicted in the illustration, but includes mounds and humps up to 3 meters in height. These mounds and humps are likely the result of decaying forest materials or of other undetermined substrate. In the upper part of the escarpment, these clearly appear to be primarily composed of old stumps, logs, and windthrown root bases. The forest at this site appears to be of at least two if not many generations, for there are the remains of fallen timbers in every state of decay. A good many of the living trees are rooted on old logs or root bases, many of which are decayed away, leaving root bridges several feet in the air.

Spruce predominate over hemlock by about 5 to 3. The spruce range in size from 22 cm in diameter. Some are sub-canopy in height. Hemlock trees are of similar size and canopy or sub-canopy in height. Locally, there are abundant hemlock seedlings and saplings. Both larger and smaller hemlock and spruce trees often show seaward branching throughout their height. The branches do not persist to old age, but do reach 10 cm or so in diameter. They are alive on some younger trees. Currently, the trees of the zones below are sufficiently tall that these branches are now in forest shade and can be expected to die shortly.

Red alder are scarce on the slope but one 20 cm dbh, non-decorticated, sub-canopy, dead individual was seen mid-slope. There are no Sitka alders either alive or dead. The forest understory is similar to that described above.

The differences in the forests on the "B" terrace and the escarpment may be due to topographic and substrate differences and not to age. This might account for the lack of any significant "marker" trees at the lip of the escarpment.

At the base of the escarpment, even more curiously than at the lip of the escarpment, there is no marked boundary of vegetation change between the escarpment and the flatlands below. Nevertheless, the forest composition changes quite visibly. Beginning at meter 76 and extending seaward, there is no longer a deep layer of dead-falls at all stages of decay, nor are there trees with elevated root bases. All of the large spruce trees have their own individual cones of litter as in first stage spruce succession. Spruce trees range in dbh from 19 to 52, with many of the smaller trees dying,

dead, and/or toppled by natural thinning. Fallen large spruce are very rare. Hemlock trees are sparse, not uncommon as saplings, and abundant as seedlings. There is little hemlock death. Red alders are sparse to occasional, 17 to 40 cm in diameter, and usually reach the canopy. Their trunks commonly are covered with bryophytes and occasional plants of Polypodium vulgaris. These trees may be approaching maturity, but no dead individuals were seen. There are no young red alders, or any Sitka alders. The forest floor is floristically similar to those of the escarpment and upper terrace except that there are fewer species of vascular plants and fewer blueberries. The lack of a sharply defined vegetation boundary between the forests of the flatlands and the escarpment is somewhat puzzling.

In the pole stand behind the former forest margin, the forest is clearly in a primary succession stage with much thinning. Spruce predominate, with dbh's of 20 to 44 cm. The naturally thinned dead trees range from 4 to 20 cm in diameter. The larger spruce show stout dead branch stubs at their base, or throughout their height, indicating that there were a number of outliers prior to the seeding of the pole stand. Very few hemlocks reach the canopy; 90 percent are saplings 2 to 4 m in height. Red alder grow here and there, usually 22 to 32 cm in diameter. They usually reach the canopy, but are leafy in their top 7 to 8 m. They are quite healthy, though occasionally somewhat leaning. Only one dead individual was seen. There are scarce to rare saplings. There are no Sitka alders.

Forest litter in this region is restricted to branch fall, thinned small spruce, and needles. The understory is similar to the previous site.

Just behind the former forest margin there are a few more red alders, with some individuals 50+ cm in diameter. Also, a few trees of spruce clearly germinated on driftwood.

The former forest margin now has a closed canopy and very distinctive old outlier, copse, and margin trees. There is very little litter, and sparse driftwood. Occasionally former galleries still retain small canopy openings. In some of these openings, there are a few sapling spruce, most of which are doing very poorly and can be expected to die. Hemlock are totally absent from this point seaward, except for a very few seedlings within 10 m or so of the contemporary forest margin.

Many of the older trees at or near the present forest margin germinated on driftwood. The drift logs are highly decayed, but their form can be seen. They usually lie at right angles to the beach. Here, too, there is heavy needle and twig litter that excludes most herbaceous and bryophyte growth (most bryophytes are restricted to roots, tree bases, boulders, etc.). A few red alders grow at the present forest margin, these being generally 22 to 30 cm in diameter. The branches of the dense tree growth at the forest margin facing the sea are dense and heavily overlapped, providing a wall of photosynthesis facing the sea. These branches extend to the ground surface.

The supra-tidal meadows begin exactly in front of the spruce branches. Zones within the meadow are not clearly distinguished except that from meter 248 seaward there has accumulated recent driftwood as well as the logs from the 1958 Lituya Bay wave. There is not a sharply defined erosional

margin to the meadows, as "bottom zone" vegetation extends down the sloping sand face until an active cobble zone is reached. For the most part, the meadow is tall in character, there being only isolated patches of low, strawberry meadows.

