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GRADIENT ANALYSIS OF PLANT GROWTH FORMS

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During the tenure of the IBP Tundra Biome program at Barrow and Prudhoe Bay and now at the onset of the RATE program an interest has emerged in the variation of vegetation productivity, plant life-forms and species diversity along microgradients at any one location and along macrogradients over large distances. At Barrow, Meade and Prudhoe the same generalized pattern is found along the microgradient of soil moisture (Fig. 9) (Wiggins 1951, Britton 1957). Bryophytes (e.g. *Drepanocladus* spp.) and single-shooted monocotyledons (e.g. most *Carex* spp.) give way to herbaceous dicotyledons (e.g. *Pedicularis* spp.) and finally to lichens (e.g. *Cetraria* spp.) and evergreen shrubs (e.g. *Ledum*) along gradients of decreasing soil moisture. Figure 9 also shows the generalized increase of productivity and decrease in number of species per unit area in response to increasing soil moisture. However in very wet and very dry sites both productivity and diversity reach minimum values. A study of life-form distribution within 75 stands of tundra vegetation from 15 international Tundra Biome sites around the world is summarized in Table X (Webber, unpublished data). The moisture preferences of each life-form agree with those in Figure 9. Thus not only has each life-form a preferred moisture regime but also a preferred soil temperature and soil nutrient regime.

Many workers have also noted the increase in the number of species along a gradient from Barrow to Meade (Clebsch and Shanks 1968, Britton 1957, Johnson and Tieszen 1973). This is generally interpreted as a response to the more favorable climate and the greater variety of substrate and habitat type at Meade than at Barrow. The same explanation is offered for the intermediate sized flora of Prudhoe where the climate and physiographic diversity are also intermediate.

These sites are different with respect to their predominant vegetation and also with respect to their zonal vegetation. At Barrow, the predominant vegetation comprises a few species and may be described as a series of wet sedge-moss meadows with few lichens and shrubs; soils are wet, acid and calcium-poor and the landscape is dominated by ice-wedge polygon complexes, ponds and former lake basins. Even on the better drained mesic sites shrubs and lichens are never abundant and the shrubs are never erect. The absence of erect shrubs places Barrow in the High Arctic Tundra zone (Alexandrova 1970). The majority of the Prudhoe/Deadhorse area is dominated by wet meadows and ice-wedge polygon complexes but the composition of the vegetation is richer in species than that of Barrow and is especially rich in calciphilous species such as *Dryas integrifolia*. Erect shrubs exist on some mesic sites and this leads to a classification of the vegetation as Low Arctic Tundra. At the immediate coast of Prudhoe Bay a narrow band of High Arctic Tundra exists which is analogous to the Barrow tundra; sites within this band have an almost identical plant species composition and even show evidence that the brown lemming (*Lemmus sibericus*) was abundant in 1975 as it was at Barrow. The vegetation at Meade is Low Arctic Tundra and has many other similarities to that of the main Prudhoe area including a calciphilous aspect. At Meade, however, upland tussock tundra and evergreen shrubs are both more widespread.

The road from Prudhoe to the northern Brooks Range offers an opportunity not only to examine patterns similar to the above in detail but to determine their underlying causes. It forms a transect which represents a complex gradient of increasingly continental climate, increasing elevation and

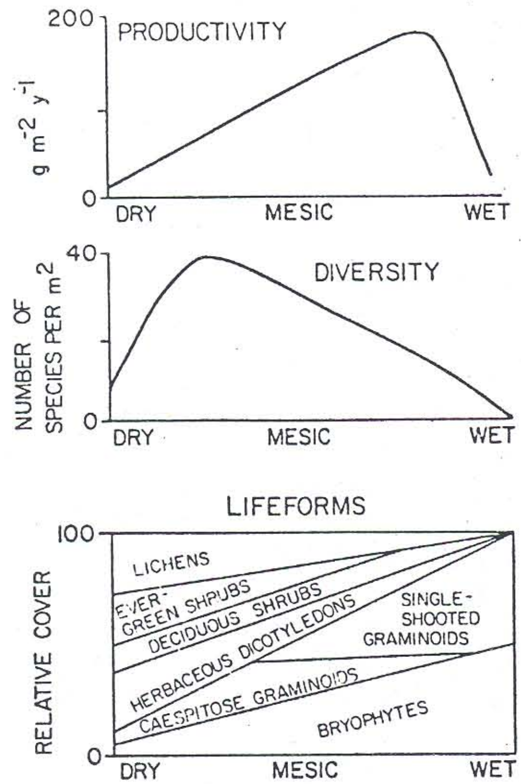

Figure 9. Generalized distribution of vegetation productivity, species diversity, and life-form along the complex soil moisture gradient of the tundra vegetation of the coastal plain, Alaskan Arctic Slope.

Table X. Correlation trends between seven common tundra life-forms and some substrate variables.

