BIOCLIMATIC ZONATION IN A HIGH ARCTIC REGION: CENTRAL QUEEN ELIZABETH ISLANDS

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Abstract

The central Queen Elizabeth Islands in the High Arctic are subdivided into four bioclimatic zones based on plant community life-forms, species diversity within plant communities, total number of species, and the presence and abundance of a variety of indicator species such as woody plants, marsh emergents, sedges, vascular cryptogams, legumes, and Compositae. These zones, which cross lithologic boundaries, establish a 'mini-treeline' north of which no woody species occur (prostrate dwarf shrubs such as arctic willow and mountain avens) and a 'mini-forest zone' in which dwarf shrubs are the major vascular plant component. This bioclimatic zonation occurs on latitudinal, altitudinal, and local scales. It appears likely that the mean daily July temperature for the limit of vascular plants is a little above 2.5°C, for woody plants ('mini-treeline') is between 3° and 3.5°C and for the 'mini-forest zone', is between 3.5° and 4°C.

Introduction

Little is known of detailed climatic variations in the broad region of the Canadian High Arctic (the region north of 74°N). Five permanent weather stations, all located near sea level, were established in this region after World War II (Fig. 53.1). Little short- or long-term weather data are available for vast areas between these stations and for areas away from the coast (Maxwell, 1980).

During a decade of fieldwork in the Arctic Islands involving the study of plant communities – their composition and relationships to surficial materials – I have observed vegetation patterns that cross lithological boundaries and seem to reflect climatic zones within the High Arctic. This report summarizes these patterns for the central Queen Elizabeth Islands between 90° and 114°W (Fig. 53.1) and parts of adjacent eastern islands.

The better understanding of the coincidence of climate and vegetation boundaries will help in the more accurate interpretation of paleobotanical samples and of paleoclimates. This knowledge also may be used to extrapolate climatic data into regions where few weather statistics are available and has implications for the delineation of critical wildlife habitats, especially for herbivores dependent on dwarf shrubs and sedges.

Previous Work

Polunin (1951) subdivided the Canadian Arctic into three major regions, based primarily on extent of vegetation cover: (1) Low Arctic, the region immediately north of treeline, with continuous vegetation on all landforms; (2) Mid Arctic, where vegetation is less continuous, with bare areas common on the tops of hills and windswept plateaus; and (3) High Arctic, the region in the far North, with continuous vegetation confined to sheltered, well watered locations such as lower slopes and valley bottoms. The Queen Elizabeth Islands lie within this High Arctic zone.

Babb and Bliss (1974) have subdivided the High Arctic into four broad categories: (1) polar desert areas of very sparse vegetation; (2) polar semi-desert having continuous vegetation only locally; (3) diverse terrain, with greater potential for tundra or sedge moss meadows; and (4) sedge-moss meadows, with nearly continuous vegetation, found mainly in lowlands. These categories primarily reflect availability of moisture. Aleksandrova (1970, 1980) included the Canadian Arctic in her circumpolar classification of vegetation, which is also based on continuity of vegetation but also takes account of degrees of floristic diversity. The central Queen Elizabeth Islands lie within her polar desert and semi-desert zones.

Young (1971) divided the High Arctic into two floristic zones based on degrees of impoverishment of the vascular flora: zone 1 is a region of extreme improverishment, with generally less than 50-75 species of which most are circumpolar, an absence of vascular cryptogams, and a lack of closed communities; zone 2 has a slightly richer flora (75 to 125 species) and a few vascular cryptogams.

Beschel (1970) subdivided the vegetation of the mountainous eastern Queen Elizabeth Islands (Axel Heiberg, Ellesmere, and Devon islands) into five categories based on species diversity and community complexity: (1) polar desert, (2) **Luzula** steppe, (3) **Dryas** tundra, (4) **Cassiope** tundra, and (5) polar steppe. The criteria for this zonation, however, were not published. He showed that for this region, changes in elevation influenced the zonation of vegetation to a greater degree than did changes in latitude and documented zones of unusually rich vegetation, atypical of High Arctic communities. Beschel (1969) also listed total number of vascular plant species for each island of the Canadian Arctic, thereby showing the variation between islands.

In all these classifications, the central Queen Elizabeth Islands region is one of extreme improverishment of vegetation.

Relationships Between Vegetation and Surficial Materials

Although my work confirms the regional impoverishment of vegetation in the central Queen Elizabeth Islands, it also indicates a greater variety of plant communities exists than previous regional classifications have recognized. During fieldwork it became apparent that some surficial materials, commonly certain types of weathered bedrock, do not readily support plant growth regardless of moisture regime or degree of shelter. Examples are areas of strongly alkaline bedrock (pH 8.0-8.6), including certain facies of limestone, dolomite, and gypsum; white quartzose sandstones which lack plant nutrients and may be prone to eolian processes; strongly acidic shales (pH 3); and extremely saline marine sediments.