For the most part, spruce trees in the meadow become less abundant and shorter with distance from the forest margin. Copses tend to be taller than free standing individuals. A typical copse slightly north of the transect contains trees 6 to 8 meters tall. All trees in the copse from the tallest to those less than 20 dm in height have begun their growth on driftwood. The driftwood is fairly intact. At the outer edge of the copse, there are a very few, somewhat more recent drift logs. The copse is really a collection of several copses, with galleries of meadow between. Nearly all germination habitats were occupied early, thus providing the distribution of the trees. It is very easy to distinguish the first trees in the copse by their very heavy branching. Trees begun in their shade are smaller in dbh and branchless until they break out above and form part of the canopy. The original trees have very large bases; for example, one individual is 78 cm in diameter, 30 cm above its drift log, and is only 26 cm in diameter, 3.5 m above the ground. The above ground roots along and around the driftwood are often massive. A very few young spruce have begun to germinate on sand substrates in the galleries.

Throughout the meadow there are a number of logs yet to be colonized. They are mostly hidden and bryophyte-covered. Treeless logs are more common closer to the sea.

An exception to driftwood germination was located in a strawberry patch. A small cluster of seedling spruce were rooted in 15 cm deep rich meadow humus. The seedlings were 4 to 5 years old, 40 to 60 cm in height, with very shallow root systems, that stayed in the organic layer and did not penetrate sands and gravels beneath. Another two-year-old spruce seedling, 12 cm tall, was also located in the same strawberry patch.

It was my impression that there is an equal representation of age classes from contemporary germination to 30+ - year-old trees in the meadows.

The outlier tree at meter 248 is very distinctive. The log upon which this tree germinated is quite visible and is surrounded by an exceptionally massive root system. Unlike most spruce trees in beach meadows or in forests, this tree has severe salt and/or wind shear on the ocean side. Such flagged spruce are very uncommon, and the susceptibility of spruce to flagging by the sea might be limited to only those individuals in highly exposed settings very near the sea. Perhaps this is indicative of the distance from surf that spruce can colonize meadow. The tree was cored 60 cm above the ground surface, at which point there were 28 rings. The innermost 7 rings occupied over 2 cm. Subsequently, there were 4 wide rings, 2 narrow rings, 5 very wide rings, and 10 wide rings. The tree experienced leader death at 2 m height above the ground. The subsequent leader died at 3.3 m above the ground. After each of these leader deaths, two or more main stalks developed, giving the tree a dense, bulky appearance. There has been continued leader death in the top m of the tree. Twin stems, 2 1/2 m above the ground surface, each have individual diameters of 25 cm. Large live branches extend from the tree outward at least 6 m from the tree base. However, although up to 1 1/2 m of some of the branches

are well covered by mosses and herbs, there is no layering whatsoever. Similarly, there is no seed germination anywhere beneath this tree. The tree has abundant cones and at least two birds' nests.

Steelhead Creek Transect - History:

Because of the large size of trees on terrace "B" and the escarpment, and because these forests are multi-generation, it did not seem to be of value to date any trees in these zones. Included on the illustration are two dates provided by Weisbrod (this volume) that clearly show there have been forests on these surfaces for centuries prior to the establishment of forests on the beach deposits below.

In the latter quarter of the 19th century, there must have been meadows extending from the base of the escarpment to at least meter 170 and probably somewhat beyond. At this time, spruce began to germinate on driftwood, forming outliers and copses. In the middle of the pole stand (near meter 110), spruce growth became retarded about 1900. At this same time there was the initiation of hemlock germination, presumably as the spruce canopy closed by the merger of copses and outliers along with the growth of pole trees. About ten years later, in the early 1920's, red alder germinated, growing rapidly until about 1950, at which time they may have reached the canopy. Subsequently, there has continued the germination of hemlocks and occasional spruce. Most of these later arrivals have very narrow growth rings and subdued growth overall.

The spruce of the former forest margin grew rapidly until about 1950 or later, at which time the present forest margin trees appear to have gained sufficient height to retard the growth of the former forest margin trees. The outlier tree at meter 164 shows no retardation in growth until 1974.

It would appear that from the closure of the forest canopy just described until the early 1930's, there was an open beach or supra-tidal meadow from approximately meter 170 to the sea (whose shore position is not determined). By the early 1930's the elevation of the sands in this region or their distance from the sea was sufficient to allow spruce germination on the well scattered driftwood. After a seeding surge in the 1930's, a new forest margin (the contemporary forest margin) was established. Subsequently, there has been continued germination in every decade of about equal amounts. There is no indication that the region of tall meadow containing recent driftwood and logs from the 1958 Lituya Bay wave, which slopes toward the sea, has any recent spruce germination. I suspect that this site is still too exposed for germination.

Consequently, there seem to be relatively few periods of geomorphological activity that have been documented by the vegetation in this transect. It is clear that the escarpment was cut and vegetated more than 400 years ago (that determination is based upon tree ages of 200 years rooted upon stumps of similar size). The establishment of spruce on beach deposits began in the 1870's and 1880's. A second surge of germination occurred in the early 1930's. No other dates appear significant.

Where there has been closure of canopy by pole stand growth, it appears to have taken about 30 years. This compares favorably with the length

of time required at similar circumstances on the Portage Creek transect.

