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Combining Research and Education: Bioclimatic Zonation along a Canadian Arctic Transect

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ABSTRACT. Scientists and students from five countries combined research and education in an investigation of bioclimatic zonation along a Canadian Arctic transect, from Amund Ringnes Island and Ellesmere Island in the north to the Daring Lake research camp at the southern edge of the tundra in Nunavut. We addressed three important needs in Arctic science: 1) to integrate education and research, 2) to provide field experiences for undergraduates, and 3) to foster international collaboration. We describe five subzones within the Arctic tundra zone. Subzones are defined by the vegetation typical of mesic environments at low elevations and the dominant growth forms of vegetation in these environments. Subzonal boundaries coincide with the northern limits of several species of woody plants with distinct upright or prostrate growth forms, and ultimately with the northern limit of woody plant species. The five subzones, A–E, from north to south, are characterized by dominant growth form: (A) cushion forb, (B) prostrate dwarf shrub, (C) hemiprostrate dwarf shrub, (D) erect dwarf shrub, and (E) low shrub.

Key words: bioclimatic zones, Canadian Arctic vegetation, circumpolar, field ecology courses, mapping, zonation

RÉSUMÉ. Des chercheurs et des étudiants de cinq pays ont combiné recherche et éducation dans une étude portant sur la zonation bioclimatique le long d'un transect de l'Arctique canadien, allant de l'île Amund Ringnes et de l'île d'Ellesmere au nord, au camp de recherche du lac Daring situé en bordure sud de la toundra au Nunavut (Canada). On a tenu compte de trois besoins majeurs dans la science de l'Arctique, soit ceux: 1) d'intégrer l'éducation et la recherche; 2) d'offrir aux étudiants de premier cycle des expériences sur le terrain, et 3) de promouvoir la collaboration internationale.

On décrit cinq sous-zones à l'intérieur de la zone de toundra de l'Arctique. Les sous-zones sont définies par la végétation typique des milieux à régime d'humidité constant à basse altitude ainsi que par la forme de croissance dominante dans ces habitats. Les limites des sous-zones correspondent aux limites septentrionales de plusieurs espèces de plantes ligneuses ayant des formes de croissance particulières verticales ou procombantes, et en fin de compte à la limite septentrionale des espèces de plantes ligneuses. Les cinq sous-zones (A-E), établies du nord au sud, sont caractérisées par une forme de croissance dominante: A) herbe non graminéenne en coussinet; B) arbuste nain déprimé; C) arbuste nain semi-déprimé; D) arbuste nain dressé, et E) arbuste.

Mots clés: zones bioclimatiques, végétation de l'Arctique canadien, circumpolaire, cours d'écologie sur le terrain, cartographie, zonation

Traduit pour la revue *Arctic* par Nésida Loyer.

> The knowledge and experience I gained from the scientists, students, and the natural setting far surpassed [that gained in] any classroom environment.
>
> A. Desjarlais, student, Arctic Field Ecology

INTRODUCTION

One of the critical needs of Arctic research is to maintain an influx of new researchers and new ideas, particularly in the Canadian Arctic (Robinson, 1998). A second is to develop the circumpolar perspective needed to conduct research on global patterns and the changes expected in the circumpolar region. This paper describes the process and initial results of an endeavor to meet these needs by combining field teaching in ecology and field research. During the summer of 1999, university students from the United States and Canada joined vegetation scientists from Canada, Germany, Norway, Russia, and the United States to investigate large-scale variation in vegetation in relation to climate along a transect from the northern to the southern Canadian Arctic. The field class was Arctic Field Ecology, offered by the Itasca Biology Station at the University of Minnesota, and the research was a component of the Circumpolar Arctic Vegetation Map (CAVM) project (Walker and Lillie, 1997). We called this mobile

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workshop and field class the *1999 Canadian Transect for the Circumpolar Arctic Vegetation Map*.

The transect described here was designed to bring the principal CAVM scientists to the Canadian Arctic to visit representative sites along the complete north-south climatic gradient. The goals were to develop (1) a consensus on zonation terminology for the vegetation map; 2) a better understanding of vegetation patterns in the least documented circumpolar region; 3) a table of major vegetation types along a mesotopographic sequence within the Canadian portion of the Canada-Greenland floristic province (Yurtsev, 1994); and 4) interest and further research in the Arctic by involving graduate and undergraduate students in the project through the University of Minnesota field course, Arctic Field Ecology. Presented here are the framework we used to integrate research and education and our initial findings on variation in vegetation related to climate, substrate, and topography.

The patterns in northern Canada are in some ways the most complex of the circumpolar Arctic in that the region is a matrix of large and small islands and open and frozen ocean, which greatly affect climatic patterns (Edlund and Alt, 1989). Mean July temperatures (MJT) range from 12˚C near the tree line to below 3˚C in the High Arctic and are strongly correlated with species richness. A predictable loss of about 25 species occurs with every 1˚C drop in MJT (Rannie, 1986). In this way, climate acts as the primary filter on potential vegetation patterns in the Arctic (Walker, 1995). Substrates across the region vary from strongly calcareous to strongly acidic, and this has a great influence on species composition (Walker, 2000). Within a given climatic regime and substrate type, topographic variation and its effect on moisture control the dominant patterns of vegetation communities on the Arctic landscape (Bliss and Matveyeva, 1992; Chernov and Matveyeva, 1997). This hierarchy of controls on vegetation led to our interest in sampling along toposequences, on acidic and nonacidic substrates, along the climatic gradient found in the Canadian Arctic.