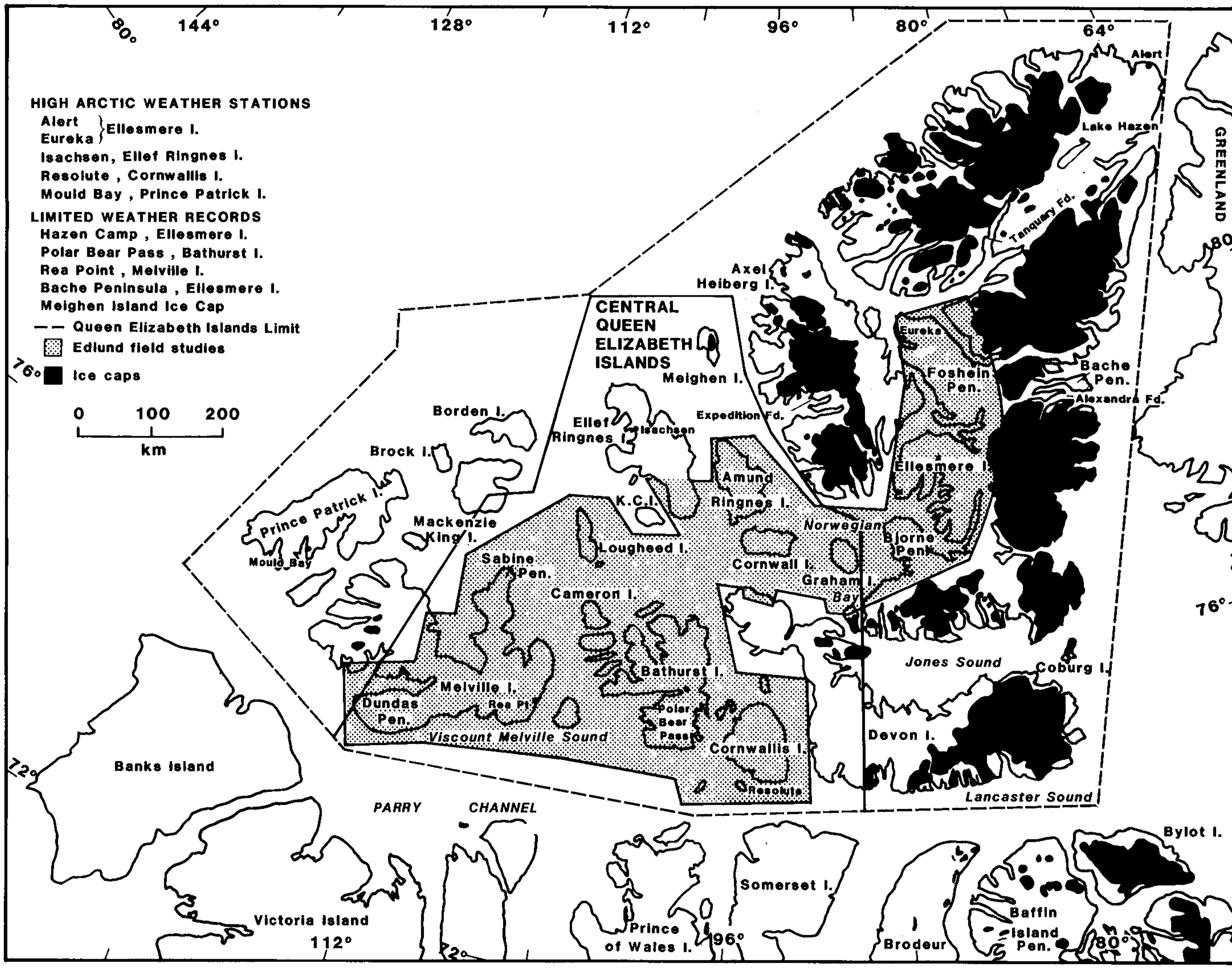

Figure 53.1. *Queen Elizabeth Islands, showing study area, the location of weather stations, field areas covered, and the extent of ice cover.*

All other types of bedrock and surficial deposits, other than those listed above, are consistently vegetated but the plant communities vary with substrate texture, chemistry, and moisture availability. Calciphilic communities occur on weakly to moderately calcareous material; certain graminoid species are most common on silts and clays; and **Luzula** (rush)-based communities occur on noncalcareous sandy silt and sand (Barnett et al., 1975; Hodgson and Edlund, 1975, 1978; Edlund, 1980, 1982a, b). Variation in type of surficial material does not, however, account for all the differences seen within plant communities in the Queen Elizabeth Islands.

Bioclimatic Zonation

For each type of material that supports vegetation, a suite of plant communities occurs, reflecting the changes in moisture regime (wet, mesic, or xeric). For each type of moisture regime on a given substrate, the vascular plant component of plant communities in the High Arctic forms a continuum in which floristic diversity and per cent cover decreases and the importance of the dwarf shrub life-form diminishes, until it is replaced by an entirely herbaceous life-form. These trends of increasing impoverishment cross lithological boundaries.

These continua may be divided into four zones, in each of which the community life-form is constant for each moisture regime, even though the individual species composition varies for different substrates. Emphasis is placed on changes in the vascular plant flora, for these changes are most readily detected. Identification of similar trends for lichens and bryophytes has not yet been attempted.

Criteria for Bioclimatic Zonation

The vegetation of the central Queen Elizabeth Islands is subdivided into four zones based on: the presence and abundance of woody species, the presence and diversity of Cyperaceae (sedges and cottongrasses), the types of emergent marsh species, the presence and types of vascular cryptogams (ferns, horsetails, and club mosses), the diversity of halophytic (salt tolerant) communities, and the total number of vascular species. Certain herbaceous species are used as zonal indicators.

The presence and abundance of woody species are the easiest recognized zonal characteristics. In the High Arctic, the only woody species are dwarf shrubs such as prostrate willows (**Salix arctica** and in a few places **S. polaris**), mountain avens (**Dryas integrifolia**), arctic heather (**Cassiope tetragona**), and bilberry (**Vaccinium uliginosum**) (Porsild, 1964; Porsild and Cody, 1980).

The presence of vascular cryptogams was used by Young (1971) to help distinguish his zone 2 from zone 1; he also used the total number of vascular species to help define his boundaries. Aleksandrova (1970, 1980) found variation of halophytic and marsh species useful in defining her zones. These criteria have been useful in my zonation as well; vascular cryptogams and diversity of marsh and halophytic species help define zones 3 and 4 (Table 53.2).