The two significant dates of the early 1870's to 1880's and the early 1930's, correspond roughly with events at the Portage Creek transect. At the same time that spruce were beginning to germinate on the Steelhead transect in the 1870's-1880's, there was scattered spruce germination in meadows and on sands in the older sites on the Portage Creek transect. The most significant correlation is the important surge of copse and outlier germination on driftwood at both sites in the mid-1930's.

Thus, the pattern of succession on beach substrates at both sites is essentially identical. The succession that has transpired on these unconsolidated substrates has occurred within the same two centuries.

The Portage Creek transect reveals several significant dates relating to geomorphological events; the Steelhead transect reveals two correlative dates. The Portage Creek transect indicates two additional periods of recent germination, the early 1950's and the 1970's, and there is active germination of spruce on driftwood in the Steelhead Creek meadows at the present time.

Tree Ages From Adjacent Beach Deposits:

Cores of five additional old large spruce trees on beach deposits near the bedrock escarpment south of Steelhead Creek show equivalent ages and growth characteristics, and correspond well with the Steelhead Creek transect. These trees germinated in 1861, 1864, 1872, 1875, and 1884. The first 50-90 years of their growth was in relatively full sunlight producing large growth rings followed by closure of the forests. Forest closure occurred from 1926 to 1954. The largest trees are both the oldest and those with the largest number of wide rings. Thus, curiously, the trees which happen to have been first established were not those at sites that first became forests.

Also cored were eight additional trees on beach deposits (one on a lateral moraine) north of Lituya Bay, all displaying life forms, growth patterns, and ages consistent with the Portage Creek transect. The two oldest of these were in the vicinity of Justice Creek at or near the landward margin of the beach deposits. They germinated in 1743 and approximately 1727. The other trees variously located on the beach deposits germinated in 1801, 1813, 1841, 1891, and 1901. The trees that germinated in 1801 and 1813 are now marginal trees along an actively degrading beach front.

The presence of multi-generation forests at the landward edge of the beach deposits northwest of Lituya Bay has not yet been firmly documented. It is clear, however, that the surface of these beach deposits became sufficiently elevated and stabilized that they began vegetating in the vicinity of 1700 or somewhat earlier. Possibly the outwash from Lituya Bay, La Perouse Glacier, and Fairweather Glacier was so great during the Little Ice Age that by 1700 there was deposition of materials north of Lituya Bay extending to the Fairweather Glacier. Some time (perhaps tens to hundreds of years) prior to that time lower land levels permitted the sea to reach the base of the bedrock escarpment east of the present lowlands. Once the beaches began to form north of Lituya Bay, the terrain between them and the escarpment became wetlands, slough, and lake. These drained

southeastwardly around the beach deposit, indicating that the offshore flow was from northwest to southeast. In recent times, perhaps as recent as 1850 judging by the tree ages on the landward half of the Portage Creek transect, it appears that the direction of off-shore deposition has been reversed. This change in apparent flow may be due to changes in the time of years when material is being deposited, and the source of the material. For example, if the principal time of deposition formerly was during the season of highest melt from glaciers, then deposition would have been in spring and summer. However, it is possible that with the loss of this heavy sediment load in post-neoglacial times that where there is now beach deposition, it occurs primarily during the winter as a response to erosion somewhere else along the coastline. Thus, we see now a minor reshaping of the beach edge due predominantly to erosion.

If this history be correct, then the fluvial fans north of Lituya Bay behind the beach deposits may have begun in neoglacial times and first were deposited directly into the sea. The bulk of their deposition likely has been within the last 200-300 years, however, as their formation would have been much retarded by the erosive activity of tidewater. Their growth ultimately redirected waterflow, opening the Justice and Echo Creek breaches in the sands, thus severely reducing streamflow at the mouth of Portage Creek, the ancestral common channel for nearly all runoff from lowlands northwest of Lituya Bay. These events, plus the capturing of lower Portage Creek by sea erosion, have certainly affected the development of the Portage Creek transect.

Forest Initiation Versus Distance From and Height Above the Sea:

At both transects a remarkable correlation (Figures 20 and 21) exists between distance from the sea and the oldest tree at each site on the transects where tree ages were determined (excluding the multi-generation sites at Steelhead Creek). Although, as pointed out elsewhere in this text, the forests have seemingly advanced and developed in spurts (which can be vaguely ascertained in these figures) the generalized pattern is progressive colonization to the seaward by spruce at rates of 2.05 and 1.31 m/year.

Seemingly more significant for colonization should be the height of substrate above the sea; however, distinctive correlations between terrain height and tree age are not as clear (Figures 22 and 23). At both transects, there is no colonization at elevations less than 6 m (6.5 m in exposed places near the sea) above mean sea level; at Portage Creek transect active colonization occurs at about 7 m and at Steelhead Creek transect around 8 m. These values should be compared with Molnia's (this volume) measurements.

Hicks and Shofnos (1965) report 0.018 m/year neoglacial isostatic rebound at the study area. Derksen (1976) determines similar uplift rates, but Goldthwait, et al. (1963) report exposed stumps near sea level at Lituya Bay as old as 9150± 275 years B.P.