There are long-standing differences in the Russian, North American, and Fennoscandian traditions of describing vegetation zonation in the Arctic (Elvebakk et al., 1999; Razzhivin, 1999; Walker, 2000). Our visit to this area with Arctic vegetation experts from North America and Europe created an international forum to discuss whether zonation schemes used in Russia, Europe, and northern Canada could be successfully applied across the Canadian Arctic (our traveling workshop). It also increased our understanding of regional vegetation patterns related to climate, substrate, and topography (our field work).

Education

Arctic Field Ecology is a four-week field class offered in one or two sections each summer. It typically has up to 10 undergraduate and graduate students and takes place in remote areas of the Canadian Arctic, often from mobile camps along rivers. The course focuses on current research in Arctic ecology, natural history, and generating hypotheses and research proposals. Ongoing research projects, either independent student projects or instructors' research, are often associated with the course (Gould and Walker, 1997, 1999; Gould, 2000). For the 1999 Canadian Transect, the course involved five students and seven CAVM scientists working along a 2000 km transect, from Amund Ringnes, Ellesmere, and Axel Heiberg Islands in the far North to a Canadian research camp at Daring Lake near the tree line in central Canada (Fig. 1).

Research

The CAVM project is an effort by an international group of Arctic vegetation experts to create a vegetation map of the circumpolar region (Walker, 1995; Walker and Lillie, 1997; Walker, 1999). The mapping effort integrates information on soils, bedrock, and surficial geology, hydrology, remotely sensed vegetation classifications, previous vegetation studies, and regional expertise of the mapping scientists. This information is used to define polygons drawn using photo-interpretation of an Advanced Very High Resolution Radiometer (AVHRR) image base map (scale = 1:4 000 000). The final map unifies and standardizes information from regional maps and legends derived over many years of vegetation study in all the circumpolar countries. It will be useful for creating an international framework and common language for studying Arctic vegetation, modeling vegetation change at the circumpolar scale, and interpreting large-scale patterns of wildlife distribution and migration, as well as for educational purposes and regional or larger-scale land management.

The scale at which the circumpolar map is being developed will capture variation in vegetation related to climate (latitudinal variation, phytogeographic subzones), substrate, topography, and longitudinal floristic variation (floristic provinces) (Yurtsev et al., 1978). Vegetation complexes characterized by dominant plant communities and functional types define each mapped polygon. In essence, this will link large-scale phytogeographic patterns with landscape units visible in AVHRR satellite imagery (Fig. 1) and with the ecological attributes of the dominant plant communities associated with these units.

METHODS

Education: Training and Activities

Students met with the instructor for ten days of training and initial field work in Cambridge Bay, Nunavut, before being joined by the CAVM scientists along the transect route. Course topics included the goals and questions associated with the CAVM project and current understanding of the ecological controls governing vegetation patterns in the Arctic. Students also gained familiarity