The diagnostic characteristics of each bioclimatic zone are described, starting with the zone of least diversity (zone 1) and progressing to the zone of greatest diversity and abundance (zone 4). This is summarized in Table 53.1 and the distribution of selected species by zones is shown in Table 53.2.

Zone 1

Zone 1 represents the most impoverished flora in the High Arctic. Permanent snowbeds are common in ravines and gullies and on the upper parts of some long, steep slopes where redistribution of winter snow creates thick drifts. Much of the terrain is unvegetated; vascular plant species total less than 35 species and are entirely herbaceous. Where vegetation occurs, total cover of vascular species is generally less than 5% and in many areas is as low as 1 or 2%.

Xeric sites, where vegetated, generally have less than 5% vascular plant cover, and rarely is there a cryptogamic lower stratum although scattered mosses and lichens may be present. Within this herbaceous vegetation, dominance varies with the different substrates: purple saxifrage (**Saxifraga oppositifolia**) is common on weakly to moderately calcareous materials; woodrush (**Luzula** species) is common on weakly acidic sand and sandy silt; and grasses such as **Alopecurus alpinus** and **Puccinellia** are common on silt and clay. In places no dominance is detected in the herbaceous layer; **Papaver**, Saxifrages, and grasses are present in about the same amounts.

Mesic sites have a higher per cent total plant cover (50-75%) than xeric sites due to a thin lower stratum of soil lichens (including **Polyblastia** species) and bryophytes. Nevertheless, as indicated above, the cover of vascular plants rarely exceeds 5%. Vascular species dominance is commonly similar to that found on more xeric areas.

Wet sites, if vegetated, are dominated by grass species (**Alopercurus alpinus** and to a lesser extent **Dupontia Fisheri**). The lower stratum, which is composed of bryophytes and soil lichens, is commonly broken (50-75%) but locally may be continuous.

Dwarf shrubs, sedges, vascular cryptogams, legumes, and Compositae do not occur in this zone, nor do exclusively emergent marsh species. Halophytic communities are generally absent; where present they consist of scattered tufts of **Puccinellia phryganodes**, which rarely flower, and the sporadic **Cochlearia officinalis.**

Zone 2

Vascular plant diversity increases to between 35 and 60 species in zone 2 and cover may reach 10%, although much of the landscape still appears unvegetated. Permanent snowbeds are less common and extensive. Dwarf shrubs (**Salix arctica** and **Dryas integrifolia**) and the sedges **Carex aquatilis** and **Eriophorum Scheuchzeri** (cottongrass), may occur locally but do not form major components of the plant communities.

Table 53.1

Change in life form, per cent vascular plant cover, and floristic diversity for the major moisture regimes within the bioclimatic zones, Queen Elizabeth Islands

Bioclimatic Zone	Total no. vascular species	Moisture Regime: Wetlands	% cover vascular	% cover total	Mesic	% cover vascular	% cover total	Xeric	% cover vascular	% cover total
1	less than 35	bryophytic mat	<1	<75	patina of soil lichens and bryophytes	<1	<75	scattered lichens	<1	<5
		graminoid-moss meadow	1-5	50-100	herb-patina tundra	1-5		herb barrens	1-5	<5
2	35-60	graminoid-sedge moss meadow	1-10	75-100	herb-patina tundra with scattered dwarf shrubs	5-10	<75	herb barrens	1-10	<10
3	60-100	sedge-moss meadow	5-15	75-100	dwarf shrub herb-patina tundra	5-25	<90	dwarf shrub-herb barrens	5-15	<20
4	greater than 100	sedge-moss wet meadow (local willow)	10-25	75-100	dwarf shrub-patina tundra	15-50	<90	dwarf shrub barrens	5-25	<30

Table 53.2

Distribution of some vascular species by bioclimatic zone, High Arctic Islands

	Bioclimatic Zone			
	4	3	2	1
Woody species				
Salix arctica	*	*	l	-
Salix polaris ssp. pseudopolaris	r	-	-	-
Dryas integrifolia	*	*	l	-
Cassiope tetragona	l	r	-	-
Vaccinium uliginosum	r	-	-	-
Major wetland species				
Alopecurus alpinus	*	*	*	*
Arctagrostis latifolia	*	l	-	-
Dupontia Fisheri	*	*	*	l
Hierochloe pauciflora	l	-	-	-
Carex aquatilis var. stans	*	*	l	-
Carex membranacea	r	-	-	-
Eriophorum angustifolium	l	-	-	-
Eriophorum triste	*	*	l	-
Eriophorum vaginatum	r	-	-	-
Emergent marsh species				
Arctophila fulva	*	-	-	-
Pleuropogon Sabinei	*	*	l	-
Caltha palustris	*	-	-	-
Ranunculus hyperboreus	*	*	-	-
Ranunculus Gmelini	l	-	-	-
Halophytic species				
Puccinellia phryganodes	*	*	l	r
Stellaria humifusa	*	l	-	-
Senecio congestus	l	-	-	-
Vascular cryptogams				
Cystopteris fragilis	l	-	-	-
Dryopteris fragrans	l	-	-	-
Woodsia glabella	l	-	-	-
Equisetum arvense	l	-	-	-
Lycopodium Selago	l	-	-	-
Tundra species and unusual colonizers of disturbed areas				
Agropyron latiglume	l	r	-	-
Deschampsia brevifolia	*	l	-	-
Hierochloe alpinus	l	-	-	-
Trisetum spicatum	l	r	-	-
Melandrium affine	l	r	-	-
Melandrium apetalum	*	l	r	-
Melandrium triflorum	l	-	-	-
Ranunculus pedatifidus	l	-	-	-
Erysimum Pallasii	l	-	-	-
Lesquerella arctica	l	-	-	-
Chrysosplenium tetrandrum	l	-	-	-
Saxifraga Hirculus	*	l	r	-
Geum Rossii	*	-	-	-
Potentilla pulchella	l	-	-	-
Potentilla rubricaulis	l	-	-	-
Potentilla Vahliana	*	r	-	-
Astragalus alpinus	l	-	-	-
Oxytropis arctobia	l	-	-	-
Oxytropis Maydelliana	*	-	-	-
Epilobium latifolium	l	r	-	-
Androcaceae septentrionalis	l	-	-	-
Armeria maritima	r	-	-	-
Polemonium borealis	r	-	-	-
Pedicularis arctica	*	l	-	-
Pedicularis capitata	l	r	-	-
Pedicularis hirsuta	l	-	-	-
Pedicularis sudetica	l	-	-	-
Campanula uniflora	r	-	-	-
Arnica alpina	l	r	-	-
Crepis nana	r	-	-	-
Erigeron compositus	l	-	-	-
Erigeron eriocephalis	l	-	-	-
Petasites frigidus	l	r	-	-
Taraxacum hyparcticum	l	r	-	-
Taraxacum lacerum	r	-	-	-
Taraxacum phymatocarpum	l	r	-	-