At the Portage Creek transect, considering only the trees seaward of the abandoned stream course on terrain that is level or sloping toward the sea (meters 275 to 399), there is a weak correlation (r=0.60) between age of trees and height of land surface, with a relationship of 0.019 m/year. Similarly, tree ages on the beach deposits at the Steelhead Creek transect are weakly correlated (r=0.66) with the height of land surface, showing a

Figure 20. Age of oldest tree per sampling location along the Portage Creek transect versus the distance from the seaward edge of the supra-tidal meadows. (next page)

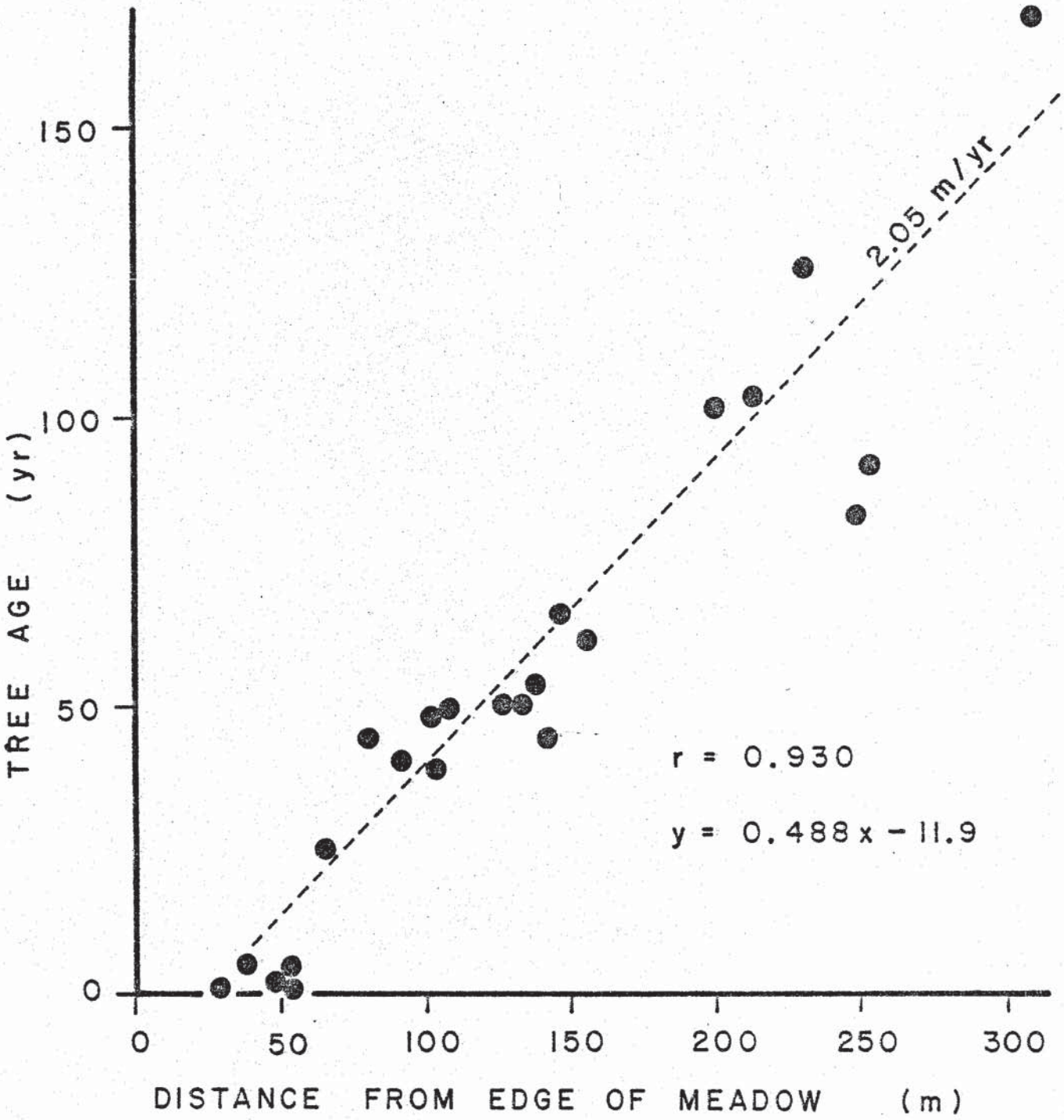

150
100
50
0
TREE AGE (yr)
2.05 m/yr
r = 0.930
y = 0.488x - 11.9
0
50
100
150
200
250
300
DISTANCE FROM EDGE OF MEADOW (m)

Figure 21. Age of oldest tree per sampling location along the Steelhead Creek transect versus the distance from the seaward edge of the supra-tidal meadows. (next page)