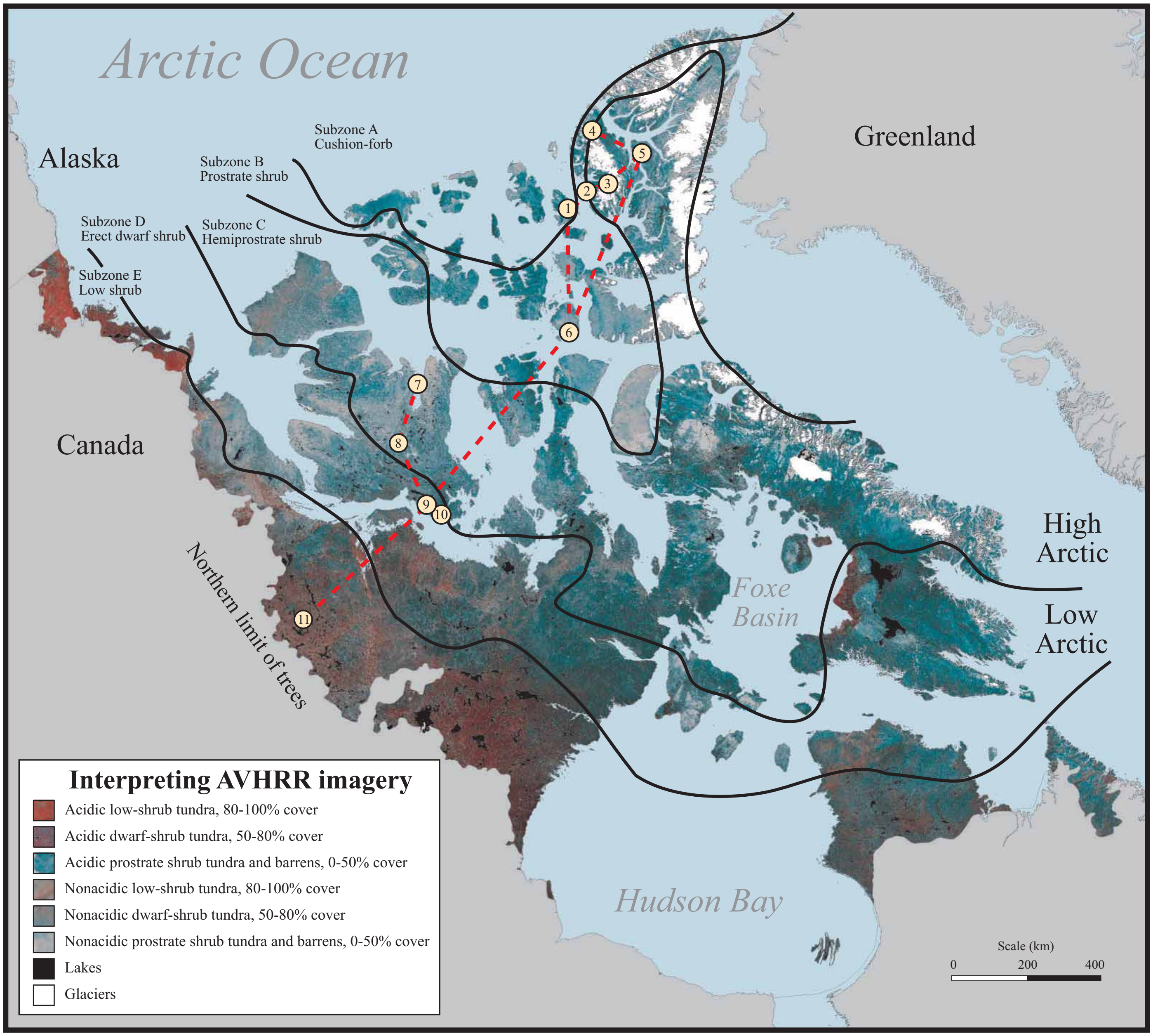


FIG. 1. Color-infrared AVHRR composite of the Canadian Arctic north of the tree line (the northern limit of trees) indicating the transect route (red dashed line), study site locations (circled) (Table 1), zonation patterns (black solid contours) (Table 2), and a simplified interpretation of variation of color-infrared imagery in terms of vegetation.

with the regional flora and experience in using sampling methods. These included relevés, or plot-based assessments of species presence and abundance (Westhoff and van der Maarel, 1978); point-frame and line-intercept methods of sampling species composition and vegetation characteristics; field collection of plants; and soil description and sampling from soil pits. Along the transect, students participated in 1) conducting relevés and floristic surveys; 2) documenting soils and vegetation with photographs, soil samples, and voucher specimens; and 3) maintaining camp logistics.

Research: Vegetation Sampling

We visited 16 locations along a 2000 km transect covering over 16 degrees of latitude (Table 1, Fig. 1). Sites were selected with four criteria in mind. Sites should 1) include locations in each of Yurtsev's (1994) five phytogeographic subzones; 2) be accessible with a minimum of flying time; 3) include a range of accessible undisturbed habitats (topographic positions and moisture conditions); and 4) be representative of regional climatic and substrate conditions. We sampled vegetation and soils on acidic substrates in the southern Arctic (subzone E) and on neutral and nonacidic substrates in the northern Arctic

TABLE 1. Sites visited along the 1999 Canadian transect, showing locations, dates of visits, and site characteristics.

Site #	Location	Date	Latitude and Longitude	Elevation (m)	Subzone	Dominant Vegetation	Mean July Temp. (˚C)	Annual Precip. (mm)
	Amund Ringnes Island							
	Northwest coast (first stop)	Aug. 2	78˚41' N, 96˚45' W	2	A	cushion-forb		
1	Stratigrapher River*	Aug. 2	78˚38' N, 96˚50' W	40–50	A	cushion-forb		
	Axel Heiberg Island							
2	Cape Levvel	Aug. 2	78˚58' N, 94˚15' W	10	B	prostrate dwarf-shrub		
4	Bunde Fiord*	Aug. 1	80˚30' N, 94˚35' W	30–40	B	prostrate dwarf-shrub		
3	Expedition Fiord	Aug. 2	79˚25' N, 90˚45' W	150	C	prostrate dwarf-shrub		
	Ellesmere Island							
5	Eureka	July 29–Aug. 4	80˚00' N, 84˚55' W	20–30	C	prostrate dwarf-shrub	5.4	68.0
	Black Top Ridge	July 30	80˚04' N, 85˚29' W	200	A	cushion-forb		
	Hare Ridge	July 30	80˚05' N, 86˚15' W	200	A	cushion-forb		
	East Wind Lake*	July 31	80˚06' N, 85˚34' W	135–150	C	hemiprostrate dwarf-shrub		
	Cornwallis Island (Resolute area)							
	North of Signal Hill*	Aug. 6	74˚44' N, 94˚52' W	125	B	prostrate dwarf-shrub		
6	Resolute Bay	Aug. 6	74˚41' N, 94˚55' W	75	B	prostrate dwarf-shrub	4.0	139.6
	Victoria Island							
7	Hadley Bay (northern island)*	Aug. 8	72˚31' N, 109˚19' W	135	B	prostrate dwarf-shrub		
8	Tuktu River (central island)*	Aug. 8	70˚46' N, 109˚09' W	150	C	hemiprostrate dwarf-shrub		
9	Thanhieser site (southern island)	July 28	69˚08' N, 105˚09' W	30	D	erect dwarf-shrub	8.0	141.0
10	Mount Pelly (southern island)*	July 19–28, Aug. 9	69˚11' N, 104˚45' W	60	D	erect dwarf-shrub	8.0	141.0
	Mainland							
11	Daring Lake*	Aug. 9 – 11	64˚51' N, 111˚31' W	70	E	low-shrub	9.5	219.5

* Relevés conducted along toposequence.

(subzones A–D). This selection typifies substrate distributions for a large portion of the central Canadian Arctic, but there is a need for more sampling on nonacidic substrates in subzone E and on acidic substrates in subzones A–D.

Our travel along the 1999 transect included stops at four sites that could provide logistical support (Daring Lake, Cambridge Bay, Resolute, and Eureka) and day travel by airplane, helicopter, all-terrain vehicle (ATV), and on foot from these locations to our 16 sampling areas (Fig. 1). Sampling areas were selected using air photos, topographic maps, and vegetation maps, when available. Vascular, lichen, and bryophyte floristic surveys were conducted at each of the 16 sites by noting species present (but outside our plots) during our plot sampling, or in opportunistic surveys of accessible habitats at each site. Sampling at eight sites involved conducting relevés along a complete mesotopographic gradient (Fig. 2) with the goal of describing the range of representative vegetation and soils in 1) dry, 2) mesic-zonal, 3) wet, 4a) early snowbed, 4b) late snowbed, and 5) riparian environments and on available substrates. Sampling at eight additional sites included either only floristic surveys or surveys with relevés along a partial topographic sequence.

