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Shoreline Vegetation of the Arctic Alaska Coast

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ABSTRACT. The vegetation of shoreline habitats was examined and systematically sampled at 15 locations along the Chukchi and Beaufort seas of arctic Alaska. In tidal salt marsh habitats, sampled at eight locations, three plant communities are described: *Puccinellia phryganodes*, at the seaward limit of vascular plant growth; *Carex subspathacea/P. phryganodes*, at midtidal levels; and *Carex ramenskii/C. subspathacea*, at the upper limits of the tidal zone. *Dupontia fisheri* was the major dominant in the upper storm zone above the tidal communities. Plant communities of raised beaches, sampled at four locations, were floristically variable, but *Salix* species and *Elymus arenarius* consistently had high prominence values. *Elymus arenarius* dominated the five gravelly beach habitats sampled. Coastal dunes were sampled at two locations and again *Salix* and *Elymus* were the most important plant genera. Finally, four eroding coastal bluffs were examined and abundance values were assigned to representative plant species.

RÉSUMÉ. La végétation d'habitats littoraux a été étudiée et échantillonnée de façn systématique à quinze endroits sur les rivages de la mer des Tchouktches et de la mer de Beaufort en Alaska arctique. Concernant les habitats de la zone des marais salants soumis aux marées, échantillonnés à huit endroits, trois associations végétales sont décrites: *Puccinellia phryganodes*, à la limite de croissance vers le large des plantes vasculaires; *Carex subspathacea/P. phryganodes*, dans la zone du niveau moyen des marées; et *Carex ramenskii/C. subspathacea*, aux limites supérieures de la zone intertidale. *Dupontia fisheri* prédomine dans la zone des marées de tempête au-dessus des associations végétales affectées par la marée. La flore des plages soulevées, échantillonnée à quatre endroits, est variée mais les espèces du genre *Salix* et *Elymus arenarius* prédominent de façon constante. *Elymus arenarius* domine les cinq habitats échantillonnés sur des plages de gravier. *Salix* et *Elymus* sont aussi les genres les plus importants aux deux endroits échantillonnés sur des dunes côtières. Enfin, pour quatre escarpements côtiers érodés, la présence des espèces représentatives fut quantifiée.

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INTRODUCTION

This study was a part of a multiyear research program administered by the Outer Continental Shelf Environmental Assessment Program (OCSEAP). The program objective relevant to this study was to provide "descriptions and definitions of the vegetation of those portions of arctic Alaskan beaches likely to be inundated by periodic, wind-driven high water" (Broad *et al.*, 1978), thus increasing predictability of the effects of oil spills on shoreline ecosystems. Comparative oil resistance of species common to arctic tundra communities has been documented by Walker *et al.* (1978). They showed that plants with the highest recovery potential included sedges, willows and some grasses, dominant groups in shoreline communities described in this paper. Most dicots had low recovery potential, especially *Dryas*, a conspicuous taxon on ice-cored mounds (pingos) and hard, rocky raised beaches.

A few of the numerous publications dealing with arctic vegetation include general overviews (Britton, 1966; Bliss *et al.*, 1973); in-depth regional floristic treatments (Johnson *et al.*, 1966; Brown, 1975; Bliss, 1977); classification of vegetation types (Hanson, 1951, 1953; Wielgolaski, 1972); and comprehensive ecosystem analyses (Bliss, 1977; Tieszen, 1978). However, most studies concerning shoreline vegetation of arctic Alaska are floristic in emphasis. A notable exception is the work of R.L. Jefferies (1977) dealing with the description and productivity of coastal salt marsh vegetation.

METHODS

Vascular plants were sampled at fifteen stations established by Broad *et al.* (1978) along the Chukchi and Beaufort sea coasts (Fig. 1, Table 1). The stations included, often in combination, such landscape units as moderately steep gravelly beaches; wave-cut, eroding shores; raised, hard-packed, gravelly beaches; and gently-sloping, muddy shorelines. At each station, the habitat was classified on the basis of physical factors (Table 1) and areas exhibiting a high degree of vegetation homogeneity were sampled. Thus representative communities were discerned.

