Disturbance and the Successional Response of Arctic Plants on Polar Desert Habitats

An important consideration in ecological research is to determine if conventionally accepted ecological principles operate in similar ways among the diverse environments of the world's major biomes. One approach to answering this question is to examine ecosystems where physical environments are extreme by comparison with temperate or mesophytic ecosystems. Barbour[1], for example, has recently reviewed the evidence for three generally-accepted adaptive features of desert vegetation (productivity, growth and pattern) and found each to lack substantial factual basis, when contrasted with features of more mesic systems. His analysis points clearly to the need for quantitative data to permit correct interpretations about the adaptations of organisms to extreme environments and, more importantly, in testing the universality of widely-held ecological principles.

The concepts of succession and climax vegetation have proved to have considerable predictive value for ecologists. Numerous examples of the successional process have been described from temperate and boreal ecosystems. Early work in the arctic tundras of North America, however, generated questions about the validity of applying classical successional concepts in these regions[2]. Questions focused primarily on the short time periods available for equilibrium communities to become established and, more importantly, on the continuous instability of most substrates caused by widespread congeliturbation. The latter was thought to generate "fragmentary successional cycles" or "heterogenous assemblages of pioneer species"[3].

The problem was later extensively reviewed by Churchill and Hanson[4] who pointed to the lack of quantitative data available on the rate and nature of replacement changes in communities and on community variation. Their conclusions on successional processes in the Arctic were generated primarily from descriptive correlative studies then available for tundra communities. The lack of quantitative data on successional processes in the Arctic remains as acute today as at the time of Churchill and Hanson's review, and knowledge of the variation in community structure on a broad geographical basis remains fragmentary[5]. These problems have recently taken on an added applied importance, since attempts to establish restorative plant covers of non-arctic plant species are underway in the Canadian Arctic islands where disturbance resulting from oil and gas exploration activities has occurred[6].

The present authors have observed during several summer seasons disturbance-induced succession on the Truelove Lowland of Devon Island (76°N) in the Canadian Arctic Archipelago. In this paper are presented the results of observations of the successional response of three vascular plant species on polar desert microenvironments subjected to vehicle disturbance.

The study area is a post-Pleistocene strand flat on the northeast coast of Devon Island. A pronounced series of raised beaches are in evidence from the present coastline inland to the upper marine limit (Fig. 1). These relict beaches provide microsites of polar desert conditions in the midst of a landscape dominated chiefly by hydric tundra meadows. As

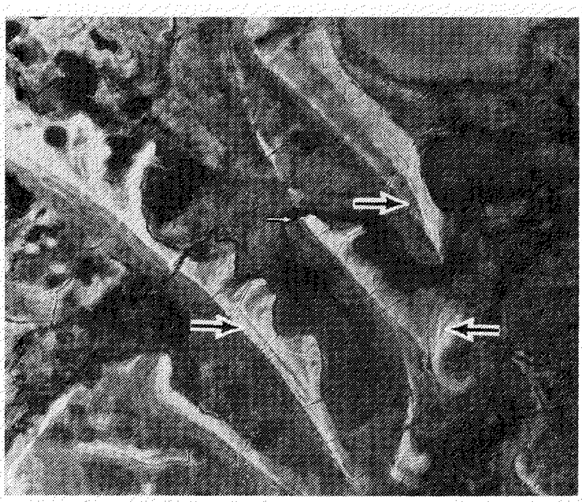

FIG. 1. Aerial view of raised beach crests as studied. Large arrows indicate locations of vehicle-disturbed pavement. Smaller arrow denotes location of hand denuded plots.

such they represent the xeric portion of a typical arctic "mesotopographic gradient" recently described by Billings[7].

Teeri[8] has validated the desert-like quality of these sites with respect to the water relations of plant species established on them, and Barr[9] has constructed isostatic emergence curves for the area. In combination the data presented by the two writers suggest that these locations have been both free from intensive congeliturbation and available for plant colonization for a relatively long time period. The beaches examined during the present study are in the order of 5,000 to 6,000 years emergent[9]. The present writers interpret the plant communities established on these sites to be in equilibrium with the present environment and thus represent climax plant communities.

The phytosociology of this community is known in detail[10]. The surface of the beach crest is composed of a desert-like pavement of pebbles and cobble. Vascular plant cover is sparse. Only four species occur consistently and may be dominant in terms of cover; *Saxifraga oppositifolia, Dryas integrifolia, Salix arctica* and *Carex nardina*. About a dozen other species are found sporadically, none showing more than trace cover in this community. Lichens normally cover between 40% and 50% of the ground surface. Most of the lichen species (56 taxa have been noted) are of crustose or foliose genera.

