Plant Ecology of the Walakpa Bay Area, Alaska

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ABSTRACT. The Walakpa Bay archeological excavation site 18.4 km. southwest of Barrow, Alaska, is on the arctic coastal plain tundra. The use of native vegetation for food is principally limited to leaves, as few species set fruit. Several species of food plants function as pioneer plants on disturbed areas. *Poa arctica* was a dominant invading species of disturbed sites. Principal physiographic forms were analyzed for vegetational composition.

RÉSUMÉ. *Ecologie végétale de la région de la baie de Walapka, Alaska.* Le site de fouilles archéologiques de la baie de Walapka, à 18,4 km au sud de Barrow, Alaska, est située en toundra arctique, dans la plaine côtière. L'utilisation de la végétation naturelle comme nourriture se limite principalement aux feuilles, car peu d'espèces fructifient. De nombreuses espèces de plantes nutritives fonctionnent comme plantes pionnières dans les zones perturbées. *Poa arctica* est une espèce dominante d'invasion des sites perturbés. L'auteur a analysé la composition végétale des principales formations physiographiques.

РЕЗЮМЕ. *Экология растений на побережье залива Валакпа (Аляска).* Территория археологических раскопок на побережье залива Валакпа в 18,4 километра от Барроу (Аляска) расположена в области арктической равнинной тундры и представляет собой обширный участок искусственно нарушенной почвы. Использование местной растительности для пищи существенно ограничено листьями, так как только немногие растения дают плоды. Несколько экземпляров съедобных растений явились первыми из появившихся на участке с нарушенной почвой. И среди них Poa arctica, как было обнаружено, является доминирующим. Основные физиографические формы растительности были проанализированы.

INTRODUCTION

A vegetational study was conducted in the summer of 1969 in conjunction with an archaeological project at Walakpa Bay, Alaska (Stanford 1972). This Bay is the large mouth of the Walakpa River which empties into the Chukchi Sea through a sand spit about 18.4 km. (11.4 miles) south-southwest of Barrow, Alaska. It is at 71°09′N., 157°4′W. (Barrow, A-5 Quadrangle, Alaska).

The coastal site represents one of the most complete records of early Eskimos on the North American continent. Here, on a promontory where the Bay has cut behind and through the coastal cliff, has been located a site of human occupation, at least seasonally, according to archaeologists (Stanford 1972) for an estimated 3,600 years.

This study was to provide an ecological description of the surrounding landscape of the arctic coastal plain tundra and its potential for a primary source of food supply. Botanical nomenclature follows that of Wiggins and Thomas (1962).

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FIG. 1. Aerial view of Walakpa Bay, Alaska. Walakpa Bay in lower left and Chukchi Sea to left. Site of excavations encircled.

GENERAL DESCRIPTION OF LANDSCAPE

The Chukchi Sea, Walakpa Bay, site of the excavations, and the surrounding arctic coastal plain are shown in the aerial photograph of Fig. 1 taken 2 July 1949. The Chukchi Sea and Walakpa Bay have been darkened to produce a better contrast with the land surface. The white areas are snow blown into depressions, the slopes of the sea cliffs, and deep drainage patterns. Within the circle on the point just north of the Bay mouth near the left edge of the photo is the site of the Walakpa Bay excavations, which is also the location of the Will Rogers and Wiley Post Monument. The highest elevation within the photo is about 57 feet above sea level. The height of the top of the bluff along the coast and the Bay is about 25 feet. The large area of high-centred polygons northeast of the excavation site is at 30 to 35 feet elevation. The highest point inland for 5 to 6 miles is only 60 feet.

All of the area represents a treeless tundra plain with varying types of patterned ground. The dominant relief feature constituting about 60 per cent of the land area north and east of Walakpa Bay is the pattern of parallel, elongated, oval-shaped basins having longitudinal axes at about 171 degrees to 351 degrees (9 degrees west of north); these represent the sites of former oriented lakes for which the arctic coastal plain is noted (Black and Barksdale 1949). These basins are in varying stages of being filled in. A few have a narrow margin of aquatic vegetation but most have large areas of drained, nearly level, very wet, marshy landscape showing relatively youthful, low-centred polygons. Within the basins, in the surrounding area and throughout much of the interior the polygons may be identified in Fig. 1 by their light-coloured margins, and dark centres due to wet soil or standing water, except when they are obscured by white patches of snow. Close to the larger bodies of water, covered by ice and snow in the figure, *e.g.*, above and to the right of the north arrow, the pattern of polygons is indistinct owing to recent exposure. Near the outer edges of the basins, the polygons are more pronounced, having wider and higher margins with a dark median line indicating the position of the initiating contraction crack. In this area the crack is commonly the site of an ice wedge which increases in depth and width with age. As described by Black (1952) and others the contraction of highly saturated soils on cooling to locally measured temperatures of $-25\,^{\circ}$C. results in the formation of open cracks both horizontally and vertically. The cracks may become partially filled by depth hoar and ice crystals; these initiate or enlarge ice wedges to which may be added more ice by freezing of run-off water in the spring. The addition of ice to the wedges results in upthrusting of a ridge on either side by two forces: the expansion of the ice during freeze-up and by the expansion of the ground during seasonal warm-up against the solids now filling the contraction crack. These peripheral ridges encircle the polygon, prevent drainage, and result in the pattern of low-centred polygons. With time the width of the ridges increases and, as with the secondary thickening of vascular plant cell elements, the central space becomes less angular and more circular. This successional development can be inferred by observing the progressive increase in width of the surrounding ridge of each polygon if one examines a series from the recently exposed parts of the basin to the longer-exposed outer edges of the basin and the surrounding area.