r = rare; l = local; * = common; - = absent

Xeric and mesic sites have a herbaceous flora similar to that of comparable sites in zone 1, although the per cent cover and diversity of herbs are greater. A component (less than 2% cover) of small dwarf shrubs, consisting of **Salix** and **Dryas**, distinguishes this zone from zone 1.

In the wetlands grasses are dominant, but sedges and cottongrass occur at some sites. The only emergent marsh species, semaphore grass (**Pleuropogon Sabinei**), grows at the edges of some ponds and lakes.

As in zone 1, halophytic communities consist of **Puccinellia phryganodes** and **Cochlearia** but these species are somewhat more common here and occur sporadically on coastal sediments. A number of typical arctic species are absent from the flora of zone 2, most notably arctic heather, bilberry, numerous sedge and cottongrass species, vascular cryptogams, and many forbs and grasses.

Zone 3

The vascular flora of zone 3 consists of between 60 and 100 species. Continuous vegetation is more common than in zones 1 and 2 although it is generally restricted to lower slopes, valley bottoms, and areas adjacent to ponds and lakes. This zone is readily distinguished by the prevalence of dwarf shrubs on xeric and mesic sites. Persistent snowbeds are less common.

Xeric sites are vegetated by dwarf willow (**Salix arctica**) and mountain avens (**Dryas integrifolia**), the latter being confined to weakly to moderately calcareous materials. Total vegetation cover reaches 15% (locally 25%), with herbaceous species (usually herbs found on similar materials as in zones 1 and 2) reaching only 5% cover; however, herbs may be more common locally. As in zones 1 and 2, a lower stratum is generally absent, although mosses may occur beneath and adjacent to dwarf shrub branches.