These raised beach sites, because of their xeric nature and hard surface pavement, provide the most acceptable locations for the movement of tracked vehicles within the area. During the period of establishment of the present research facilities in 1960-61, and during the years of 1962 through 1969, a variety of tracked vehicles were utilized for logistic activities associated with maintenance and supply of the research station. The repetitive use of particular beaches along main travel routes resulted in what appears upon casual inspection to be a virtual elimination of the plant cover on the beach crests (Fig. 2). Since 1969 the use of tracked vehicles has been severely restricted, and many beaches have been essentially free of disturbance by heavy vehicles since that time. During the summer of 1973 the present authors analysed three beach ridges (Fig. 1) to ascertain in a quantitative manner the difference between those sites now in the process of recovering and adjacent undisturbed communities. Quadrats 0.5 m x 5.0 m in size were placed at 10-metre intervals along vehicle-disturbed areas, and at three metres to the side at the same intervals in undisturbed portions of the beach. Individual species were counted at each quadrat. Total cover values for vascular plants and lichens were estimated visually by two observers and the averages of their respective estimates recorded. Results of these analyses are presented in Table 1. Data have been included for only the three most consistently encountered species, since these made up the majority of vascular plant cover on the plots analysed. Other vascular species occurred only sporadically. Data from quadrats on the undisturbed portion of the beach show expected values. Vascular plant cover is low, lichen cover dominates and *Saxifraga oppositifolia* and *Dryas integrifolia* are prominent both in terms of numbers and cover. *Minuartia rubella,* while consistently present is represented by only a few individuals on each quadrat. The high count on plot 1 of beach A is due to a group of seedlings found beneath a single mature plant.

The values for total plant cover on the

FIG. 2. Vehicle track along the surface of a raised beach crest. Lighter colour results from sandy material exposed after removal of the lichen mat and vascular plant cover.

TABLE 1. Individual counts and overall cover values for plants on undisturbed and vehicle-disturbed beach pavement.

Beach	A			B			C						MEAN
Sample no.	1	2	3	4	5	6	7	8	9	10	11	12	
Undisturbed beach pavement													
Vascular plant cover (%)	35	30	7	40	36	28	25	45	27	33	40	26	31
Lichen cover (%)	50	53	55	57	48	55	50	40	45	43	37	33	47
Plant counts per 2.5m²:													
**Saxifraga oppositifolia*	89	59	37	127	90	77	69	79	61	88	87	87	79
**Dryas integrifolia*	20	24	7	40	46	14	42	33	25	25	28	15	27
Minuartia rubella	35	3	4	2	2	11	1	1	1	0	4	2	5
Vehicle-disturbed beach pavement													
Vascular plant cover (%)	8	4	3	6	3	9	7	6	3	6	4	3	5
Lichen cover (%)	less than unity												
Plant counts per 2.5m²:													
**Saxifraga oppositifolia*	48	38	37	84	89	94	96	99	65	47	33	116	72
**Dryas integrifolia*	5	2	0	7	6	8	12	6	1	7	3	6	5
Minuartia rubella	32	44	35	14	16	75	51	78	19	18	29	44	38

*Cushions of *Saxifraga* and *Dryas* were recorded as individual plants.

vehicle-disturbed pavement are, not unexpectedly, drastically reduced. More interesting, however, are comparisons of the three species in recolonization. The two species found most commonly in undisturbed communities show quite distinctive responses following disturbance. *Saxifraga oppositifolia* seedlings yielded counts similar to those for undisturbed terrain, while *Dryas integrifolia* populations remained severely reduced in numbers. *Minuartia rubella,* on the other hand, had substantially increased its numbers in comparison with those for the species on undisturbed terrain. Further, in the majority of quadrats on disturbed areas *Minuartia rubella* was now the major contributor to the total vascular plant cover. *Saxifraga oppositifolia* while prominent numerically was represented chiefly by smaller seedlings and thus contributed substantially less to cover values. Similar results were also obtained on small quadrats artificially denuded of all vegetation in 1969 (Table 2). Counts of individuals on four quadrats showed the presence of a number of invading *Minuartia rubella* seedlings and occasional *Saxifraga oppositifolia,* but after four years all plots still lacked *Dryas integrifolia.*

Harper[11] has suggested that the artificial creation of low-diversity communities in the field may be a fruitful method for understanding the way in which observed patterns in climax communities are established with time. Observations made during the present study

TABLE 2. Individual counts of three plant species from 40 x 40 cm plots which were cleared of vegetation by hand in the summer of 1969.

Plot no.	1		2		3		4	
Year of mapping	1971	1973	1971	1973	1971	1973	1971	1973
Plant counts (40 cm x 40 cm)								
Saxifraga oppositifolia	1	1	1	1	0	0	1	0
Dryas integrifolia	0	0	0	0	0	0	0	0
Minuartia rubella	5	8	12	18	6	9	2	8

indicate that, for these habitats at least, important shifts in the numerical relationships between species occur following vehicle disturbance (and subsequent reduction in community diversity). The sharp increases in populations of *Minuartia rubella* and the distinctive recolonization rates of *Saxifraga oppositifolia* and *Dryas integrifolia* populations may be easily viewed as disturbance-induced succession. The causal reasons for these population responses are not known. All three species appear to produce substantial amounts of seed in the field. These observations do serve to emphasize, however, that our present understanding of the population dynamics of Arctic tundra plants may be inadequate for predictive purposes. It is unlikely, for example, that in selecting native plants for restoring vegetation on disturbed xeric tundra *Minuartia rubella* would have been favoured over *Dryas integrifolia* if we were to rely solely on our observations of the two species in undisturbed communities.

The study of responses of vegetation to current land manipulations in the Arctic may provide valuable clues to the understanding of the successional process in this region. It is the authors' belief that existing data on succession in tundra in the High Arctic are inadequate for the long-range planning of land use in many tundra habitats, and that greater emphasis should be directed towards this problem in the future.

ACKNOWLEDGEMENTS

This work was financed in part by the Arctic Institute of North America and by the ALUR Program of the Department of Indian and Northern Affairs. The authors, however, assume full responsibility for all information presented. They would particularly like to thank Mr. Fred Alt of the Polar Continental Shelf Project, which provided logistic support.

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