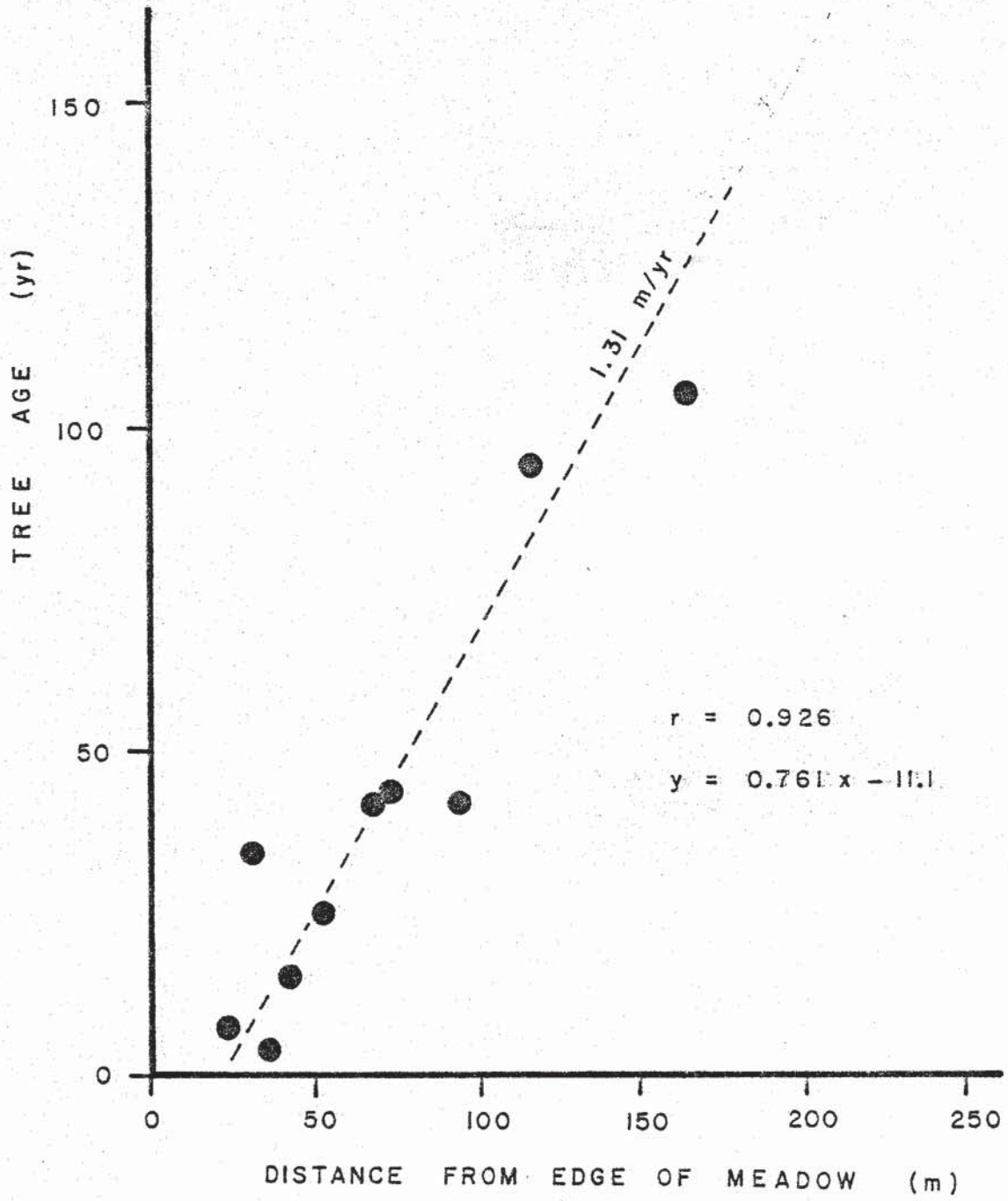

150
100
50
0
TREE AGE (yr)
1.31 m/yr
r = 0.926
y = 0.761 x − 11.1
0
50
100
150
200
250
DISTANCE FROM EDGE OF MEADOW (m)

Figure 22. Age of oldest tree per sampling location along the Portage Creek transect versus height of terrain above mean sea level. "Older forest" refers to sites landward of the abandoned stream channel, and "younger forest" refers to sites seaward of that channel. Open triangles are Alnus oregona, the open hexagon is Tsuga heterophylla, all other are Picea sitchensis. (next page)