Data from each site include location; a general site description; site photographs; a list of vascular species; relevé vegetation data, including presence and abundance of vascular, bryophyte, and lichen species; and relevé soil data, including depth of horizons, active layer depth, United States Geological Survey (USGS) classification, a “B” horizon soil sample for data on texture, pH, mineral analysis (Ca, N, P, K, Na), volumetric/gravimetric soil moisture, color, and % organic matter. These data were compiled at the University of Alaska (González et al., 2000).

RESULTS

Subzonation

Five distinct subzones of the Arctic Tundra zone are recognizable in Canada (Yurtsev, 1994; Elvebakk et al., 1999; Gould et al., 2002). They represent a vegetation pattern related to the shift in mean July temperatures from 12˚C at the continental tree line to less than 3˚C in the far North. The subzones can be distinguished by dominant growth form and floristic composition on the mesic or zonal, (i.e., *plakor*) habitats (Razzhivin, 1999) and by differences in the less extensive intrazonal habitats such as snowbeds, wetlands, and riparian areas. Shifts in dominant growth form are consistent across substrate types, and shifts in species composition are strongly controlled by substrate within each subzone (Walker, 2000; Gould et al., 2002).

The five subzones are A) cushion-forb, B) prostrate dwarf-shrub, C) hemiprostrate dwarf-shrub, D) erect dwarf-shrub, and E) low shrub subzones (Table 2, Fig. 1). Prostrate dwarf-shrub species include *Salix arctica* and *Dryas integrifolia*. Hemiprostrate dwarf-shrubs include *Cassiope tetragona* and *Empetrum nigrum*. Erect shrub species may be dwarf (< 20 cm), low (20–50 cm), or tall (50–200 cm). *Betula glandulosa* and several *Salix* species can be found at a variety of heights, depending on climate. *Alnus* is typically found as a low or tall shrub. Subzones A–C correspond to the High Arctic and subzones D and E correspond to the Low Arctic, as described by Bliss (1997) (Fig. 1).

Variation within subzones is a function of substrate chemistry, with acidic and nonacidic substrates strongly affecting species composition (Fig. 3). Within substrate

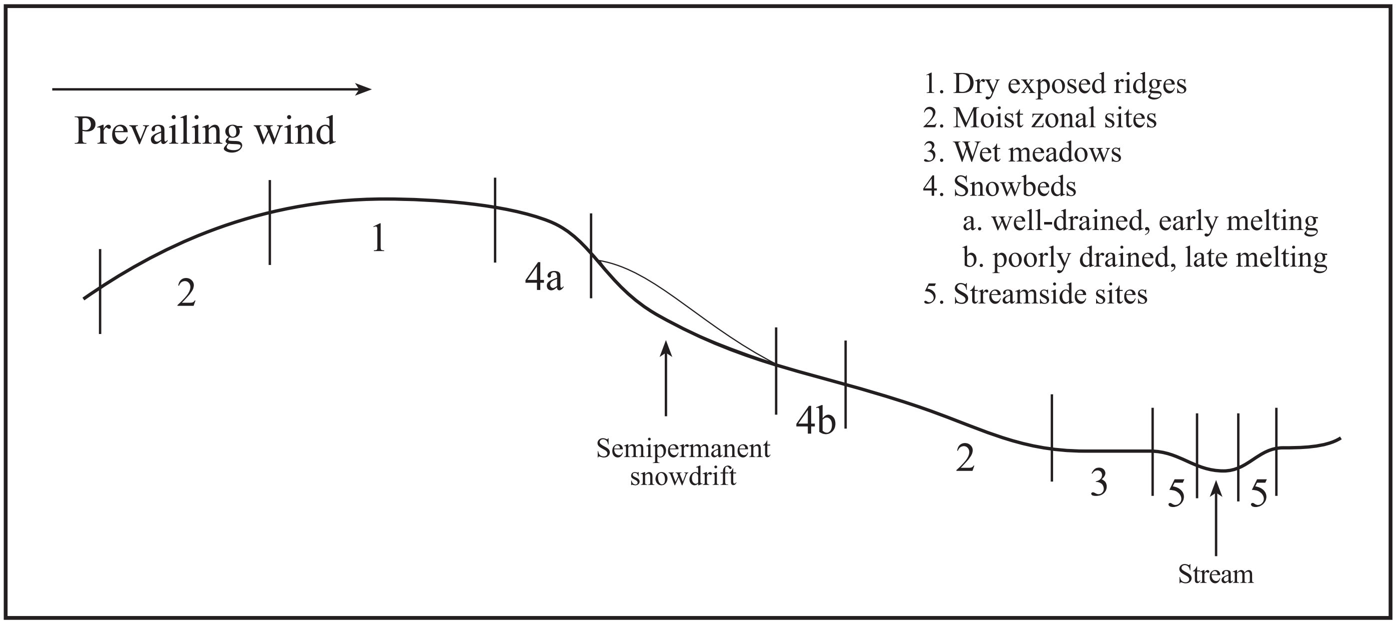


FIG. 2. Sampling scheme for determining variation in vegetation along mesotopographic gradients. Replicate relevés were conducted in dry, mesic, wet, snowbed, and riparian habitats along a toposequence at each of eight study sites along the climatic gradient of the transect (shown by * in Table 1).