Divergence from the theoretically simplest and common shape of polygon, a hexagon, is determined by the nature of the material, slope, or other factors which may affect the direction of stress. This is well illustrated by the tetragonal pattern along the sloping margin of the large basin just below its outlet to Walakpa Bay and to the northwest of the north arrow. The cracks here are formed parallel and at right angles to the slope.

Outside of the large basins, the landscape is better drained and is predominantly patterned with high-centred polygons. These areas are occasionally dissected by relatively deep-cut drainages connecting the large basins with the Bay. Along the coast and also into Walakpa Bay are relatively short and steeply eroded drainages, which in Fig. 1 are white with snow. In the relatively flat areas between basins and the Bay are found gradations from poorly-drained flat meadows to well-developed high-centred polygons. Slight linear depressions a few inches deep and several inches wide have developed from contraction cracks and form angular outlines of poorly-developed polygons. Lesser cracks across the surface of the polygon indicate division into smaller, secondary and tertiary polygons. Britton (1958) emphasizes the importance of the earlier thawing of the crack area and the melting of the upper part of the ice-wedge which lowers the surface level and accentuates the ditch-like trough around the polygon. Further deepening of the trough depends on the development of drainage lines along the system of troughs. It was observed that improved drainage encourages greater plant productivity and peat accumulation along the edges of the trough and sides of the high centers. The mechanism of development of the high-centred polygons, whether by increase of organic matter, upwelling of mineral soil with or without horizontal ice formation, or some combination, was not determined. The troughs outlining the high-centred polygons appear in Fig. 1 as dark lines due to the water content from snow melt and drainage from the active layer.

Black (1952) suggested a possible sequential development from initial contraction cracking to low-centred polygons to high-centred polygons, which sequence the writer does believe exists in the areas which started from recent basins. In other areas, generally of higher ground and with better drainage, contraction cracks lead to depressed troughs surrounding level, high-centred polygons. In some areas these become raised, or "pillow" polygons.

The relief characteristics and the physical factors of formation of thaw lakes, high- and low-centred polygons, and ice-cored mounds have been well summarized for the Point Barrow area by Hussey and Michelson (1966).

The relation of vegetation to the development of polygonal ground pattern near Point Barrow has been summarized by Wiggins (1951) and generally by Britton (1958), Johnson (1969), and Schenk (1970).

VEGETATION

Ponds and low-centred polygon pans

The tundra lakes, pools, and pans of low-centred polygons were not sampled in a quantitative manner. Typically small pools have a dominant zone of emergent aquatic grass, *Arctophila fulva*. This species is common in mud, wet gravel, and shallow water at the margins of lakes, pools, and streams to depths of 3 feet. Centres of the pools are frequently devoid of this grass. It extends along the depressions between polygons, and even occasionally as remnants in deep cracks across high-centred polygons where the soil is frequently saturated with water. *Arctophila* in this area is usually purplish in colour which is mentioned by Wiggins and Thomas (1962, p. 20) as being indicative of and correlated to a pH of 6 to 7 rather than 5 to 6 where the colour is normally bright yellowish-green. A second grass increasing in density at the expense of *Arctophila* in the shallow water and the wet borders only temporarily flooded is *Dupontia fisheri*. It also extends into the depressed margins of the surrounding polygon areas. Other graminoid dominants include the sedges *Carex aquatilis* var. *stans, Eriophorum scheuchzeri,* and *E. angustifolium*. One of the most common emergent aquatic herbs of tundra pools is *Hippuris vulgaris,* whereas *Hippuris tetraphylla* is found along the shoreline of coastal bays in brackish water. In shallow pools and along lake margins may be found *Ranunculus pallasii,* with its long, floating rhizomes, and *R. gmelini.*

Sedge-willow meadows

On the gentle slopes on either side of the principal drainage channels, as the one connecting Walakpa Bay and the oval-shaped depression in Fig. 1, were expanses of meadows. These areas varied from uniform slopes to a slight indica-

TABLE 1. Vegetational analysis of communities. I: sedge-willow meadows; II: troughs around high-centred polygons; III: high-centred polygons; IV: high-centred polygons with frost boils.