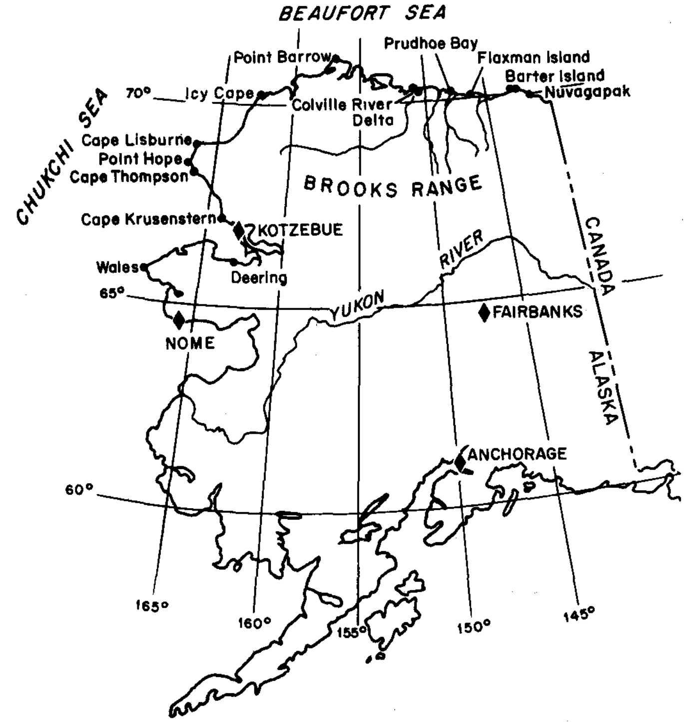

FIG. 1. Location of research stations along the Chukchi and Beaufort seas of arctic Alaska.

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TABLE 1. Research stations and associated habitat types

Station	Lat. N	Long. W	Habitat types
Chukchi Sea			
Wales	65° 37′	168° 02′	Gravelly beach; coastal bluff
Deering	66° 05′	162° 45′	Coastal bluff
Cape Krusenstern	67° 09′	163° 44′	Gravelly beach; raised beach
Cape Thompson	68° 06′	165° 48′	Gravelly beach; raised beach
Point Hope	68° 21′	166° 45′	Gravelly beach; raised beach
Cape Lisburne	68° 52′	166° 09′	Gravelly beach; raised beach
Ice Cape	70° 17′	161° 52′	Coastal bluff
Beaufort Sea			
Point Barrow	71° 23′	156° 27′	Salt marsh
Prudhoe Bay	70° 20′	148° 15′	Salt marsh; coastal dune
Colville River (2)	70° 29′	150° 25′	Salt marsh; coastal dune
Flaxman Island	70° 12′	146° 59′	Salt marsh
Barter Island (2)	70° 06′	143° 38′	Salt marsh
Nuvagapak Pt.	69° 53′	142° 19′	Salt marsh; coastal bluff

Vegetation sampling was conducted during July and August, 1977, using the sampling format of Bliss (1963). At each station, five 4 × 8 m plots were laid out parallel to the shoreline (Fig. 2). The 8 m side was marked and numbered at 1 m intervals. Four of the eight numbers were randomly selected to establish points from which four 4-m transects were perpendicularly oriented. Along each transect, five 20 × 50 cm frames were systematically centered at 0.7 m intervals with 0.5 m between frames (Fig. 3). Coverage values were estimated for each species in each frame using the cover class system of Daubenmire (1959). The mean cover (C) and percent frequency (F) within the five 4 × 8 m plots were used to calculate the prominence value (PV) of representative species using the formula $PV = \sqrt{F} \times C$.

Attempts at sampling coastal bluffs were abandoned and only relative species abundance was recorded.

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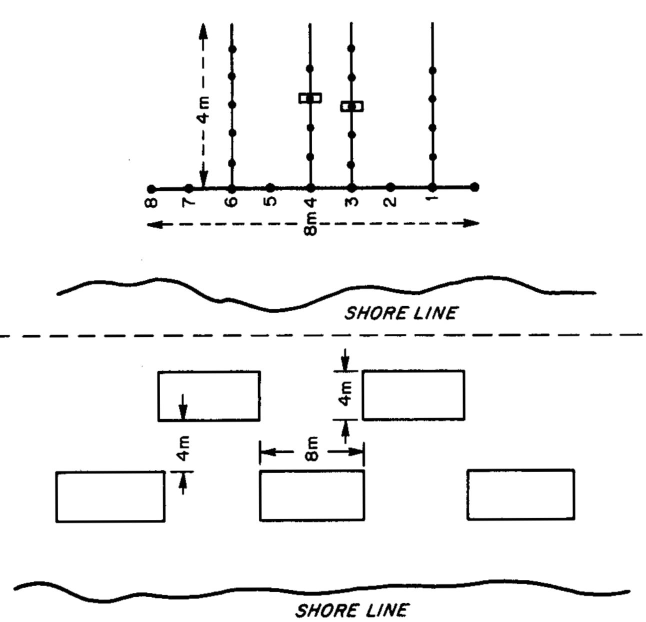

FIGS. 2. and 3. Sampling format. FIG. 2: Arrangement of five 4 x 8 m plots within each plant community at each habitat-type. FIG. 3: Illustrated presentation of the sampling format used in each 4 x 8 m plot.