TABLE 2. Phytogeographic subzones of the Arctic Tundra zone in the North American Arctic, with dominant growth form (DGF), equivalent Yurtsev subzone, approximate long-term mean July temperatures (MJT), and typical ranges of vegetation cover (%) and vascular plant species richness (number of species).

Subzone	DGF	Equivalent Yurtsev (1994) zone	MJT (˚C)	% vegetation cover	Number of vascular species
A	Cushion-forb	(1) Polar desert	0 – 3	0 – 5	> 75
B	Prostrate dwarf-shrub	(2n) Arctic tundra: northern variant	3 – 5	05 – 50	75–125
C	Hemiprostrate dwarf-shrub	(2s) Arctic tundra: southern variant	5 – 7	50 – 80	125–175
D	Erect dwarf-shrub	(3) Northern hypoarctic	7 – 9	80 – 100	175–225
E	Low-shrub	(4) Southern hypoarctic	9 – 12	80 – 100	225–300

types, variation in moisture (usually related to topography) controls species composition (Gould and Walker, 1999; Walker, 2000).

Subzone Descriptions

Subzone A is restricted to the low-lying northern Queen Elizabeth Islands and the northern and westernmost edges of Ellesmere and Axel Heiberg Islands (Fig 1). In this subzone, herbaceous dicots, grasses, rushes, and cryptogams are dominant, and woody plants and sedges are absent (Fig. 4a). Species composition is relatively similar in all habitats, with *Luzula confusa* and *L. nivalis* more predominant on acidic substrates and *Saxifraga oppositifolia* more dominant on alkaline substrates (Edlund, 1990). The landscape is noticeably barren on a majority of the subzone, but surprisingly well vegetated mesic slopes are found on both weakly acidic and weakly alkaline fine-grained substrates (Fig. 5a). The southern boundary of subzone A represents the northern limit of woody species and sedges (Figs. 3, 4b).

Subzone B is restricted to the Arctic Islands (Fig. 1) and characterized by prostrate dwarf-shrub vegetation, including *Salix arctica* on more acidic sites and *S. arctica* and *Dryas integrifolia* on nonacidic sites (Fig. 4b). Large areas with scant vegetation cover exist on the strongly calcareous, coarse-textured substrates of Cornwallis, Devon, Somerset, and parts of Baffin Island (in subzone C) (Fig. 5b). Dry and mesic habitats are similar in composition, but vegetation cover increases on weakly acidic and alkaline fine-grained, mesic substrates. The sedge *Carex aquatilis* var. *stans* occurs in wet areas, and *Arctagrostis latifolia* becomes prominent in wet and streamside habitats. The southern boundary of subzone B represents the northern limit of the hemiprostrate shrubs *Cassiope tetragona* and *Empetrum nigrum*, with upright growth forms but limited stature (Figs. 3, 4c).

Subzone C is found on the Arctic Islands in eastern and western Canada and on the mainland west of Foxe Basin. It extends far north on Ellesmere and Axel Heiberg Islands, encompassing the somewhat sheltered plains on eastern Axel Heiberg Island and western Ellesmere Island. These have relatively high percentages of vegetation cover (Fig. 5c) (Gould et al., 2002) and higher average summer temperatures than less mountainous areas to the south (cf. Eureka vs. Resolute, Table 1). Subzone C is characterized