	I		II		III		IV	
Total Cover (incl. mosses and lichens):	100%		100%		98%		98%	
Foliage Cover (phanerogams):	83%		75%		84%		56%	
Species	*Rel. Cover %	Freq. Index %	*Rel. Cover %	Freq. Index %	*Rel. Cover %	Freq. Index %	*Rel. Cover %	Freq. Index %
Arctagrostis latifolia	<1		<1		2	26	2	8
Carex spp.	62	100	73	96	30	88	15	25
Cassiope tetragona							3	4
Dupontia fisheri	2	22	10	64	1	6	<1	
Eriophorum spp.	<1		4	26	5	12	28	50
Festuca brachyphylla					1	10		
Luzula spp.	1	12	2	8	9	46	29	72
Petasites frigidus	3	64	6	40	10	62	4	22
Poa spp.	2	28	<1		3	36	8	36
Potentilla hyparctica					<1		3	14
Rubus chamaemorus							1	2
Salix arbutifolia	<1				8	18	<1	
Salix pulchra	1	4	<1		31	52	3	4
Salix rotundifolia	28	66						
Saxifraga cernua	1	32	1	16			<1	
Vaccinium vitis-idaea					<1		3	28

*Relative cover is expressed as % of total phanerogam cover.

Other species with less than 1% relative foliage cover:

Alopecurus alpinus I
Arctagrostis latifolia I, II
Arctophila fulva II
Calamagrostis neglecta I
Cardamine pratensis I, II
Cochlearia officinalis II
Pedicularis sp. I, II, III
Polygonum viviparum I
Puccinellia phryganodes I, II
Ranunculus spp. I, II, III
Salix reticulata I
Saxifraga foliolosa I
Saxifraga hieracifolia I
Saxifraga hirculus I
Saxifraga punctata I
Senecio atropurpureus I, II, III, IV
Solidago multiradiata I

tion of broad, shallow depressions outlining low-relief polygons. The entire area, regardless of slight variations in relief, was quantitatively sampled as a unit by 50 one-foot square quadrats. The vegetational analysis is given in Table 1. Of the dense (83 per cent) phanerogam cover, 90 per cent consisted of *Carex* spp. and *Salix rotundifolia.*

Because of the lack of specific relief patterns vegetational variations were not pronounced. Subtle changes occurred across drainage slopes but the entire area had a meadow appearance.

Depressions or troughs between high-centred polygons

In the depressions surrounding raised-centre polygons about 73 per cent of the phanerogam cover is composed of species of *Carex,* especially *Carex aquatilis* (see Table 1). *Dupontia fisheri* is common in dense stands, followed by clumps of *Petasites frigidus* which is more common on the upper edges of the troughs. Species of *Eriophorum,* including *E. angustifolium, E. scheuchzeri, E. russeolum,* and *E. vaginatum* are apparently present. In the low part of some troughs extensive mats of *Sphagnum* formed deep, wet cover through which the graminoid plants emerged and by their basal growth occasionally lifted up sheets of *Sphagnum* into arched mounds.

The encircling troughs of high moisture in the summer are also areas into which snow being blown across the tundra would collect and provide protection from wind and desiccation during many months of the year.

These protected troughs, with a dense *Carex-Dupontia-Eriophorum* cover, are the principal habitats of the lemming which during periods of high population clip the vegetation as a mowed field. Cut stalks and leaves lie on the surface and provide for covered passageways or tunnels criss-crossing and running lengthwise of the depressions. Compact, bowl-shaped nests with a covering of cut shoots are common. Lemming runways frequently follow shallow contraction cracks which were observed to extend for distances over 125 feet and to divide at the junction of cracks to form side trails. Lateral cracks and trails extended up the sides of the depressions and followed contraction cracks across the raised-centre polygons.

It is very significant that the troughs dominated by *Carex aquatilis, Dupontia fisheri,* and *Eriophorum angustifolium* provide the bulk of the lemming diet. It has been shown that the nutrient levels, including nitrogen, fluctuate with forage production and with lemming populations. According to VanDyne (1969) increases in forage production of 3- to 4-fold can be obtained by fertilization with a resulting disruption of the normal cyclic population pattern of lemmings. He also reports an increase in depth of the thawing of the active layer in years of high lemming populations with corresponding heavy grazing of graminoid cover.