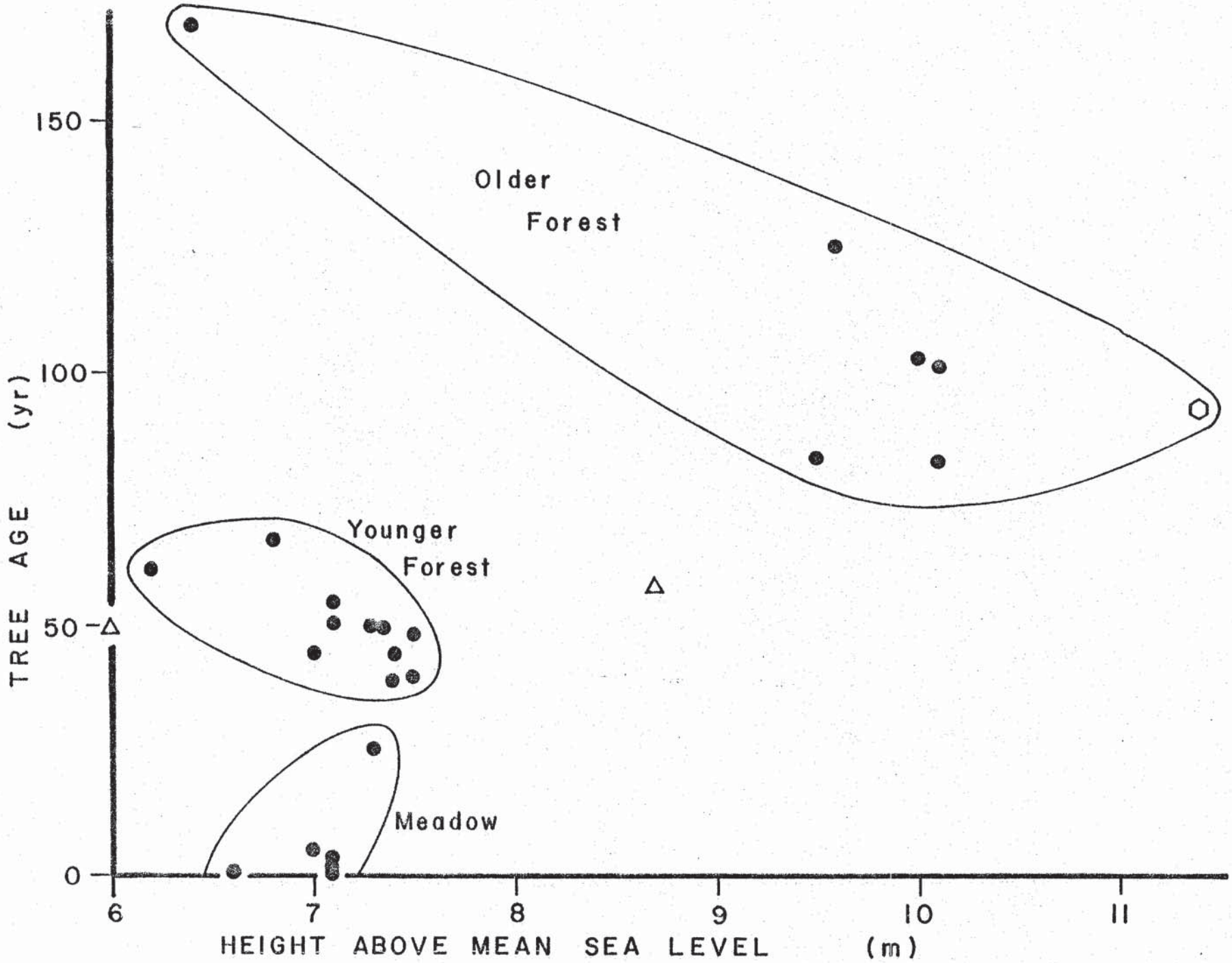
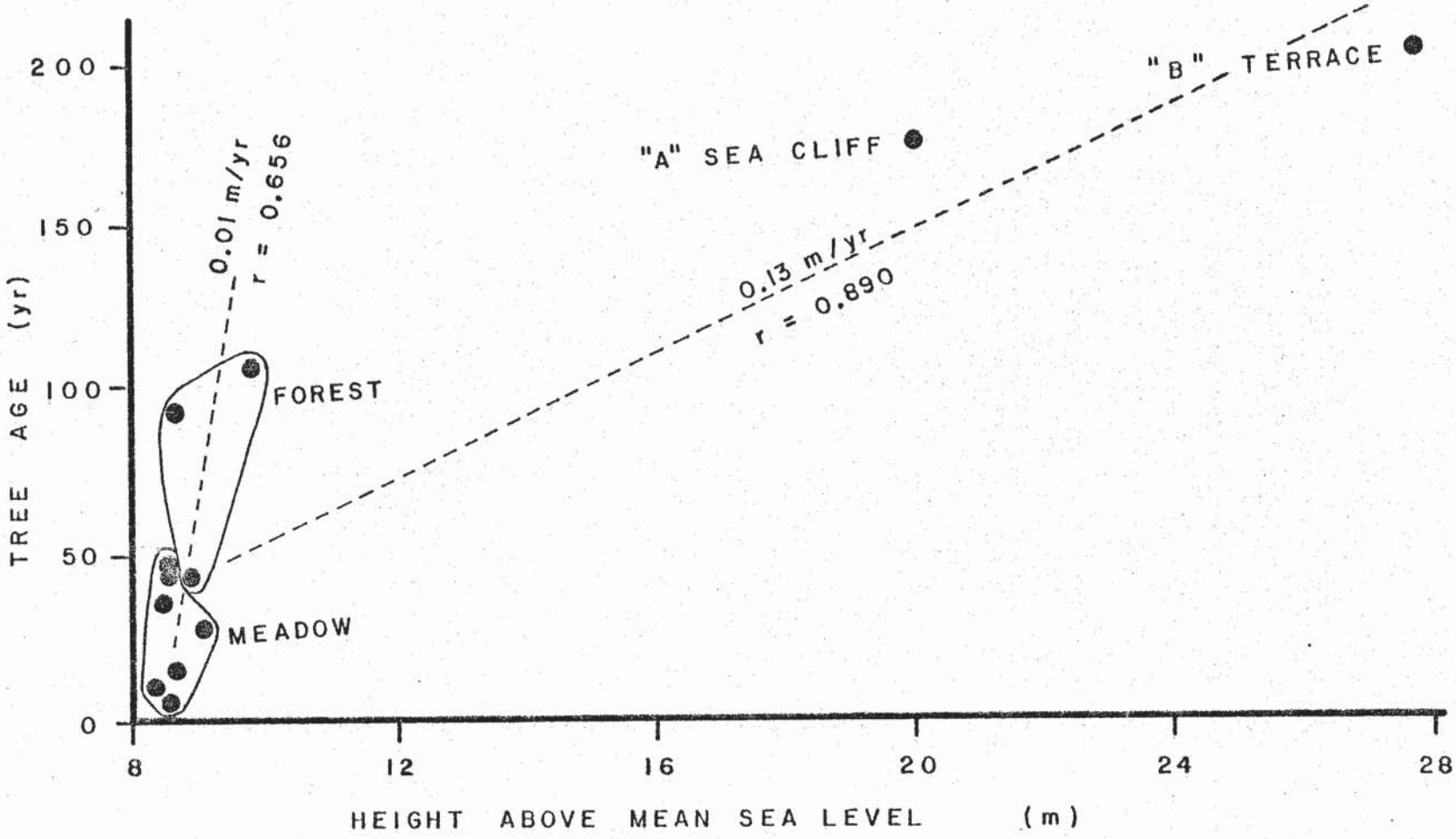