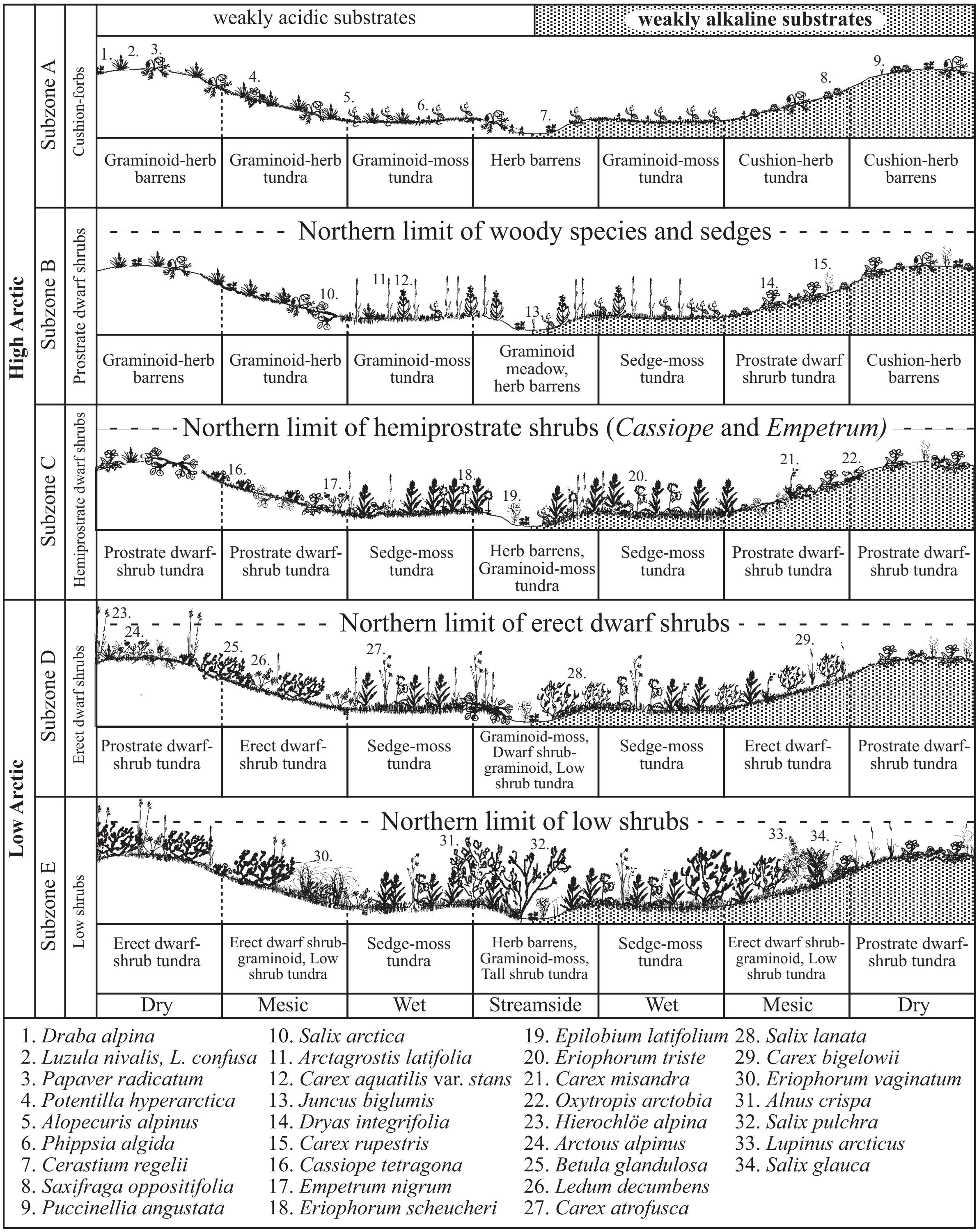
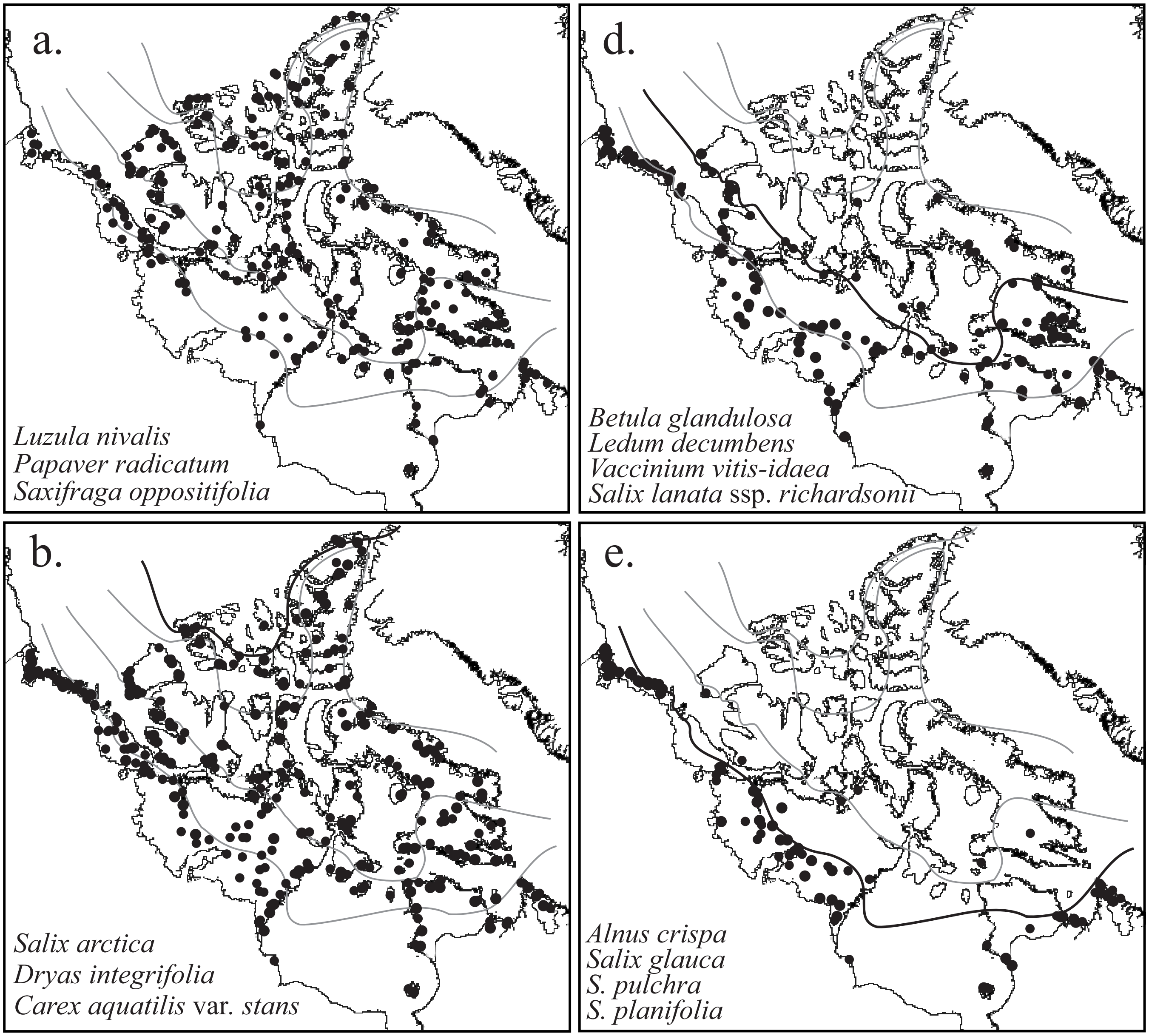


FIG. 3. Representative species (numbers) and growth forms along toposequences on acidic and nonacidic substrates within each of the five bioclimatic subzones in the Canadian Arctic. Modified from Edlund (1990), with additional information on subzones D and E from Gould and Walker (1997, 1999), González et al. (2000), and Gould et al. (2002).