High-centred polygons

Upon reaching an apparent mature state of polygon development, the centres surrounded by wide depression areas commonly have a relief of 3 feet. With the elevation and improved drainage, a dense covering mat of tufted vegetation develops with definite differences in composition (Table 1).

The total phanerogam cover is high because of the dominance of species of low, matted growth such as *Salix pulchra* which makes up 31 per cent of the foliage cover. Few species are able to grow up through the mat. Horizontal growth occurs by creeping surface stems. These are used by the Eskimos for various purposes including bindings or lashings where leather thongs are not used. Vegetative growth is 1 to 2 inches tall whereas fruiting catkins are 2 to 3 inches tall. Occasionally patches of willow show death and the surface is covered by a mat of woody stems which resist decomposition and surface erosion. Of equal cover are several species of *Carex*. As drainage and aeration are improved by the uplift of the centre, *Petasites, Luzula,* and *Salix arbutifolia* increase in coverage. The first of these, whose leaves are important as a principal source of leafy food, profits by the disturbance of the sod resulting from frost activity.

Small knobs on the surface, providing increased elevations of 2 to 4 inches, become covered by crustose and foliose lichens and are then apparently invaded by species of *Luzula*. Other species on locally slightly drier sites include the grasses *Poa, Arctagrostis, Festuca,* and *Dupontia.*

The sloping sides of the raised centres provide a transition to the moist troughs. These slopes are frequently hummocky with tufts of *Eriophorum* or *Carex* and are the preferred habitats of *Petasites frigidus,* which forms dense mats between the tufts.

Contraction cracks may be continuous from the depressions up the slopes of the raised centres, where cracks may be 4 to 6 inches wide and over 1 foot deep, and across the raised centre. Such cracking is often associated with frost-boil activity.

Polygons with frost boils

High-centred polygons which are initially relatively flat-topped may become transversely dissected by deep contraction cracks. These cracks may be several feet deep and expose stratified organic layers and underlying mineral soil. The cracked mounds have a decrease in phanerogam cover and an increase in lichens. The writer observed that these deep cracks were frequently used by lemmings as runways and resting sites, resulting in accumulation of droppings. The extremely limited distribution of *Marchantia polymorpha,* found only in these cracks, may be related, at least in part, to the enrichment of the peat by these nitrogenous wastes.

Frequently accompanying the raised centres were evidences of frost boil activity. These sites of activity varied from several inches to several feet in diameter. The latter were frequently the result of two or more overlapping or coalesced frost boils. Within the circle of frost activity was usually a level area of mineral soil of silt and clay thrust up from below as was determined by several bisects. A few pebbles were frequently scattered across the surface. The surface often had small contraction cracks forming mini-polygons within the bare area. Apparently the bare areas were not invaded for one to several years after exposure. The margins of the large boils were often rolled up and outward with segments of a ring of sod held intact by its cover of *Luzula, Eriophorum,* and *Carex,* which species made up the dominant cover of the disturbed polygons (Table 1). The surrounding ring of sod served as a rim of the flat basin. If not level, silt and clay washed to the low side of the basin leaving a greater concentration of pebbles on the higher side.

A typical plant successional sequence started with the invasion of the small contraction cracks by *Luzula*, *Carex*, and *Stellaria*. Crustose lichens were common across the surface. Other vegetation appeared to invade from the surrounding rim. *Salix pulchra* and *S. arbutifolia* may form a dense mat across the surface by creeping, vegetative growth. These mats may be disturbed by renewed frost boil activity.

Small knobs about an inch in diameter and elevation across the surface of the polygon centre have a grayish appearance due to a cover of whitish-grey to black crustose lichens. Slopes of the knobs are frequented by mosses and by foliose lichens. Slopes and tops of older knobs are occupied by tufts of *Luzula* forming compact, brownish mats. Infrequently, dense, competitive mats of *Cassiope tetragona* occur and on dying turn grey matching the grey crustose and foliose lichens. The dry woody fragments of *Cassiope* are gathered locally for use as a tinder or fuel.

The disturbed polygons are also interesting because they are sites for the growth of two species of potential berry production: *Rubus chamaemorus,* cloudberry, and *Vaccinium vitis-idaea,* lingenberry.

Coastal Beaches and Bluffs

The shoreline of the Chukchi Sea during the summer is subject to large breaking waves carrying a large burden of rolling sand and gravel. Winds may carry abrasive sands. Washing by ice cold salt water and burial under beach material create an unfavourable habitat for summer growth. At any period of the summer the coastline may be subject to the mechanical plowing, shearing, and burial due to ice thrust when the ice flow may be forced many feet above the normal shoreline.