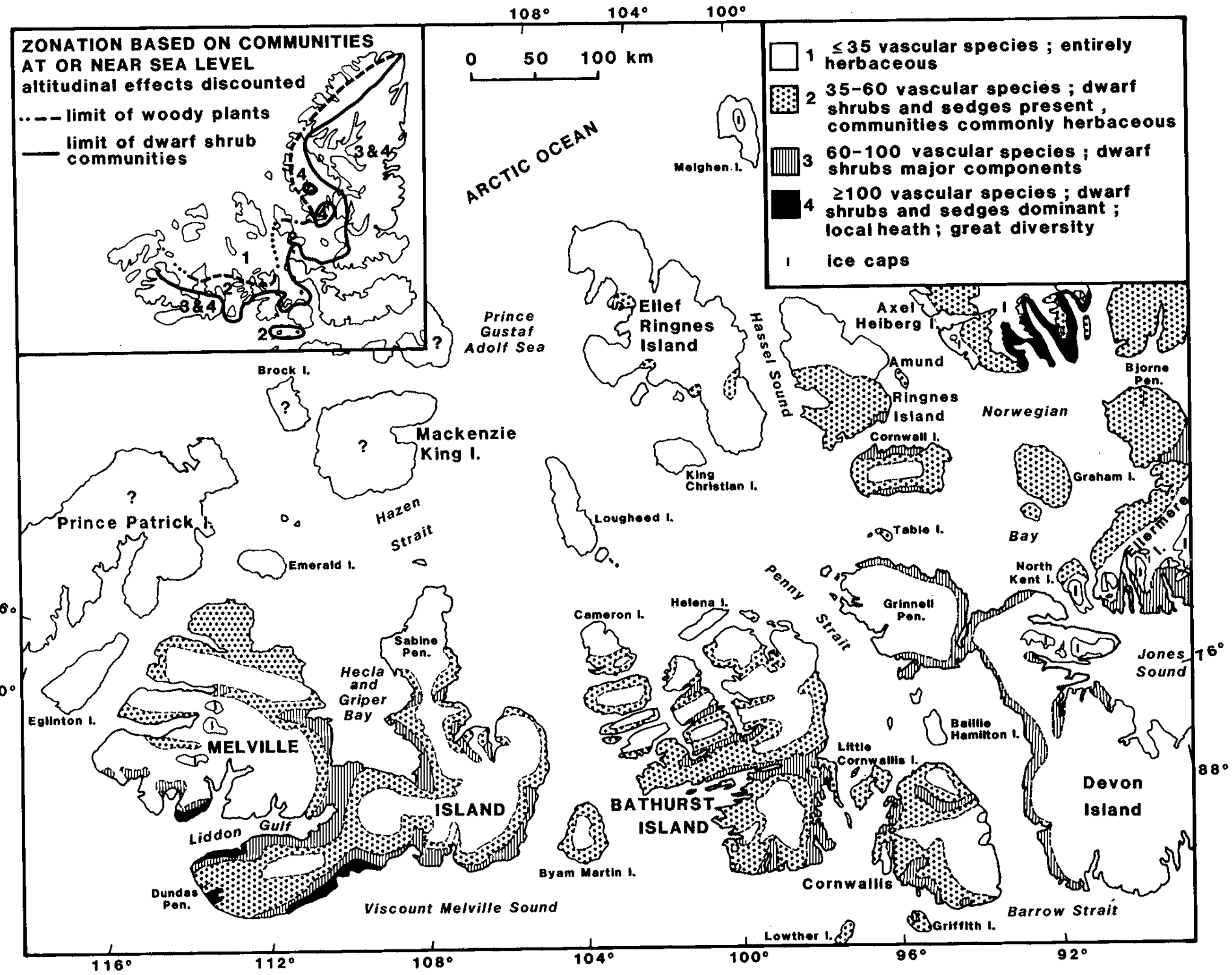

Figure 53.2. *Bioclimatic zonation of the central Queen Elizabeth Islands and vicinity.*

On mesic sites total vascular plant cover reaches 25% and, as on xeric areas, willow and mountain avens are dominant, with herbs as significant associates. A lower stratum may be present and is similar to that described for zone 1. Arctic heather may occur locally in sheltered locations, generally on noncalcareous materials.

Carex aquatilis and **Eriophorum** species are the major components of wetland communities, although grass species are common associates as well. Marsh emergents include the grass **Pleuropogon Sabinei** and, in places, **Ranunculus hyperboreus.** A continuous lower stratum of bryophytes, especially **Drepanocladus** species, occurs on wetlands.

Halophytic communities, consisting of **Puccinellia phryganodes** turf and some mats of **Stellaria humifusa,** occur on many undisturbed coastal sediments. Vascular cryptogams, including the club moss **Lycopodium Selago** and horsetails (**Equisetum arvense** and **E. vaginatum**), occur locally on sandy materials.

Zone 4

At least 100 vascular plant species are found in zone 4 which has the richest vegetation in the High Arctic. Vegetation is commonly continuous on mid to lower slopes and in valley bottoms on all materials capable of supporting vegetation. Persistent snowbeds rarely last through mid August.

Xeric sites have vegetation similar to that of zone 3; however vascular plant cover commonly reaches 25%, because of an increase in dwarf shrub cover.

Mesic sites are also dominated by dwarf shrubs, as in zone 3, with up to 50% vascular plant cover. In some areas a thin patina, with bryophytes in cracks and depressions, makes the vegetation cover nearly continuous (50-75%). Local thickets of arctic heather occur in sheltered locations on noncalcareous materials. Legumes, **Geum Rossii,** Compositae, and Cyperaceae (e.g., **Carex, Kobresia,** and **Eriophorum**) are common.

Wetlands include a variety of sedges and grasses, with cover up to 25%, and a continuous bryophytic lower stratum. Willow may occur locally on some raised moss hummocks. Marsh emergents include **Caltha palustris, Arctophila fulva, Ranunculus Gmelini,** as well as those emergents found in zone 3.

Halophytic communities are similar to those of zone 3; in some sheltered lagoons, **Senecio congestus** occurs. Vascular cryptogams are more common and diverse than in zone 3; ferns occur in some areas but generally are rare. Herbs are diverse and many species common to low and mid arctic tundra communities make rare appearances in this zone (Table 53.2), generally in specialized niches such as stablized eolian deposits and recently deposited alluvium.

Table 53.3

Selected climatological data from weather stations in the Queen Elizabeth Islands, 1948-1970[1]

Location (cf. Fig. 53.1)	Average length of melt season (days)[2]	Days of frost[3]	Mean daily temperature °C July	Mean daily temperature °C Maximum, July	Mean daily temperature °C Annual
Resolute, Cornwallis Island	96	321	4.3	6.9	-16.4
Eureka, Ellesmere Island	100	299	5.5	8.5	-19.4
Isachsen, Ellef Ringnes Island	86	338	3.3	5.7	-19.0
Mould Bay, Prince Patrick Island	-	332	3.7	6.2	-17.8
Alert, Ellesmere Island	92	336	3.9	6.9	-18.0
Rea Point, Melville Island	-	-	4.7	7.4	-17.4
Polar Bear Pass, Bathurst Island (summers, 1971-76)[4]	-	-	4.4	7.1	-
Bache Peninsula, Ellesmere Island (1930-33)[4]	-	-	5.0	8.9	-15.6
Meighen Island Ice Cap (1960-62; 1968-70)[4]	-	-	0.6	-	-

[1]Atmospheric Environment Service, 1975
[2]Days with daily maximum temperature above 0°C
[3]Days with daily minimum temperature of 0°C or lower
[4]Maxwell, 1980

Regional Distribution of Vegetation Zones

Figure 53.2 shows the four bioclimatic zones in the central Queen Elizabeth Islands. The regional picture shows only a weak correlation of the zones with latitude; on the other hand, a strong correlation exists with elevation, as revealed by the prevalence of zone 1 vegetation in the central (higher) parts of the more southern islands. Furthermore, this zonation also occurs at an extremely local level downslope from snowbeds. This latitudinal, altitudinal, and local bioclimatic zonation is discussed below and some comparisons are made with vegetation of the eastern Queen Elizabeth Islands.