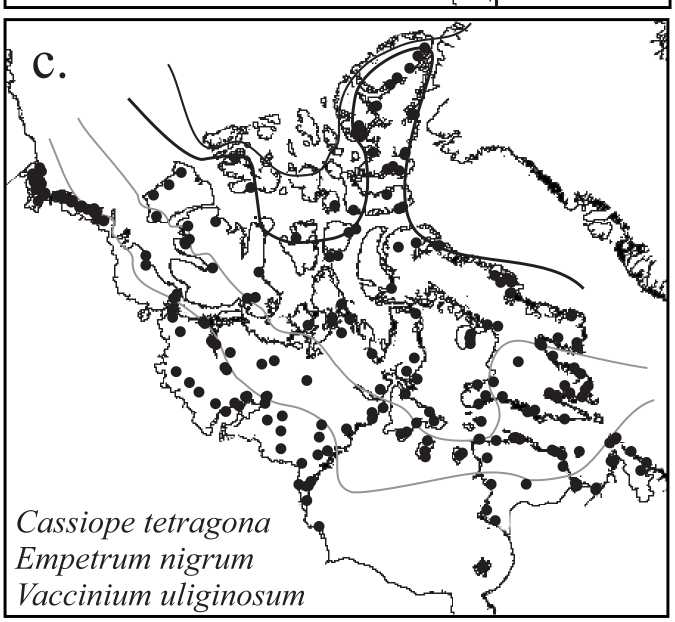
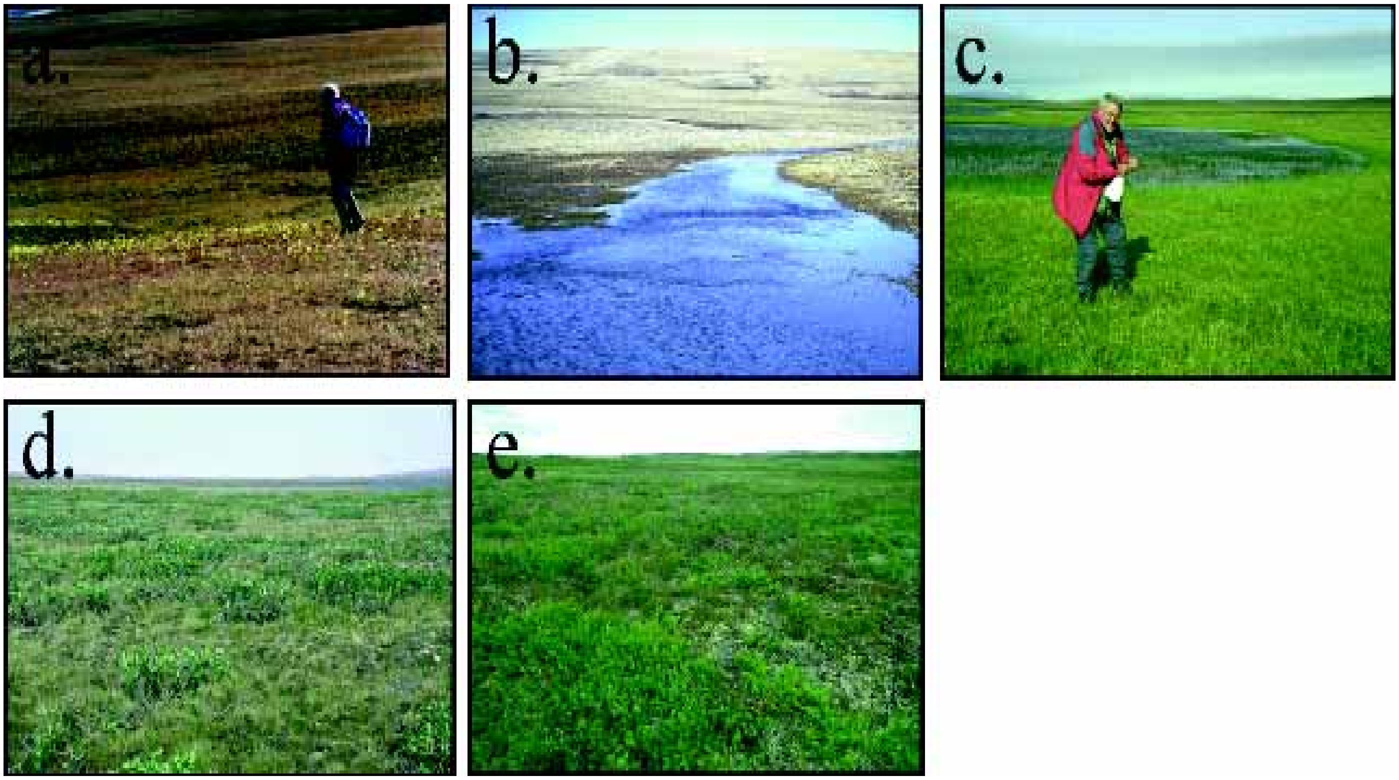


FIG. 4. Distributions of selected species and growth forms in the five subzones (Fig. 1, Table 2), modified from Porsild and Cody (1980) to show only collection sites within the Canadian Arctic. Light contour lines indicate subzonal boundaries. Bold contour lines show northern boundary of subzone containing northern limit of species listed. **(a)** Forb and graminoid species with northern limit in subzone A, where mean July temperatures (MJT) are below 3˚C. **(b)** Two prostrate dwarf shrubs and a sedge with northern limit in subzone B (MJT < 5˚C). **(c)** Hemiprostrate dwarf shrubs with northern limit in subzone C (MJT < 7˚C). **(d)** Erect and prostrate (*V. vitis-idaea*) dwarf shrubs with northern limit in subzone D (MJT < 9˚C). **(e)** Low and tall shrub species that are restricted to subzone E (MJT = 9˚ – 12˚C).