The sand spits which separate the open sea from Walakpa Bay are repeatedly scoured by waves and ice and are, therefore, nearly devoid of vegetation. Along the shore of the more protected bay are found the typical coastal species of *Mertensia maritima, Arenaria peploides, Elymus mollis,* and *Puccinellia phryganodes.* Also common are patches of *Cochlearia officinalis, Cerastium beeringianum, Stellaria humifusa,* and *Saxifraga caespitosa.*

In the Walakpa Bay area there is a prominent coastal bluff forming a sea wall about 25 feet high. Not only is there severe cutting from the coastal side by wave action during storms, but a major effect from ice shove across the gently sloping beach. Following the undercutting there is slumping of the upper part of the bank, often with large areas held together by the tundra mat vegetation. Cornices of sod hanging over the bank several feet protect the brink and provide protection for small mammals and birds. In other areas the melting of snow and runoff of water from the active layer in the spring thaw results in solifluction and deep gullies cutting to the beach level. The heads of gullies cut back several hundred feet into the upland tundra. Snow banks are retained in these deep drainages along the beaches until mid-August or in some areas, perennially. Such snow banks often have a pinkish colour due to accumulations of "red snow" or "watermelon snow":

aggregations of a red-pigmented algae identified as *Chlamydomonas nivalis*, a member of the green algae found in both arctic and alpine snow fields.

Exposed areas of the bluff face, brink, and gully sides may be wind-swept free of snow and subject to fluctuations of temperature and moisture which lead to instability. Colonization of such areas of bare soil is frequently by tap-rooted species of plants. *Cochlearia officinalis,* an important food plant; dandelion, *Taralacum xyratum; Sagina intermedia;* and *Oxyria digyna,* mountain sorrel. Other common species include *Cerastium beeringianum*, and *Saxifraga rivularis* which is especially common in wet seep and snow beds. The rapid growth of these early invaders is aided by the increased temperature of the barren, black soil which increases light absorption. Among these pioneer plants are several which serve as food plants for the Eskimo and aid in supplementing the diet of meat from the land and sea.

Revegetation of abandoned sod house

On the same ridge of the sea cliff as the Walakpa Bay excavation is the remnant of a sod house abandoned approximately 100 to 120 years ago. Such sod houses were normally occupied only in the winter. The outline of a main rectangular room is still apparent as a depression surrounded by walls rising about 3 to 4 feet above the general level of the tundra. The upper parts of the walls have slumped down forming sloping ramparts. To determine the succession on the soil eroded from the disintegrated sod, 4 belt transects, each of 20 contiguous 1-foot quadrats, extending outward from the wall were analyzed for foliage cover and frequency. Each series of 20 quadrats started at the top and middle of one wall and extended outward and down the sloping bank of disintegrated earth wall material a distance of 20 feet. Profile sketches indicated that the eroded wall material extended outward and reached the general level of the drained tundra at about 12 to 15 feet from the wall.

In the surrounded tundra all species of grasses made up about 7 per cent of the total foliage cover with dominance in the following order: *Poa*, *Arctagrostis*, *Festuca*, and *Dupontia*. By contrast the young vegetation on the slopes deposited to the outside from the eroded house walls consisted of a foliage cover of *Poa* spp. of over 70 per cent on the inland-facing sides (NE and SE) and 35 per cent on the seaward-facing sides (SW and NW) for an average of 54 per cent coverage (see Table 2). The species was principally *Poa arctica* R. Br. ssp. *arctica* with a representation of some *Poa alpigena* (E. Fries) Lindm. and *Poa komarovii* Roshaw. *Poa arctica* has the advantage of slender, wide-spreading, subterranean runners in addition to seed production which facilitates its successful invasion of bare areas. Statistical analysis of the relative foliage cover of *Poa* spp. along the transects indicated no significant difference between the northwest and southwest sides and none between the northeast and southeast sides. The greater coverage of *Poa* spp. on the inland side (northeast and southeast) was highly significant at the 0.995 confidence level over that of the oceanside. *Poa* coverage reached its maximum part way downslope. Also, the total phanerogam foliage cover was higher on the inlandside than on the oceanside (Table 2).

TABLE 2. Vegetational analysis of 4 lines of 20 1-foot quadrats along transects extending at right angles outward down the slope from the top and centre of each degraded sod wall.