Abundance values were based in part on incomplete sampling data (owing to steepness and lack of soil stability on some coastal bluffs, standard methodology was impossible) and in part on the subjective determination.

Plant nomenclature follows Hultén (1968). Voucher specimens are housed in the Western Washington University Herbarium (WWB), Bellingham, Washington.

RESULTS AND DISCUSSION

The following five habitat types were recognized: salt marsh, gravelly beach, raised beach, coastal dune, and coastal bluff (Table 1). The salt marsh type was further divided into tidal and upper storm zone. Within each habitat type, plant communities were consistent in distribution and floristically similar. The major observed distinction between shorelines of the Chukchi and Beaufort seas was a predominance of high-relief gravelly beaches with strand vegetation along the former, and low-relief shorelines along the latter. Salt marsh vegetation was mostly restricted to lagoons and estuaries along the Chukchi Sea, reflecting severe wave and ice action, but was widely distributed along the Beaufort Sea coast. There was also greater floristic diversity along the Chukchi shoreline, especially on raised beaches. Species present on the Chukchi beaches but not documented along the Beaufort Sea coast include *Cnidium cnidifolium, Lathyrus maritimus, Poa eminens* and *Potentilla villosa.*

Tidal Salt Marsh

This habitat type occurs as a broad to narrow band along much of the arctic Alaskan coast, and is best developed in lagoons with gently sloping shorelines. The seaward limit of vegetation appears to be controlled by mean high water level.

A number of intergrading plant communities become differentiated with very subtle environmental variations. For example, an elevational gain of only a few centimeters may result in a clearly defined community change. Very slight depressions also produce distinct plant communities. In the latter situations, salt-burn, as indicated by varying degrees of necrosis, often occurs, especially in areas above the normal tidal zone but subject to the influence of storms.

Tidal salt marsh habitats were observed and quantitatively analyzed in eight locations (Table 1).

Puccinellia phryganodes community: *Puccinellia phryganodes* was the dominant species on tidal mud flats and low, sandy shorelines. Individual plants were seldom erect but crept along the tide lands by leafy stolons forming extensive copper to reddish colored clones.

In this community, percent cover ranged from less than 10% near mean high water level to nearly 100% at the upper community limits, with a mean of 55.8% (Table 2), and was highest in lagoons where the plants were protected from wave action and ice scouring. *Puccinellia phry-*

ganodes was also often locally dominant in depressed saline areas beyond the community limits, following salt water inundation by storms and destruction of previously existing vegetation.

Carex subspathacea / Puccinellia phryganodes community: The vegetation of this community formed a low reddish mat with coverage ranging from 78% to 100% and averaging 96%. Although the relative cover values of the codominants varied among stations, from approximately 1:1 to 4:1 (*Carex:Puccinellia*), and to a lesser extent within stations, the two species consistently occurred together. Average cover values were 85% and 52% respectively (Table 2).

Carex ramenskii / C. subspathacea community (Fig. 4): With a slight increase in elevation, coupled with greater stability, *Carex subspathacea* tended to be replaced by the more robust *C. ramenskii*. However, the two sedges are difficult to distinguish in the field, especially in the absence of fruiting material, and the values in Table 2 are therefore suspect. Interestingly, *Puccinellia phryganodes* assumed an upright stance in this community and was frequently found in a fruiting condition. This community was more or less intermediate, in terms of species composition, between the tidal salt marsh and upper storm zone communities, containing elements of each.

It was observed that *Carex ramenskii* achieves its optimum development in brackish lagoons and river deltas. Here the vegetation is relatively tall, lush, and nearly monospecific. Jefferies (1977) reported *C. ramenskii* to have the highest biomass of species found in salt marsh communities.