Altitudinal Zonation

Bioclimatic zonation shows strong altitudinal control. On Dundas Peninsula, Melville Island, where all four zones occur, zone 4 occurs locally at elevations of less than 50 m a.s.l.; zone 3 from near sea level to 75 m; zone 2, which covers much of the plateau, up to 150 m; and zone 1 occupies the highest, most continental part of the peninsula (Fig. 53.2). Similar altitudinal differences occur in the rest of the central Queen Elizabeth Islands, although the elevation of the zone boundaries varies from island to island. The plateaus and highlands above 150 m of the more southerly islands invariably have zone 1 vegetation. In the northern part of the region, zone 1 vegetation occurs at 50 m or less, and on some islands, such as Lougheed (Edlund, 1980) and northern Amund Ringnes (Hodgson and Edlund, 1978), zone 1 vegetation exists at sea level. Floristic data on King Christian Island (less than 35 vascular species, no woody plants collected) (Bell and Bliss, 1977) and Meighen Island (Kuc, 1970) confirm that these islands also lie entirely within zone 1.

Beschel's (1970) zonation of the eastern Queen Elizabeth Islands shows similar increasing depauperization with increasing elevation. He speculated that the altitudinal limit for vascular plants on these islands occurs roughly at 400 m near the coast and a bit higher inland. His zones of greatest impoverishment occur along the western fringe of Axel Heiberg Island and northwestern Ellesmere Island. This area is near the eastern boundary for my zone 1 in the north-central Queen Elizabeth Islands (see inset Fig. 53.2).

Latitudinal Zonation

When vegetation near sea level is compared on an inter-island and regional basis (to eliminate an altitudinal bias) there is a weak trend towards latitudinal zonation in the central Queen Elizabeth Islands. The richest vegetation, zones 3 and 4, occurs in the southern parts of Melville, Bathurst, Cornwallis, and Cornwall islands and is confined to coastal and lowland areas (Fig. 53.2). Zone 2 is common in the east-central region, around Norwegian Bay near Graham Island, and on Melville Island, Bathurst, and the Cornwallis islands. Zone 1 dominates the northwestern islands of the region, including northern Amund Ringnes, most of Ellef Ringnes (Savile, 1961), Meighen, northern Sabine Peninsula of Melville Island, Lougheed, northernmost Bathurst, and Cameron.

The broad latitudinal trend does not occur in the eastern Queen Elizabeth Islands, however, where zone 3 and 4 vegetation occurs as far north as the northeastern tip of Ellesmere Island. Young (1971) and Beschel (1970) noted this pattern as well. Zonation runs at right angles to latitudinal trends and parallels the north-south trending mountains. Arctic heather thickets are reported at Expedition Fiord and southern Axel Heiberg Island (Beschel, 1970); Waterston and Waterston (1972) and Parker and Ross (1976) reported zone 3 and 4 vegetation on eastern Axel Heiberg Island and Fosheim Peninsula, Ellesmere Island. Zone 3 vegetation occurs even farther north on Ellesmere, at Tanquary Fiord (Brassard and Beschel, 1968), Van Hauen Pass (Brassard and Longton, 1970), and Lake Hazen (Powell, 1961; Savile, 1964; England et al., 1981), and zone 4 vegetation at Alexandra Fiord on eastern Ellesmere Island (Svoboda and Freedman, 1980).

In the central Queen Elizabeth Islands, only parts of southern Melville Island have zone 4 vegetation. The fact that it and the eastern High Arctic islands fall mostly within zones 3 and 4 helps to explain the presence of disjunctive distribution of species such as **Lycopodium Selago, Cystopteris fragilis, Dryopteris fragrans, Hierochloe alpina, Trisetum spicatum, Geum Rossii, Androsaceae septentrionalis,** and **Chrysosplenium tetrandrum,** all of which in the High Arctic occur only in the northeastern Queen Elizabeth Islands and southwestern Melville Island.

Local Zonation

Detailed plant community studies show that vegetation downslope from persistent snowbeds on Cornwallis, Bathurst, and Melville islands exhibit the same trends as the regional bioclimatic zonation. The areas farthest downslope from the snowbed, which still receive abundant meltwater, have the richest flora, whereas vegetation immediately downslope from the snowbed is extremely impoverished, consisting of bryophytes, lichens, and only a few herbs, even though the materials are as wet as those below. The plant communities grade sharply from great diversity to great poverty, for example, from a willow-sedge-dominated community to a sparse grass community. This rapid change in diversity, which can represent a transition from zone 4 to zone 1 in a short distance, probably reflects the length of time various parts of the slope are snowfree, i.e., length of growing season. This snowbed zonation is described in detail for the calciphilic vegetation of Cornwallis Island (Edlund, in press). In regions characterized by zone 4 vegetation, all four bioclimatic zones may be present downslope from major snowbeds. Farther north of course only those zones more impoverished than the regional vegetation occur in these local anomalous positions.