150
100
50
0
TREE AGE (yr)
Older
Forest
Younger
Forest
Meadow
6
7
8
9
10
11
HEIGHT ABOVE MEAN SEA LEVEL (m)

Figure 23. Age of oldest tree per sampling location along the Steelhead Creek transect versus height of terrain above mean sea level. The regression including the two tree dates on the "A" sea cliff and "B" terrace is included to show the absolute maximum uplift rate (which is even too great because those trees are at least second generation trees). (next page)


200
150
100
50
0
TREE AGE (yr)
0.01 m/yr
r = 0.656
"A" SEA CLIFF
"B" TERRACE
0.13 m/yr
r = 0.890
FOREST
MEADOW
8
12
16
20
24
28
HEIGHT ABOVE MEAN SEA LEVEL (m)

relationship of 0.011 m/year.

Consequently, it seems plausible that, at least within the last 100 years or so, tree colonization of beach deposits may be related to post-Little Ice Age isostatic rebound. This rebound cannot account for the remainder of the vegetational features along the Portage Creek transect.

Consequently, on sand deposits along the outer coast of the study area:

a) Forests (i.e. spruce) cannot colonize at elevations below 6.5 m above mean sea level adjacent to active beaches.
b) At the present rate of isostatic rebound, provided sands are available, forest colonization can keep pace with the available terrain as it reaches sufficient elevation (at least 6.5 m, and perhaps 7+ m. I am prone to think that the elevations of recent tree colonizations of the two transects are more similar than indicated; the calculation of mean sea level may be slightly in error at one or both transects).
c) When extensive terrain is available for colonization (and perhaps even overshadowing "b" above) forest colonization begins at the farthest distance from the sea, and progresses seaward.

If sea and land relationships were to remain the same in the next decades, perhaps centuries, one can expect that the closed canopy forests will continue to mature through natural thinning and diversification, with hemlock gaining added importance and organic materials accumulating rapidly upon the forest floor.

At both transects where there are now beach meadows with active spruce germination, one can expect by 2010 or before that the meadows will be replaced by youthful spruce forest with a predominantly closed canopy. This forest might extend completely to the sea's edge at the Portage Creek transect depending upon the ability of spruce to develop at the eroding lip. Depending upon the rate of erosion of the sands, that margin would either be heavily branched and thick down to the ground surface if the erosion rate is quite slow, and would be composed of more or less exposed boles and shrubby undergrowth if the rate of erosion is rapid. At Steelhead Creek, a new forest margin can be expected to form at the landward edge of the zone of recent drift and logs from the 1958 Lituya Bay wave. At this time, there is no clear indication that the area of recent driftwood is initiating a cycle of germination leading to forest; perhaps this is because of its low elevation or proximity to the active sea.

Future:

The general pattern of vegetation activity on the beaches of the outcoast of the study area is that wherever there are well-established beach meadows on sand, there currently is colonization of the meadows by spruce. Sporadic events such as large storms, Lituya Bay waves, and uplift in the relationship of the beach to the sea provide substrate for forest growth. The spruce germinate on decorticated driftwood, initially producing the phenomenon of outliers and scattered copses. The density of trees in the meadows is less and the trees are somewhat younger and shorter nearer to the sea, and the migration of the closed canopy forest to the sea is not uniform. Once colonization begins, and the copses and outliers become established, there continues a unidirectional change providing a closed canopy within 30-50 (?0)

years, with a pole stand overtaking and overtopping the outliers.

The active beach front takes two forms in general along the coast: a) that of an erosion scarp where the sea is directly cutting into either beach meadows or forest, and b) a depositional beach margin in which water and wind-borne sands are building. In the former situation there is every indication that spruce are capable of occupying all or nearly all of the elevated terrain (be it of sufficient height above mean sea level) right to the point of erosion. In the second case, it is not clear if the spruce can occupy sites with over-wash or shifting sands. Certain herbaceous species such as Carex macrocephala can persist on these sands and accomodate their changes. Presumably, the spruce could invade beach deposits only after their stabilization, and then principally upon driftwood, but apparently only if the sands are 6.5 m or more above mean sea level.