Additional minor and usually very local communities occurred within the tidal salt marsh zone. Occasionally *Stellaria humifusa* existed either as the only species or major dominant, e.g. at Barter Island in depressed areas where water runoff was restricted. Here it was sometimes necrotic, reflecting salt-burn. *Cochlearia officinalis* quickly invaded bare areas, forming near-monospecific seral communities, where vegetation had been destroyed by salt water inundation during storms. Occasionally one or a combination of *Carex ursina, Puccinellia vaginata* and *P. andersonii* formed distinct communities or were associated with *Carex ramenskii* and *C. subspathacea* as codominants. In shallow ponds containing salt water, *Hippuris tetraphylla* and *Potamogeton filiformis* dominated. Finally, bryophytes sometimes formed mats in wet, disturbed sites such as vehicle tracks but were generally uncommon in the tidal zone.

Upper Storm Zone Salt Marsh

This zone exists as a band between the limits of normal and maximum tidal activity, the latter usually marked by the presence of driftwood. Along the Beaufort Sea coastline, driftwood levels range from 1.4 to 3.4 m above sea level and extend inward up to 5000 m (Colville Delta) (Reimnitz and Maurer, 1979). According to reports cited by Reimnitz and Maurer, September and October storm surges responsible for the upper driftwood level have recurrence intervals of 25 to 50 years. This would allow

TABLE 2. Percent cover (C), frequency (F) and prominence value (PV) of salt marsh species

	Salt Marsh Communities (Sampled at 8 locations)											
	Puccinellia phryganodes			*Carex subspathacea / P. phryganodes*			*Carex ramenskii / C. subspathacea*			*Dupontia fisheri*		
Species	C	F	PV	C	F	PV	C	F	PV	C	F	PV
Puccinellia phryganodes (Trin.) Scribn. & Merr.	*55.8*	*97.3*	*549.7*	*58.2*	*100*	*581.2*	6.5	36.0	39.0	—	—	—
Carex subspathacea Worsk.	6.1	33.3	35.4	*85.2*	*100*	*852.0*	*24.5*	*71.3*	*206.9*	—	—	—
Carex ramenskii Kom.	0.1	6.0	0.4	1.6	18.0	2.4	*85.9*	*100*	*858.8*	8.3	29.8	45.3
Stellaria humifusa Rottb.	<0.1	<1.0	<0.1	6.8	38.0	42.0	21.1	68.4	174.5	0.9	7.3	2.4
Carex ursina Dew.	<0.1	<1.0	<0.1	1.6	13.1	5.8	5.6	18.8	24.3	<0.1	<1.0	<0.1
Dupontia fisheri R. Br. ssp. *psilosantha* (Rupr.) Hult.	—	—	—	—	—	—	23.8	50.5	169.1	*68.4*	*99.2*	*681.3*
Carex aquatilis Wahl. var. *stans* Drej.	—	—	—	—	—	—	—	—	—	18.3	47.9	126.7
Arctophila fulva (Trin.) Anderss.	—	—	—	—	—	—	—	—	—	15.5	35.4	92.2
Cochlearia officinalis L.	—	—	—	—	—	—	<0.1	<1.0	<0.1	2.7	37.0	16.4
Arctagrostis latifolia (R.Br) Griseb.	—	—	—	—	—	—	—	—	—	3.7	8.3	10.6
Eriophorum angustifolium Honck.	—	—	—	—	—	—	—	<1.0	—	1.6	18.0	6.8
Saxifraga cernua L.	—	—	—	—	—	—	—	—	—	1.4	21.7	6.5
Alopecurus alpinus Sm.	—	—	—	—	—	—	—	—	—	0.6	3.4	1.1
Poa arctica R. Br.	—	—	—	—	—	—	—	—	—	0.4	4.2	0.8
Saxifraga hirculus L.	—	—	—	—	—	—	—	—	—	0.2	13.6	0.7
Salix ovalifolia Trautv.	—	—	—	—	—	—	—	—	—	0.5	2.0	0.7
Salix arctica Pall.	—	—	—	—	—	—	—	—	—	0.1	1.0	0.1
Carex rariflora (Wahl.) J.E. Sm.	—	—	—	—	—	—	—	—	—	—	1.0	—
Eriophorum scheuchzeri Hoppe	—	—	—	—	—	—	—	—	—	—	1.0	—
Bryophytes (as a group)	—	—	—	insignificant			locally important			18.8	48.0	130.0