From unpublished International Tundra Biome vegetation comparison by Webber.

Life-form	*Moisture*	*Temp*	*Nitrogen*
Evergreen shrub	Dry	Cold	Low
Deciduous shrub	Mesic	Warm	High
Herbaceous dicotyledon	Dry-Wet	Cold–Warm	Low-High
Caespitose monocotyledon	Dry	Warm	High
Single monocotyledon	Wet	Cold	High
Bryophyte	Wet	Cold	High
Lichen	Dry	Cold	Low

more varied substrates southward and increasing age northward. The road net traverses from High Arctic Tundra at the immediate coast, through Low Arctic Tundra to an Alpine Tundra in the Mountains and thus it also offers the opportunity to reassess the zonal classification of the Arctic Slope. Eight stations on a transect from the drainage divide of the Brooks Range to the coast of the Arctic Ocean were established along the road during summer 1975 (Table XI). At each station three permanently marked plots were sampled for plant composition. The three plots represent the dry, mesic and wet segments of the local moisture gradient at each station. The following results and discussion are based on preliminary analysis of the data.

Only a life-form analysis is presented here. The individual species data are incomplete as taxonomic determinations must still be verified; also the sampled quadrats very much undersample the

Table XI. Description of study plots.

Plot	Name	Latitude (North)	Longitude (West)	Elev m (ft)	Moisture regime	Active layer (cm)*	No. species/m²
1	Dietrich Pass	68°08′	149°28′	1520 (5000)	Mesic	–	34
2	Dietrich Pass	68°08′	149°28′	1460 (4800)	Wet	11	18
3	Dietrich Pass	68°08′	149°28′	1490 (4900)	Dry	–	21
4	Atigun Camp	68°11′	149°26′	1160 (3800)	Wet	18	3
5	Atigun Camp	68°11′	149°26′	1190 (3900)	Mesic	14	25
6	Atigun Camp	68°11′	149°26′	1170 (3850)	Dry	–	23
7	Galbraith Lake	68°30′	149°29′	810 (2650)	Mesic	17	21
8	Galbraith Lake	68°30′	149°29′	810 (2650)	Dry	37	26
9	Galbraith Lake	68°30′	149°29′	790 (2600)	Wet	15	4
10	Toolik Lake	68°38′	149°36′	750 (2450)	Dry	–	25
11	Toolik Lake	68°38′	149°36′	730 (2400)	Wet	22	5
12	Toolik Lake	68°38′	149°36′	760 (2500)	Mesic	13	33
13	Happy Valley	69°02′	148°50′	400 (1300)	Mesic	13	22
14	Happy Valley	69°08′	148°50′	320 (1050)	Wet	17	5
15	Happy Valley	69°08′	148°50′	320 (1050)	Dry-Mesic	N.D.	23
16	Franklin Bluffs	69°44′	148°45′	110 (350)	Dry	35	30
17	Franklin Bluffs	69°44′	148°45′	110 (350)	Wet	31	6
18	Franklin Bluffs	69°44′	148°45′	110 (350)	Mesic	19	25
19	Pipeline Junction	70°01′	148°43′	45 (150)	Dry	25	31
20	Pipeline Junction	70°01′	148°43′	45 (150)	Mesic	18	18
21	Pipeline Junction	70°01′	148°43′	45 (150)	Wet	21	2
22	Putuligayuk River	70°11′	148°48′	15 (50)	Dry	N.D.	30
23	Putuligayuk River	70°11′	148°48′	15 (50)	Mesic	N.D.	22
24	Putuligayuk River	70°11′	148°48′	15 (50)	Wet	N.D.	8

* Measured between 21 and 30 June 1975.
– Too rocky to determine active layer.
N.D. - No data.

Table XII. Mean relative cover values of the life-forms for all plots with the same site moisture regime.

Life-form	Moisture regime Dry	Mesic	Wet
Evergreen shrub	8	3	0
Deciduous shrub	10	10	0
Herbaceous dicotyledon	16	4	2
Caespitose graminoid	1	6	0
Single-shooted graminoid	4	10	40
Bryophyte	32	60	57
Lichen	29	7	1
Number of species/m²	26.1	25.0	6.4

total flora. We have used the simple seven life-form system developed for the RATE program. Relative plant cover values were used in this assessment in order to avoid the complexity imposed by surface water, bare soil and rocks in some plots.

If all plots of each moisture regime from along the transect are pooled (Table XII) then the distribution of life-forms along the microgradient of site moisture is very similar to the generalized patterns of Figure 9 and Table X. The increase in number of species per square meter with increasing site moisture is not as clear as depicted by Figure 9. However, a finer moisture regime classification of the sites would probably enhance the agreement.