Total Foliage Cover (Phanerogams):	NE 91%		SE 90%		SW 70%		NW 82%		Aver. 83%	
Species	*Rel. Cover	Freq. Index	*Rel. Cover	Freq. Index	*Rel. Cover	Freq. Index	*Rel. Cover	Freq. Index	*Rel. Cover	Freq. Index
Poa spp.	70	100	73	100	36	95	35	90	54	96
Cochlearia officinalis	5	90	1	25	32	95	37	100	19	78
Alopecurus alpinus	6	70	2	40	9	85	18	95	9	73
Calamagrostis neglecta	2	40	5	60	15	60	2	40	6	50
Stellaria humifusa	7	85	4	90	3	55	4	45	5	69
Carex spp.	8	30	7	40	<1	10			4	20
Dupontia fisheri	1	25	2	40	2	30	1	5	2	25
Saxifraga cernua	2	50	3	70	2	55	2	15	2	48
Petasites frigidus			4	30	1	30			1	15
Ranunculus nivalis	<1	10							<1	3
Ranunculus pygmaeus	<1	10							<1	3
Taraxacum lyratum	<1	10							<1	3

*Relative cover is expressed as % of total phanerogam cover.

It is suggested that nitrogenous enrichment may have played a role in the increase in grass cover. It is known that the Eskimos frequently tanned skins against the sides of such house structures and used urine in the tanning process. The inhabitants very likely urinated on the inlandside. The use of skins for roofs with resultant leaching of nitrogenous compounds onto the walls would not be true here. Permanent sod houses of this area were not used in the summer and were not covered by skin roofs, except for skin over a relatively small hole in the roof which was used as a skylight and a portal. Skin roofs were used on temporary summer structures. No evidence was seen of walls being commonly used as perch sites by birds with a resulting enrichment from their droppings. The successful flowering and fruiting of *Poa*, however, is a favourable indicator of nitrogen enrichment.

The success of *Poa arctica* as an invader of disturbed areas such as sod houses and old meat cellars was noted in other areas near Barrow and confirms the observations of Wiggins and Thomas (1962). They also mention the abundance of *Marchantia polymorpha* on the lower slopes of these mounds. As has been mentioned earlier, *Marchantia* was also found in deep cracks occupied as resting sites by lemmings and enriched by fecal droppings and urine so it would seem to be a nitrophilous species. There seems to be a relationship between the success of both *Poa arctica* and *Marchantia polymorpha* to nitrogen enrichment.

The high success of *Poa* in the invasion of bare areas suggests it as a possibility for revegetation of disturbed areas in the Arctic. Or perhaps one might consider northernmost seed-bearing ecotypes of *Poa pratensis*, which Hultén (1968) reports as far north as the Brooks Range.

Other grass species included *Alopecurus alpinus* (9 per cent relative cover), *Calamagrostis neglecta* (6 per cent), and *Dupontia fisheri* (2 per cent). The plant second in importance to the genus *Poa* in the recovery succession as seen in Table 2 was *Cochlearia officinalis*, not a grass but a member of the mustard family. The dark green basal leaves of this plant are used as food by the Eskimos. It was found on other sites disturbed by removing sod as recently as a year before the time of observation. Its greatest natural abundance is along disturbed shorelines and slumping coastal cliffs. It seems to thrive especially well under conditions of continued disturbance.

The vicinity of Walakpa Bay shows another example of vegetational change due to occupation by Eskimo populations. Several protected swales close to the Walakpa site, known to be sites of defecation and urination, show indications of vegetational differences in species composition and in luxuriance of flowering due to enrichment by nitrogenous wastes. For example, a nearby swale is carpeted with a dense mat of moss, *Splachnum*, typical of nitrogen-enriched sites. This area also has more luxuriant growth of the yellow-flowered *Saxifraga hirculus* than on adjacent tundra.

ETHNOBOTANY

The paucity of plant species for food and other uses in the Walakpa Bay area is acute. Wiggins and Thomas (1962) have identified 59 species of higher plants from the Walakpa Bay area. Of these, 15 are known to be used by the Alaskan Eskimo as food sources according to Heller and Scott (1967). At Walakpa Bay there are available only about one-third of the species of plants listed by Oswalt (1957) which are used for food by the residents of Napaskiak, a Western Eskimo village, in southwestern coastal Alaska.

Land plants are used as food principally as a supplement to the meat diet and when in season are gathered and stored in seal oil for winter use. Much of the terrestrial vegetation plays a major role, naturally, at the primary producer level in an area classically cited for its short and simple food chain. From lichen to caribou to man represents minimal loss in energy conversion. Of course, while living along the coastal area there was an important nutrient addition to the diet via the marine plant-invertebrate-vertebrate food chain which would have included eating partially digested marine organisms such as clams from the stomachs of walrus. Unlike the common use of the caribou stomach content of partially digested vegetation with its vitamin content, the stomachs of seal are well cleaned before eating (Heller and Scott 1967, p. 229). The nutrient value of vital organs is obtained by eating intact.

The principal plants used at Walakpa Bay are given below in phylogenetic order.