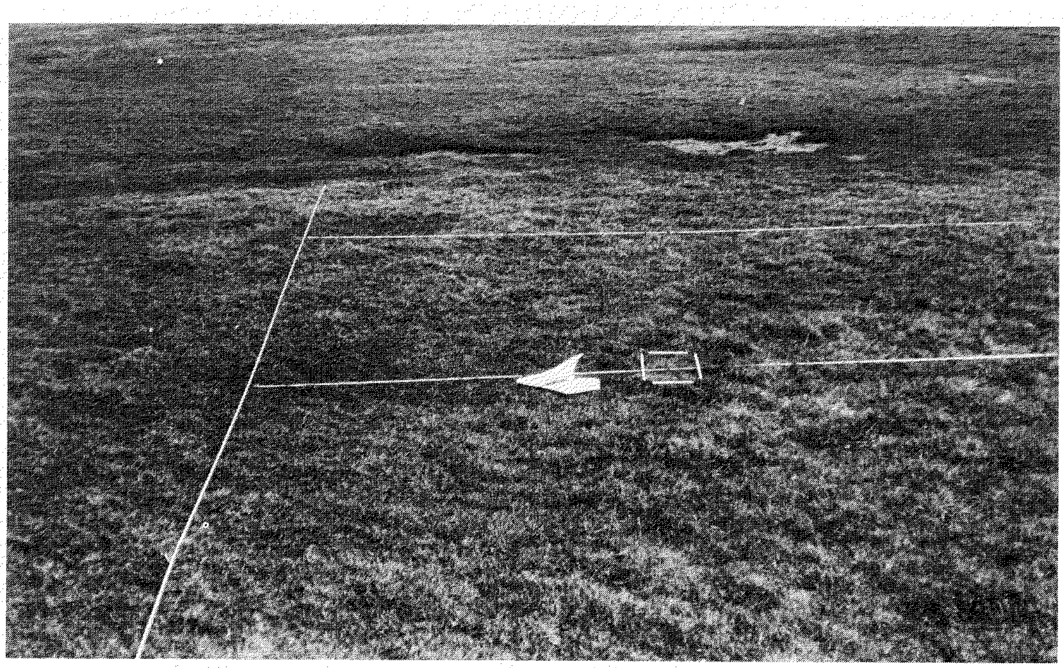

FIG. 4. *Carex ramenskii* / *C. subspathacea* salt marsh community at Colville Delta. Shoreline is at the top and left of sample plot.

recovery time of vegetation killed by salt water inundation and would explain why upper storm zone communities are usually diverse with mixing of salt marsh and non-salt marsh species. However, the communities are generally dominated by *Dupontia fisheri* var. *psilosantha*.

Dupontia fisheri community: *Dupontia* is a medium-sized (20-40 cm) grass which exhibits extreme variation throughout its range. It is common over most of the coastal lowlands in fine-textured, moist to marshy soil. Important associated plants include *Arctagrostis latifolia, Arctophila fulva, Carex aquatilis* var. *stans, Eriophorum angustifolium, Salix ovalifolia* and *S. arctica*. Although collective coverage by these taller species tends to be complete, mosses as a group comprise an important understory element with average values (in eight locations sampled) of 48% frequency, 18.76% coverage and a prominence value of 129.97, second only to *Dupontia* (Table 2).

Gravelly Beach

This habitat type differs from the salt marsh in several important aspects: the beach is generally narrower and steeper; the soil texture is much coarser with better drainage and consequent nutrient leaching; wave action and ice scouring are more intensive. Very unstable conditions result and vegetation is more or less limited to the upper 20% of the beach. This habitat is usually rather abruptly terminated by a raised beach or coastal bench. The gravelly beach habitat type is especially common along the shoreline of the Chukchi Sea (Table 1).

Elymus arenarius community: *Elymus* is a tall, coarse grass that spreads over gravelly or sandy beaches by rootstalks, forming clumped clones. It forms a distinctive community in association with a few usually prostrate and succulent species (Table 2). Coverage is usually low, depending on the stability of the beach, and *Elymus* is the only dominant species except in very local situations.

Raised Beach (Coastal Bench)

Raised beaches are composed of coarse-textured gravel and sand and are often very dry. They affect drainage patterns since they are normally of greater elevation than the adjacent tundra. On rare occasions during severe storms, salt water and driftwood pass over the crest of the raised beach to be deposited on the leeward side. The resulting salt influx may influence the vegetation and in extreme cases, especially in depressions, may cause saltburn. Existing vegetation must either be able to tolerate occasional flooding by salt water or become established between major storms.