The distribution of the seven life-forms along the macrogradient from the coast to the crest of the mountains (Fig. 10) reflects the increasing continentality and better site drainage conditions. For example the single-shooted graminoids are dominant on the wet coastal plain and lichens are

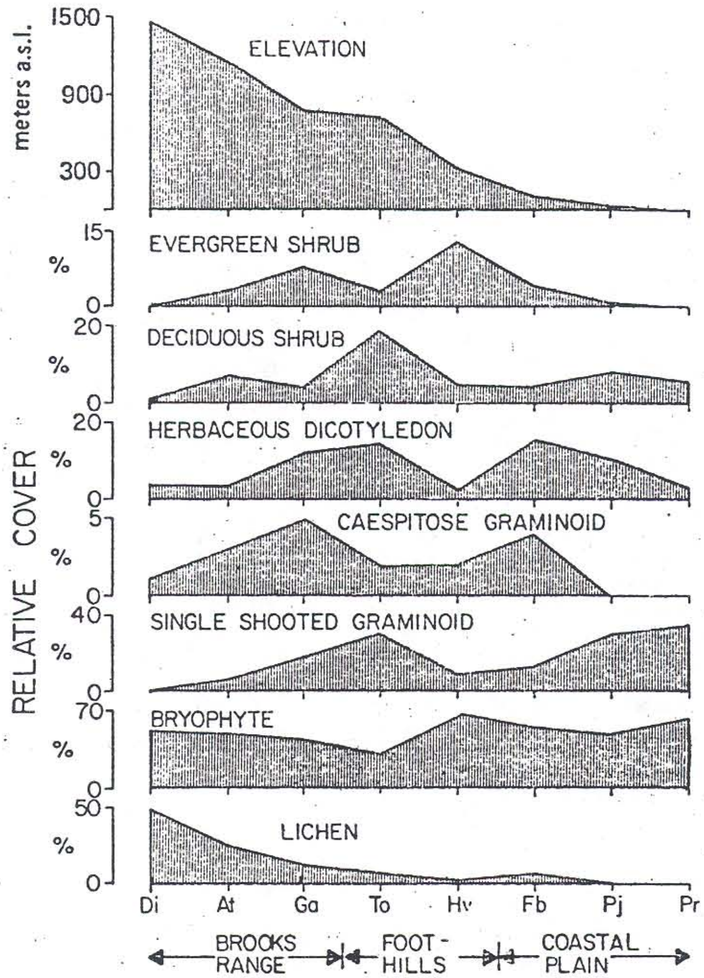

Figure 10. Elevation and relative cover values (%) for the seven life-forms along the study transect. Values are means of the three sampled plots at each transect station.

dominant on the better drained mountain surfaces. In the coastal plain section lichens, caespitose graminoids, and shrubs are never abundant while the single-shooted graminoids and bryophytes are abundant. The decreasing importance of shrubs towards the coast supports the notion of classifying a coastal strip as High Arctic Tundra. Bryophytes are plentiful throughout the transect but there is a shift in emphasis from wet-preferring pleurocarpous mosses to dry-preferring acrocarpous mosses along the complex gradient inland. Evergreen and deciduous shrubs and caespitose graminoids are characteristic of the central foothills section of the transect. Our data suggest that the shrub form almost disappears in the high mountains above 1000 m. The restricted distribution of shrubs gives support to the classification of the mid-section of the transect as Low Arctic Tundra. The caespitose or tussock graminoid form is epitomized by *Eriophorum vaginatum* which is prevalent in the central portions of the transect. However other caespitose graminoids are to be found, for example *Luzula confusa*; most of these are characteristic of drier sites than *Eriophorum vaginatum*. Herbaceous dicotyledons are present throughout the transect, being less abundant at each end. Extension of the transect to the shore of the Beaufort Sea would result in herbaceous dicotyledons occupying an insignificant component of the vegetation as they do at Barrow. The herbaceous dicotyledon category of this study is not a very distinct life-form group. In other studies we have subdivided it into erect, rosette, mat, and cushion forms; each of these has preferred positions along various gradients. Any further studies of this present type should make a more careful assessment of the herbaceous dicotyledons.

Table XI contains values for the number of species per square meter and the thickness of active layer at each plot and site. Preliminary analysis does not reveal any distinct patterns of these variables and replication is required in the future.

The transect data are insufficient to shed much insight on the problems of zonal classification for the Arctic Slope. However if the transect were extended to higher elevations and to the coast proper and if both the number of sampling intervals and the size of sample were increased a valid assessment of the zonal classification would be forthcoming.

This preliminary survey has shown that each life-form has a specific distribution along local moisture gradients and along the complex gradient from the Arctic Ocean to the crest of the Brooks Range. The patterns detected show strong similarities with those generalized for the coastal tundra and for 15 circumpolar sites. No cause and effect mechanism which might explain the adaptation and distribution can be elucidated at the present. Nevertheless these answers can be forthcoming with a field and experimental study within this phenomenal outdoor laboratory which the pipeline corridor has made accessible to plant ecologists.

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