Lichens

Cladonia spp. and *Cetraria* spp. fruticose lichens common on arctic tundra are highly flammable when dry and may be used as fuel. Species of "rock tripe," lichens of species of *Umbilicaria* and *Gyrophora*, as well as *Cladonia* and *Cetraria* are reported by Porsild (1951) to be valuable for food but not to be used by natives, although Oswalt (1957) reports their occasional use, as in soups.

Sphagnaceae

Sphagnum lenense H. Lindb. Bog and tundra moss growing in saturated areas, especially if acidic, forming dense thick mats, common in depressions between polygons. Because of its outstanding absorbent qualities, it has many uses including a substitute for towelling to wipe up water, to clean fish, as an absorbent agent inside of a sealskin diaper, as toilet tissue, and as boot stuffing. It is also used as a caulking material in house construction.

Gramineae

Several species of grasses, *Calamagrostis* and *Elymus,* as well as *Carex* and *Eriophorum*, are used elsewhere for weaving (Bank 1953), as well as for matting, insoles, and absorbents (Oswalt 1957), but I have no knowledge of such use at Walakpa Bay. *Arctophila fulva* most common marsh and pond grass, often reddish-stemmed. Plant pulled up and rootstock eaten.

Salicaceae

Several species of willow (*Salix*) are used for a variety of purposes including small branches as floor matting; as fuel; as a mat-like material in front of doorways to houses (apparently to wipe feet on); twigs are shredded to use as packing in mukluks, as diapers, as tinder for fire-building, and as floor matting; and split twigs are used as bindings. *Salix pulchra* var. *pulchra.* A creeping, prostrate shrub only a few inches tall at Walakpa (while farther south may be up to three meters tall) with broad, green persistent leaves. Young leaves and inner portions of young twigs are eaten raw or mixed with seal oil. Reported to be good with meat. Heller (1953) reports that Totter found the leaves to be 7 to 10 times more effective as a source of ascorbic acid than oranges. Other species with pubescent leaves are preserved in oil but not eaten raw. Young, flexible, creeping stems are used for lashings or bindings. Older stems are used for a variety of products of household and hunting use.

Polygonaceae

Oxyria digyna. Mountain sorrel has basal, green, reniform leaves and is common to wet snow beds, stream and cliff banks, and hummocks. The leaves, but not the roots, are eaten raw. Reported by natives as the "salad" plant.

Rumex arcticus. Called sorrel, dock, or sourdock, is common in wet places and snow beds. The leaves are boiled and eaten or put in seal oil. Stems can be eaten but must be collected young. Tastes like rhubarb. It may be stored for winter use as food or for treatment of diarrhea.

Caryophyllaceae

Honckenya peploides. Seabeach sandwort is a fleshy, branched plant of sandy seashores. It is found in the brackish water of the mouth of Walakpa Bay. The plant is gathered before the flowers turn white. Eaten raw the leaves are a good source of vitamins A and C or they may be cooked with sugar, and stored. In some areas they are chopped and cooked with other greens, allowed to sour, then mixed with caribou fat and berries to make "Eskimo ice cream."

Ranunculaceae

Ranunculus pallasii. Grows in shallow water or wet mud of pond margins with long floating rhizomes which root at nodes. Young shoots are eaten boiled.

Cruciferae

Cochlearia officinalis ssp. *arctica.* Spoonwort or scurvy grass is common along coast on bare soils of upper beach and sea bluff and on mineral soil of disturbed sites. Leaves are eaten raw as a salad or boiled. Valuable as an antiscorbutic. It is interesting that this valuable plant is perpetuated by disturbance.

Saxifragaceae

Saxifraga punctata. Growing on upland tundra on tops of hummocks, ridges, or banks. Porsild (1951) reports that the leaves are commonly used.

Rosaceae

Rubus chamaemorus. Variously called "salmonberry", "cloudberry", or "bake-apple", this plant reaches its northern limits for North America in this area. It is the only fleshy-fruited, rosaceous species there. It rarely, if ever, bears fruit at Walakpa. Natives report it to be susceptible during flowering to winds which blow the blossoms off and no fruit develops (probably a lack of pollinators). Those who live, or visit, farther south consider it as a principal berry-crop which is gathered and stored in sealskin bags or wooden barrels. Farther south at Hooper Bay, quantities of 150 to 300 pounds per family are reported to be gathered for winter use (Heller and Scott 1967). Berries are eaten as fresh fruit or made into a pudding or "Eskimo ice cream".

Haloragaceae

Hippuris vulgaris. Aquatic herb common in tundra pools. Local use reported as an ingredient in soups.

Ericaceae

Cassiope tetragona. White heather is a coarse, dwarf, creeping shrub with tightly imbricated leaves forming dense tufts on drained sites. According to Porsild (1951) it is ". . . so rich in resin that it will burn even when moderately wet." It was one of the few plant materials found in the excavations at Walakpa.