The vegetation of raised beaches tends to be floristically intermediate between the *Elymus arenarius* community and adjacent tundra plains. However, because of the hard rocky soil, many species occurring here are more frequently found on fell-fields or in other rocky habitats. There was also a lack of consistency in vegetation structure from one station to another; therefore, no attempt was made at community classification. At some stations *Salix ovalifolia* and/or *S. arctica* were the principal dominants. At other stations such grasses as *Festuca brachyphylla* and *Poa arctica* were of great importance. *Artemisia tilesii* and *A. arctica* were often important and various other species were locally dominant or had high prominence values, especially *Elymus arenarius* (Table 3). Finally, both mosses and lichens were conspicuous elements of the communities.

TABLE 3. Percent cover (C), frequency (F), prominence value (PV) and notations of non-salt marsh species

	Habitat-Types (number of locations in parentheses)									
	Gravelly beach (5)			Raised beach (4)			Coastal Dune (2)			Coastal bluff (4)
	C	F	PV	C	F	PV	C	F	PV	Abundance[a]
Elymus arenarius L. ssp. *mollis* (Trin.) Hult.	*42.9*	*78.2*	*379.4*	20.2	63.0	160.3	28.3	69.0	235.3	O
Mertensia maritima (L.) S.F. Gray	1.9	16.0	7.0	—	—	—	—	—	—	—
Honckenya peploides (L.) Ehrh.	1.0	4.2	2.0	—	—	—	—	—	—	—
Lathyrus maritimus L.	0.8	5.5	1.9	0.2	8.0	0.6	—	—	—	—
Equisetum arvense L.	0.5	4.2	1.0	0.2	16.0	0.8	1.0	17.0	4.0	C
Cochlearia officinalis L.	0.2	4.2	0.4	—	—	—	<0.1	2.0	<0.1	F
Poa arctica R.Br.	<0.1	<1.0	<0.1	5.0	27.0	25.7	0.3	10.0	1.1	—
Senecia pseudo-arnica Less.	<0.1	<1.0	<0.1	—	—	—	—	—	—	—
Artemisia tilesii Ledeb.	—	<1.0	—	0.5	11.0	1.7	—	—	—	A
Salix ovalifolia Trautv.	—	—	—	*34.1*	*52.0*	*245.5*	7.6	23.0	36.5	C
Festuca brachyphylla Schult.	—	—	—	10.3	49.0	71.5	—	<0.1	—	—
Androsace chamaejasme Host	—	—	—	4.4	38.0	26.9	0.2	5.0	0.5	—
Potentilla villosa Pall.	—	—	—	4.9	23.0	23.7	—	—	—	—
Salix arctica Pall.	—	—	—	4.6	20.0	20.7	—	—	—	C
Cnidium cnidifolium (Turcz) Schischk.	—	—	—	3.1	40.0	19.3	—	—	—	—
Astragalus alpinus L.	—	—	—	2.7	25.0	13.3	—	—	—	—
Oxytropis campestre (L.) DC.	—	—	—	1.9	17.0	7.9	—	—	—	—
Artemisia arctica Less.	—	—	—	1.5	14.0	5.5	—	—	—	C
Stellaria longipes Goldie	—	—	—	0.7	20.0	3.4	—	—	—	—
Myosotis alpestris F.W. Schmidt	—	—	—	0.1	5.0	0.2	—	—	—	—
Oxytropis nigrescens (Pall.) Fisch. ssp. *bryophylla* (Greene) Hult.	—	—	—	0.1	3.0	0.2	1.2	5.0	2.6	—
Papaver macounii Greene	—	—	—	<0.1	<1.0	<0.1	—	—	—	F
Pedicularis sudetica Willd.	—	—	—	—	<1.0	—	—	—	—	—
Petasites frigidus (L.) Franch.	—	—	—	—	<1.0	—	—	—	—	C
Polygonum bistorta L.	—	—	—	—	<1.0	—	—	—	—	—
Polygonum viviparum L.	—	—	—	—	<1.0	—	—	—	—	—
Saxifraga caespitosa L.	—	—	—	—	<1.0	—	—	—	—	—
Saxifraga tricuspidata Rottb.	—	—	—	—	<1.0	—	—	—	—	—
Senecio residifolius Less.	—	—	—	—	<1.0	—	—	—	—	—
Artemisia borealis Pall.	—	—	—	—	—	—	3.6	32.0	20.4	—
Chrysanthemum bipinnatum L.	—	—	—	—	—	—	3.7	29.0	19.7	—
Festuca rubra L.	—	—	—	—	—	—	3.6	20.0	16.3	—
Stellaria laeta Richards	—	—	—	—	—	—	1.6	19.0	6.6	—
Taraxacum ceratophorum (Ledeb.) DC.	—	—	—	—	—	—	0.4	11.0	1.3	—
Poa glauca M. Vahl.	—	—	—	—	—	—	0.4	8.0	1.1	F
Alopecurus alpinus Sm.	—	—	—	—	—	—	0.1	5.0	0.3	—
Braya purpurascens (R.Br.) Bunge	—	—	—	—	—	—	<0.1	2.0	<0.1	F
Puccinellia andersonii Swallen	—	—	—	—	—	—	<0.1	2.0	<0.1	F
Sedum rosea (L.) Scop.	—	—	—	—	—	—	<0.1	2.0	<0.1	F
Bryophytes (as a group)	<0.1	<1.0	<0.1	22.2	63.0	176.1	not	sampled		O
Salix pulchra Cham.	—	—	—	—	—	—	—	—	—	A
Poa eminens Presl.	—	—	—	—	—	—	—	—	—	C
Oxyria digyna (L.) Hill	—	—	—	—	—	—	—	—	—	C
Phippsia algida (Soland.) R.Br.	—	—	—	—	—	—	—	—	—	C
Stellaria humifusa Rottb.	—	—	—	—	—	—	—	—	—	C
Primula borealis Duby	—	—	—	—	—	—	—	—	—	F
Salix glauca L. ssp. *acutifolia* (Hook.) Hult.	—	—	—	—	—	—	—	—	—	F
Saxifraga bracteata D. Don	—	—	—	—	—	—	—	—	—	F
Eutrema edwardsii R.Br.	—	—	—	—	—	—	—	—	—	O
Luzula confusa Lindeb.	—	—	—	—	—	—	—	—	—	O