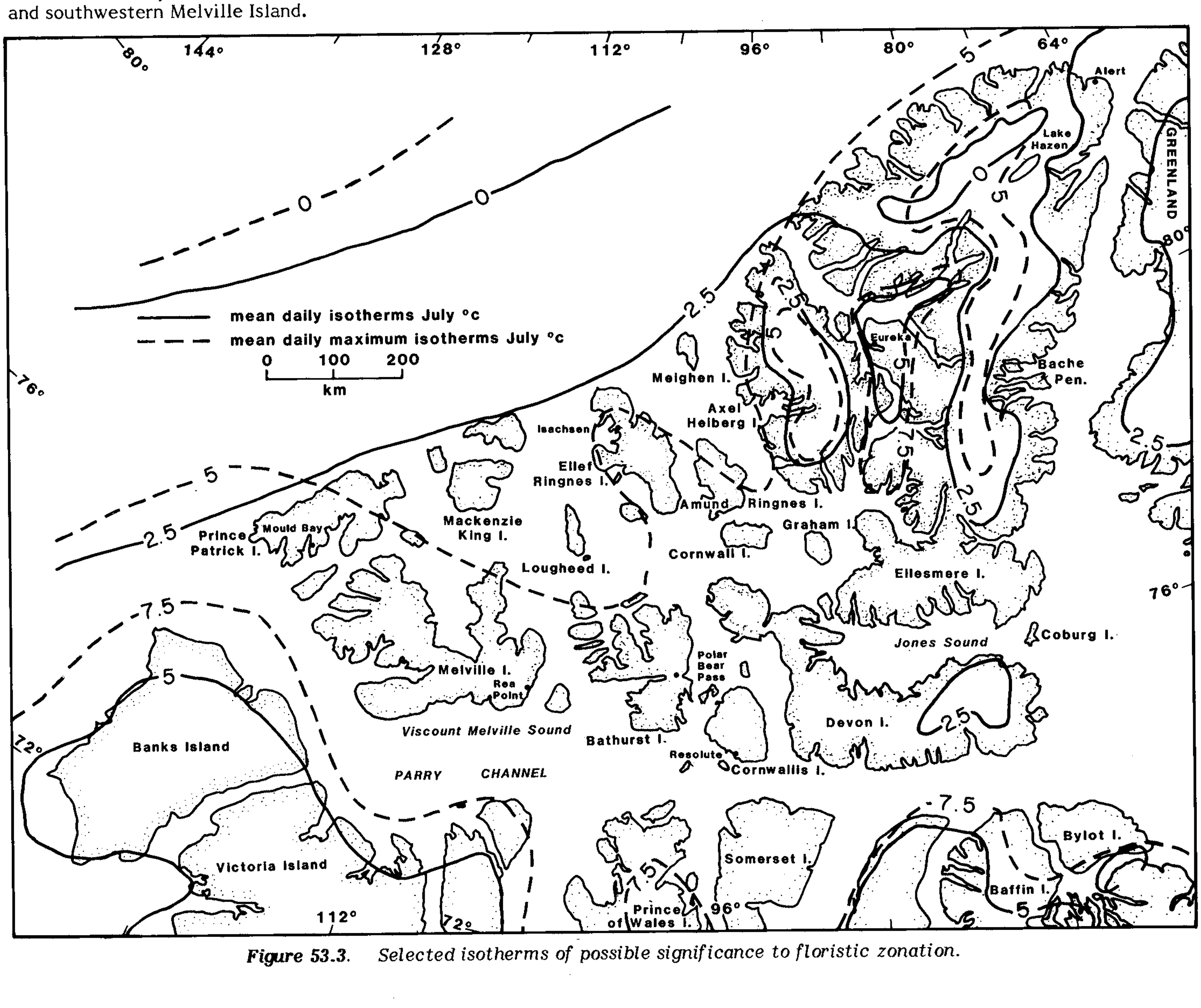

Figure 53.3. *Selected isotherms of possible significance to floristic zonation.*

Discussion

Climatic Controls

The climatic controls that influence the bioclimatic zonation are not yet understood. Bliss (1974) suggested that moisture availability or desiccation by wind is a major controlling factor; but since annual precipitation is lower in the eastern Queen Elizabeth Islands, where zones 3 and 4 predominate, than in the central region (Maxwell, 1980), moisture availability is probably not the major climatic control of zonation. The sparse climatic data available for the Arctic Islands (Maxwell, 1980) do reveal regional climatic trends that parallel those of the vegetation. For example, the eastern Queen Elizabeth Islands, where zones 3 and 4 prevail, are warmer and have longer growing seasons than the central and northwestern Queen Elizabeth Islands, even though mean temperatures are low (see data for Eureka, Table 53.3).

The reversed L-shaped patterns of circumpolar vegetation zones in the Arctic Islands (see inset, Fig. 53.2) as shown by this study, as well as by Young (1971) and Aleksandrova (1970, 1980), also match other climatic parameters mapped by Maxwell (1980), such as persistence of snow, mean daily summer maximum and mean annual temperatures, and thawing degree-days.

Vegetation downslope from snowbeds in an environment in which moisture is available throughout the growing season shows definite zonal stratification similar to regional zonation, which suggests that moisture availability is not the limiting factor, at least not at wet and mesic sites. The controlling factor is probably best expressed in growing degree-days or the length of the growing season on a local scale. In the High Arctic, where summer lasts for less than 2.5 months, the persistence of regional snow cover a week or two longer in spring and its reappearance a week or two earlier in August would curtail the growing season in a fashion similar to that of local, persistent snowbeds, which sequentially expose the surface as their margins retreat.

The limit of dwarf shrubs – the boundary between zone 1, which is entirely herbaceous, and zone 2, which has scattered dwarf shrubs – forms a 'mini-treeline' that delimits the northernmost extent of woody plants in northern Canada. Zones 3 and 4, where dwarf shrubs are the dominant vascular plant component, form what is here called a 'mini-forest zone'.

Such analogies, particularly the one to regional treeline, are appropriate in this treeless environment, for treeline (northernmost limit of the tree life-form), and the limit of the northern boreal forest (where trees are the dominant plants) are biological boundaries long observed to coincide either directly or indirectly with various isotherms.

Köppen (1936) showed that the northern limit of trees roughly corresponded with the 10°C mean July isotherm; Nordenskjöld (in Nordenskjöld and Mecking, 1928) suggested that for the northern hemisphere, the mean July 10°C isotherm does coincide closely with the limit of tree growth in continental climates but is less accurate in maritime environments; Bird (1967) showed similarities between the -7°C mean annual isotherm and treeline.