Vacciniaceae

Vaccinium vitis-idaea. This heath, commonly called lingenberry, or low-bush cranberry, is a low, creeping, dwarf shrub with evergreen leaves and small red berries. Scarce at Walakpa, they grow on high-centred polygons but no fruits were found. Farther south along the coast they are used in abundance, being picked and stored in tight barrels for winter use. Although sour, they are edible and make excellent jam, are now eaten fresh with an abundance of sugar, or made into a beverage. Older natives claim they are good for headaches. No other species of *Vaccinium* grow as far north as Walakpa Bay.

Scrophulariaceae

Pedicularis sudetica. Species of coastal plain growing on muddy pond margins and meadows. Young shoots are eaten boiled in soup by Siberian natives (Hultén 1968) and reported by Heller and Scott (1967) to be used in Alaska.

Compositae

Petasites frigidus. This species forms a dense cover of green leaves on the sides of raised-centre polygons and on disturbed tundra soils. Locally, the leaves are eaten raw and Hultén (1968) reports the roots to be roasted by Siberian Eskimos.

Taraxacum lyratum. Dandelion common along the bare soil of coastal bluffs. No record of use at Walakpa, but known to be used as a "greens" elsewhere (Anderson 1939).

The paucity of plant species for use as food is especially serious when viewed from a dietary viewpoint. A serious nutritional omission from the Walakpa Bay flora is the near absence of fruit-bearing species, *e.g.*, crowberry, wild rose, bog cranberry, blueberry, lingenberry, and cloudberry — all rich sources of ascorbic acid. Only the last two are represented and according to local natives these rarely bear fruit. Ascorbic acid deficiency may be partially avoided by the common use of *Salix pulchra* leaves which are rich in ascorbic acid.

Also missing in the flora is a ready source of carbohydrate such as is commonly obtained from *Hedysarum alpinum* (Eskimo potato) and *H. hedysaroides* farther south along the coast and also inland. The conical lateral roots and rootstocks of these plants are eaten raw, boiled, or roasted.

Most of the plants in the above list provide a form of "greens" to a predominantly meat diet. Several of the species used as food plants are also "pioneer" plants on disturbed areas, *e.g.*, *Cochlearia officinalis, Oxyria digyna,* and *Petasites frigidus.* Several species are common to wet snowbeds and shallow pools, e.g., *Rumex arcticus* and *Ranunculus pallasii.* The scarcity of woody plants places a demand on willows which are used for a variety of purposes; the leaves of some species are eaten. The principal tinder and fuel plants are fruticose lichens, *Cassiope tetragona,* and *Salix* spp.

SUMMARY

The site of archeological excavation of the Eskimo occupation at Walakpa Bay, southwest of Barrow, Alaska, is on the shoreline of the Chukchi Sea and the arctic coastal tundra. Inland, the relief is slight with the landscape dominated by large oval-shaped depressions and various forms of patterned ground. The vicinity illustrates development from lakes and open ponds to low-centred polygons and to high-centred polygons with contraction cracks and frost boils. The vegetational composition and cover of these sites was analyzed by a series of quadrats.

Coastal beaches and bluffs provide an area of unstable soils on which pioneer species are common. Several of these, *e.g., Cochlearia* and *Oxyria* serve as supplementary plant foods in the Eskimo diet.

A study of the plant succession invading the soil deposited from the eroded walls of a 100-year old abandoned sod house indicated that *Poa arctica* was the dominant invading species, composing 54 per cent of the vegetational cover. Its aggressiveness suggests its possibility for revegetation of disturbed arctic sites. *Cochlearia* was of secondary importance in relative coverage, followed by *Alopecurus* and *Calamagrostis.*

Several sites in the area showed a different vegetational composition due to increased nitrogenous wastes, human and otherwise.

Available plant food supplies are very limited. Walakpa Bay is beyond the northern edge of the range of several species of berry-producing plants which are rich in ascorbic acid. Only *Vaccinium vitis-idaea* and *Rubus chamaemorus* are represented. These rarely are successful now in producing fruit because of the wind and the shortness of the growing season. There are few species with succulent roots, such as *Hedysarum* which is common farther south and inland. The leaves of a variety of species are gathered and eaten raw, boiled, or preserved in seal oil for winter use. Some of these, *e.g., Salix pulchra* are rich in ascorbic acid. The few suffrutescent and woody species are used for fuel, matting, or bindings.

Existence at this site would depend strongly on a combination of meat supply from sea animals along the coast, supplemented by migrating caribou. Frequent use of the latter is indicated by the abundance of caribou bone material from the excavation.

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