Primula stricta Hornem.	—	—	—	—	—	—	—	—	—	O
Saxifraga punctata L.	—	—	—	—	—	—	—	—	—	O
Saxifraga rivularis L.	—	—	—	—	—	—	—	—	—	O
Stellaria crassifolia Ehrh.	—	—	—	—	—	—	—	—	—	O

[a]Species abundance: A = abundant, C = common, F = frequent, O = occasional

Coastal Dune

Dune areas were studied at Prudhoe Bay and Colville River Delta. In both cases, the sand particles were very fine and the areas were characterized by a combination of blow-outs and low-lying areas, wind-oriented channels of variable depth and width, and irregular profiles of alternately stabilized and wind-eroded surfaces. Cover varied from very sparse in unstable areas to high on stabilized mounds and leeward slopes.

The principal plant species were grasses (particularly *Elymus arenarius*) and mat-forming dicots such as *Salix ovalifolia* and *Artemisia borealis*. Important localized species were *Oxytropis nigrescens* (at Prudhoe Bay) and *Chrysanthemum bipinnatum* (at Colville River Delta). *Elymus arenarius* was the most important dune species, occurring in scattered tufts and dense clones. Its success is due in large part to its ability to tolerate sand deposition and blowouts, as well as salt spray. Quantitative data for the two stations are presented in Table 3.

Coastal Bluffs (With Sloughing Soil)

In most locations along the Chukchi and Beaufort seas, coastal erosion rates are very high. An average retreat rate of 0.31 m per year has been reported for the cliffed coastline of the Chukchi Sea near Barrow (Harper, 1978), and 1-10 m per year for the Beaufort Sea coast east of Barrow (Lewellen, 1977). The slumping and solifluction of coastal bluffs is triggered by strong westerly winds accompanied by large waves and ice gouging (Reimnitz and Maurer, 1979). Soil sloughing and general erosion continue as the exposed permafrost melts. The inward retreat of the shoreline is speeded by transection of lakes along the coastal plain (Weller and Derkson, 1979).

Because of the widespread occurrence of coastal erosion, this habitat type is important, even though vegetation coverage is generally low, varying inversely with erosional activity. As was the case with raised beaches, the plant communities of the four stations examined (Table 1) were not well defined. However, certain species occurred with some degree of regularity (Table 3).

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