by the presence of hemiprostrate dwarf-shrub vegetation with *Cassiope tetragona*, *Vaccinium uliginosum*, and *Empetrum nigrum* on mesic acidic substrates and the prostrate dwarf shrubs *Salix arctica* and *Dryas integrifolia* on nonacidic zonal sites (similar to subzone B) (Fig. 4c). *Cassiope tetragona* is found in snowbeds on both acidic and nonacidic substrates. There is a higher diversity of sedges in the wetlands and increased presence of *Epilobium latifolium* communities in the riparian areas. The southern



boundary of subzone C represents the northern limit of the upright shrubs *Betula glandulosa* and *Salix lanata* ssp. *richardsonii* (Figs. 3, 4d).

Subzone D is found on the Arctic Islands in the west and on the mainland of eastern Canada (Fig. 1). Substrate controls on species composition become more apparent here, with mesic (zonal) nonacidic sites characterized by the presence of *Salix lanata* ssp. *richardsonii* (Fig. 5d), while the more acidic mainland is dominated by *Ledum decumbens*, *Vaccinium vitis-idaea*, *Rhododendron lapponicum*, and *Betula glandulosa* (Fig. 4d). Dry sites on nonacidic, coarse-textured soils are dominated by *Salix arctica* and *Dryas integrifolia*. Low shrub vegetation can be found along sheltered streambanks. The southern boundary of subzone D represents the northern limit of shrubs over 50 cm in height and the northern limits of a wide variety of shrub species, including *Alnus crispa*, *Salix glauca*, *S. planifolia*, and *S. pulchra* (Figs. 3, 4e).

Subzone E is found entirely on the mainland in Canada. The acidic substrates of the Canadian Shield dominate the central portion of this subzone, with nonacidic tundra found along river valleys and uplifted marine deposits and on limestone in the area west of Coronation Gulf (Fig. 1). This subzone is characterized by low shrub vegetation on the zonal sites, primarily *Betula glandulosa* and *Ledum decumbens* on acidic sites (Fig. 5e) and *Salix lanata* and *S. glauca* on nonacidic sites. Boreal floristic elements are common (Yurtsev, 1994). A variety of tall shrubs is found in riparian and sheltered areas (Fig. 3). The southern boundary of subzone E is represented by the northern limit of trees. This represents the southern boundary of the area mapped for the CAVM in Canada (Gould et al., 2002).

DISCUSSION

Education: Integrating Research and Education

Five students enrolled in the course. One has finished an undergraduate degree and will pursue further studies in Arctic wildlife behavior. Two are returning as field assistants to the Arctic; one is beginning Ph.D. work in Antarctica; and one is working on analysis of field data collected as part of an independent project conducted along the transect. The field course, research activity, and continued interaction with the scientists have had a positive impact on their decisions to continue their work and study in polar ecology.

The influence of the students on the research aspect of the transect was also positive. In our field sampling, each scientist focused on a habitat related to his or her own expertise as we sampled along a mesotopographic sequence. Relevés were conducted with a student/scientist team of two people. Students rotated from one scientist to another, assisting with data collection, and gained insight into each scientist's particular area (wetland ecology, cryptogams, syntaxonomy, floristics, or natural history). Most of the scientists also enjoy teaching, and this informal instruction while working became a natural extension of the field sampling. The unflagging energy of the students kept us going into the long summer evenings as we processed samples before moving on along our transect. All parties agreed that the integration was successful and worthwhile and should be pursued in the future as a method of integrating research and teaching.

Research: Zonation

The most common zonation scheme used in North America is the Low Arctic-High Arctic zonation of Bliss (1997). This boundary closely corresponds with our subzone C–subzone D boundary indicating the northern limit of erect-shrub species and most of the associated boreal floristic elements. The greatest contrast between the North American, Russian, and European schemes is in their further subdivision of the High Arctic zone. Bliss (1997) accurately describes this region as a mosaic of polar desert, polar semidesert, and tundra vegetation. This mosaic is quite striking in the extensive pattern of barren and semibarren areas in the Canadian Arctic, visible in satellite AVHRR imagery (Fig. 1). Overlying this mosaic, we see a distinct pattern of floristic zonation related to climate: a continual loss of species diversity, functional type (growth-form) diversity, and associated ecological properties with decreasing summer warmth. This pattern, seen consistently on a circumpolar scale, is useful in observing and modeling global patterns of vegetation change related to climate (Kittel et al., 2000; Walker, 2000).

The subzonal names and boundaries described here are a step in reaching consensus among the CAVM scientists, and the discussion is ongoing. A more thorough treatment will be available as the map is completed (expected 2003). Confusion has arisen among Arctic vegetation scientists and ecologists from their differing use of the term “polar desert.” In the Russian and European traditions, this term refers to the climatic zone north of the limit of woody plants, i.e., the cushion-forb subzone (A) in the scheme presented here. In much of the North American literature, “polar desert” refers to a vegetation type rather than a bioclimatic zone, i.e., to barren areas (< 5% cover) in a range of climatic zones that have scant vegetation cover (Bliss, 1997). The mosaic of barren, semibarren, and tundra vegetation that crosses bioclimatic boundaries in the Canadian Arctic is related to the relatively recent deglaciation of large areas and the extent of coarse, strongly calcareous deposits that limit vegetation cover. The zonation presented here, based on floristic composition related to climate, is well suited to circumpolar descriptions of Arctic vegetation zonation and therefore useful in global modeling efforts.

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