The broad beaches of dense meadow growth which now occupy so much of the terrain adjacent to Lituya Bay are a phenomenon of succession and can be maintained only through persistent growth of beach deposits at a rate at least as rapid as forest colonization.

If uplift continues at a site, with no corresponding outgrowth of shoreline (an unlikely situation), there will come a time when the height of beach will be sufficient that a stable vegetation interface will form. At this point, one can expect a dense forest stand to colonize the beaches, with a very narrow beach meadow. The forest ultimately will be spruce and hemlock in the traditional multi-generation composition. Sitka alder may form a lateral fringe along the forest, although it is not at all clear that this will indeed happen. Or, if there is a broad zone of mobile sands, then one will not expect extensive beach meadows of great density but rather communities with scattered Elymus and Carex macrocephala like those found at Inner Point and Astrolabe Beach (Dixon Harbor study area), and at certain locations in this study area. At other places where there is a lag concentrate of boulders and/or bedrock forming the transition between the active sea and the stable beach deposits, one can expect a very narrow marginal beach meadow to form.

Molnia (this volume) provides data which bear on the prognosis for these various possibilities.

Portfolio of Photos Along Transect:

A group of photos illustrating principal features of each transect's vegetation is retained in the Bartlett Cove library.

Susceptibility to Disturbance

Succession on the beach deposits appears to be vigorous and active. In the vicinity of Portage Creek and Echo Creek this succession has definitely obscured the considerable human activity, both native and European, that has occurred on those beaches. It is not likely, therefore, that low levels of visitor usage in the form of pedestrians would cause significant alteration of the vegetation sequence or ground surface. Recovery times from human scale disturbances appear to be in terms of one to several decades until most or all traces have been masked. This assumes, of course, that recovery is not impeded by continued human activity.

If the beach sands were to be mined for gold, titanium, or other minerals, then there could be distinctive alteration of the beach geomorphology, not to mention the tremendous devastation of the surface vegetation. Presumably sands that were dug would recolonize rather quickly, although there are no data to estimate the recolonization rates. Likely within ten years following a mining operation, most beach meadow plants would have become re-established.

Since the initial spruce depend upon an organic, raised, substrate for germination, one could speed the subsequent forest recovery by the careful deposition of decaying wood. Once the spruce become established, then succession would approach normalcy and closed canopy could be anticipated within 50 years or so of spruce establishment. However, even one or two years of exposed sands might be adequate for a significant amount of active dune formation to begin. Dunes, per se, in their active form are not now known in the study area. If dunes were to form because of the large exposure of the sands, they would likely move landward. The forests of spruce cannot stand cover by sand around the tree bases and, therefore, would subsequently be killed. There would then be the loss and alteration of considerable amounts of habitat. If, north of Lituya Bay, the sand dunes migrated through the forests to the sloughs behind, they would enter the streams such as Justice Creek or Echo Creek and be recycled to the mouths of those streams, causing alteration of the general beach topography. The extent of this alteration would depend upon the magnitude of the mining.

Oil spills along these beaches would have an unknown effect. It is eminently clear that the presence of organic substrates and of spruce trees are the two most important features in the establishment and maintenance of the vegetated landscape on the beach deposits. If the spruce are susceptible to windborne and waveborne oil, then severe catastrophe could occur. It is clear that wave splash is carried, during storms, onto the land by winds that ride over the forest canopy and by winds that enter the forests below the canopies wherever there is not a continuous bulwark of heavy branching. These winds could carry oil several hundred meters from the shore. Since the effect of oil upon spruce is not known, the effect of such airborne oil is not known. It is apparent, however, that the spruce are definitely affected by sea spray nutritionally. Spruce within 100 or 200 m of the sea are clearly richer and darker in color than spruce at a distance from the sea. If the oil spill were sufficient to kill spruce trees, whether or not they were immediately adjacent to the sea or further back on the deposits, it is not likely that a single spill would cause significant damage to the essential character of the beach deposits, for the dead spruce trees would likely remain in situ for a long period of time. As they broke and their twigs and stems fell, or were blown over, more organic material would be deposited beneath them on an existing organic substrate. Presumably very quickly after the oil spill, a number of adventive or weedy species would occupy the terrain, leading quickly to a recolonization by spruce of the beaches. (It could be that the rather slow colonization of the beaches at the present time is partly due to a slow dispersion rate by spruce seeds, with spruce seeds not moving seaward nearly as well as they move landward. However, it should be noted that many trees along forest margins are often heavy with cones and presumably bear viable seeds.) Thus, the death of the forests, a negative feature in itself, would probably not lead to a significant alteration in the beach sand geomorphology. There would, however, be a tremendous change in biotic habitat were the spruce to die.

If the oil spill killed the majority of the herbaceous plants in the beach meadows, there could be considerable acceleration of erosion or re-deposition by winds along the beaches. The period of time for recolonization by the meadows is not known. Possibly it is long enough that considerable alteration of the beaches could occur.

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