Other isotherms have been suggested as significant boundaries within the polar regions. Nordenskjöld and Mecking (1928) proposed that the mean July 5°C isotherm coincides with the limit of bushes (erect and semi-erect shrubs), the southern limit of high arctic vegetation, and the northern limit of continuous vegetation. As this isotherm falls to the south of the central Queen Elizabeth Islands, it cannot be applied to the study area. However the 5°C isotherm does occur in a pocket around Eureka, Ellesmere Island (Fig. 53.3) and no bushes have been observed.

In the High Arctic, zone 1 corresponds to the zone of coolest temperatures and the shortest growing season. Only herbs tolerate this severe climate. Woody plants, sedges, and herbs, more typical of the Low and Mid Arctic regions, appear to require the longest growing seasons, for they grow in those parts of the Queen Elizabeth Islands with the warmest summer temperatures. Thus it seems likely that the vegetation zones coincide with thermal balance rather than moisture.

Possible Congruency of Vegetation with Isotherms

Although climatic data are limited for the region, it is still possible to speculate on possible thermal constraints on vascular plants. These comparisons are extremely speculative and physiological control is not likely to be as simplistic as isothermal control (Larsen, 1974; Wardle, 1974); however, these are offered as suggestions as to areas where future multidisciplinary investigations may be beneficial.

Figure 53.3 shows the mean daily and mean maximum daily isotherms for July, the warmest month (cf. Table 53.3). The 0°C isotherm, which marks the limit of plant growth because it approximates the zone in which the ground is permanently frozen, lies to the north and west of the Queen Elizabeth Islands except in the vicinity of the ice caps on Ellesmere Island. Even the 2.5°C isotherm lies to the north and west of most islands, except in the vicinity of ice caps. The 5°C isotherm lies south of Parry Channel, except for the Eureka area (Ellesmere Island), which is an oasis of warmth. The islands that form the northern rim of the Queen Elizabeth Islands all have a vascular plant component to their plant communities (Porsild, 1964). Thus the limit of vascular plants seems to coincide with an mean daily isotherm (July) marginally greater than 2.5°C. Areas with no vascular plants occur only in the mountainous regions of Axel Heiberg and Ellesmere islands, close to present day ice caps and permanent snowfields (Beschel, 1970), in highlands of northern Bathurst and Melville islands, and locally near the base of persistent snowbeds.

The only weather station close to the 'mini-treeline' is Isachsen, Ellef Ringnes Island, which has a mean daily temperature for July of 3.3°C, and sporadic willow growing in sheltered locations (Savile, 1961). The other stations with long term weather data – Resolute, Alert, Rea Point, and Polar Bear Pass – all have dwarf shrub dominated communities in the vicinity, and all have mean daily (July) temperatures of 3.9°C or greater (Table 53.3). The sites lie well within the limit of woody growth. The mean daily (July) isotherm coincident with dwarf shrub survival ('mini-treeline') seems to be one of less than 4°C, perhaps between 3 and 3.5°C; the isotherm coincident with the 'mini-forest' line is less than 4°C but greater than 3.5°C.

The richest vegetation, in areas of the Queen Elizabeth Islands that have weather statistics, occurs at Eureka and Bache Peninsula, Ellesmere Island, both of which have a mean daily July temperatures greater than 5°C. While Nordenskjöld (Nordenskjöld and Mecking, 1928) suggested that the 5°C isotherm is coincident with the limit of erect shrub growth, this hypothesis cannot be tested in the Queen Elizabeth Islands because the woody species that have a potential for erect growth (**Salix alexensis, S. lanata, S. cordifolia**, and **S. niphoclada**) do not occur in the area (Porsild and Cody, 1980).

The isotherms possibly coincident with vascular plant growth, the 'mini-treeline' and the 'mini-forest' line fall within a narrow range of mean daily July temperatures of greater than 2.5°C and less than 4°C. This suggests that a small change in mean summer temperature, a fraction of a degree, could have major effects on plant community composition.

Summary

The islands of the High Arctic can be divided into four vegetation zones which cross lithological boundaries. These zones may eventually be helpful in the prediction of high arctic climate in more detail than is possible from the limited number of meteorological stations presently operating in the region. These zones are based on vascular plant physiognomy and floristics, e.g. the presence, diversity, and abundance of woody species, Cyperaceae, emergent marsh species, vascular cryptogams, halophytic species, and a number of indicator species, as well as comparisons of the total number of vascular species present.

Zone 1 represents the region with the most depauperate flora; its vascular flora is entirely herbaceous, and the total number of species is generally less than 35. Zone 2, having between 35 and 60 vascular species, is also primarily herbaceous but includes small amounts of dwarf shrubs. The boundary between zones 1 and 2 may be regarded as a 'mini-treeline' within the Canadian High Arctic. Zone 3, having 60 to 100 vascular species and a major component of dwarf shrubs and Cyperaceae, comprises a 'mini-forest zone' together with zone 4. Zone 4, which has the richest and most diverse flora, occurs only on southwestern Melville Island in the central High Arctic but is more common in the eastern Queen Elizabeth Islands.

This bioclimatic zonation, based on vegetation patterns, is roughly correlated with regional climatic trends and as such may have predictive value. Present data indicate that the mean daily July temperature for the limit of vascular plant growth is a little above 2.5°C, for woody plants is 3°-3.5°C, and for dwarf shrub communities, is 3.5°-4°C.

The 'mini-treeline' and the 'mini-forest zone' are also biological markers that nonbotanists can easily identify and hence may assist in further refining of vegetation zone boundaries.

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