United States Department of State

RECONNAISSANCE OF NOATAK NATIONAL PRESERVE AND BIOSPHERE RESERVE

U.S. Man and the Biosphere Program

The U.S. Man and the Biosphere Program (U.S. MAB) is an interdisciplinary research, education and training program on the relationship of people to their environment. U.S. MAB is supported by the United States Department of State, United States Department of the Interior-National Park Service, United States Department of Agriculture-Forest Service, National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration, the Peace Corps, and the Smithsonian Institution. The opinions, conclusions, and recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of the participating agencies and institutions. Inquiries concerning the U.S. MAB Program should be addressed to the Executive Director, U.S. MAB Secretariat, OES/ENR/MAB, United States Department of State, Washington, D.C., 20520.

Available from National Technical Information Service, (NTIS) U.S. Department of Commerce, 5285 Port Royal Rd. Springfield, Virginia, 22161 - No. NTIS PB 88-100037

RECONNAISSANCE OF NOATAK NATIONAL PRESERVE AND BIOSPHERE RESERVE AS A POTENTIAL SITE FOR INCLUSION IN THE INTEGRATED GLOBAL BACKGROUND MONITORING NETWORK

PB88100037

A Joint Project of:

U.S. MAB Directorate 6
Arctic Ecosystems
and
U.S. MAB Directorate 14
Pollution

June 1986

G. Bruce Wiersma
Idaho National Engineering Laboratory
Idaho Falls, Idaho

Charles Slaughter
Jerry Hilgert
Institute of Northern Forestry
Fairbanks, Alaska

Art McKee
Charlie Halpern
Oregon State University
Corvallis, Oregon

Work made possible by a grant from the
U.S. Man and the Biosphere Program

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO.	2.	3. Recipient's Accession No. NTIS PB 88-100037

4. Title and Subtitle Reconnaissance of Noatak National Preserve and Biosphere Reserve as a potential site for inclusion in the Integrated Global Background Monitoring Network	5. Report Date June 1986
	6.
7. Author(s) G. Bruce Wiersma, Charles Slaughter, Jerry Hilgert, Art McKee and Charlie Halpern	8. Performing Organization Rept. No.
9. Performing Organization Name and Address U.S. Man and the Biosphere Program U.S. Department of State (OES/ENR/MAB) Washington, D.C. 20520	10. Project/Task/Work Unit No. 11. Contract(C) or Grant(G) No. (C) P.O. 1753-600540 (G)
12. Sponsoring Organization Name and Address U.S. Department of State Washington, D.C. 20520	13. Type of Report & Period Covered Final
	14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

This report presents results of the initial reconnaissance effort of a pilot study to assess the suitability of Noatak National Preserve (also a designated UNESCO/MAB 1/ International Biosphere Reserve) as a site for an Integrated Global Background Monitoring site. Sites currently established as part of this pilot network are Olympic National Park, Washington, USA, and Torres del Paine National Park, Chile. Objectives of this global network are to 1) establish reference levels for pollutants that already exhibit global contamination, 2) establish baseline measurements of ecosystem parameters that permit comparison of more impacted areas, and 3) serve as an early warning system for detectiong increases in hazardous pollutants and changes in ecosystem processes. Because of its remote and pristine nature, Noatak National Preserve appeared to be an excellent candidate for inclusion in such a baseline network. The objectives of the Noatak pilot study were to 1) determine the suitability of pollutant sampling methodology, 2) sample existing levels of certain kinds of pollutants--primarily trace elements--and 3) collect ecosystem data to help plan a full-scale monitoring program. The report discusses terrestrial vegetation, trace element and nutrient analysis of selected plant and soil materials and of stream and lake water, periphyton, and potential whole-catchment sites (watersheds) for long-term environmental monitoring.

1/ United Nations Educational, Scientific and Cultural Organization - Man and the Biosphere Programme (UNESCO/MAB)

17. Document Analysis a. Descriptors

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
	UNCLASSIFIED	91
	20. Security Class (This Page)	22. Price
	UNCLASSIFIED	A05 $15.95

(See ANSI-Z39.18) See Instructions on Reverse OPTIONAL FORM 272 (4-77) (Formerly NTIS-35) Department of Commerce

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

Any successful reconnaissance of a remote and pristine area unfamiliar to the field investigators depends heavily upon the technical and management staff serving at that site. In the case of our reconnaissance in the Noatak National Preserve, this was particularly true. We would like to express our sincere appreciation and thanks to Ms. Kate Roney, Resource Management Ranger for the Noatak National Preserve, for all her help, advice, and guidance. We also express our appreciation to Mack Shaver, Park Superintendent and pilot, and to Ray Bane, Management Assistant, for their advice, support, and skillful flying.

The Institute of Northern Forestry, United States Department of Agriculture (USDA) Forest Service, Fairbanks, and the Idaho National Engineering Laboratory (INEL), Idaho Falls, provided administrative and other support for this reconnaissance effort.

Finally, we wish to acknowledge the financial support of the U.S. Man and the Biosphere Program (MAB), a grant from whom made this initial reconnaissance possible.

INTRODUCTION

In September 1985, a pilot study was initiated to assess the suitability of the Noatak National Preserve (also a designated UNESCO-MAB[1] International Biosphere Reserve) as a site for an Integrated Global Background Monitoring Site. Two sites currently established as part of the pilot network are Olympic National Park, Washington, U.S.A.; and Torres del Paine National Park, Chile. The objectives of this integrated global background monitoring network are 1) to establish reference levels for pollutants that already exhibit global contamination, 2) to establish baseline measurements of ecosystem parameters that permit comparison of more impacted areas, and 3) to serve as an early warning system for detecting increases in hazardous pollutants and changes in ecosystem processes. Because of its remote and pristine nature, the Noatak National Preserve appeared to be an excellent candidate for inclusion in such a baseline network.

The objectives of this immediate pilot study in the Noatak National Preserve were 1) to determine the suitability of pollutant sampling methodology, 2) to sample existing levels of certain kinds of pollutants, primarily trace elements, and 3) to collect ecosystem data to help plan a full-scale monitoring program. This report presents results of that initial reconnaissance effort.

The report concentrates on factors which were easily characterized during a restricted time period, in a restricted area--a snowy, high water week in September, in the immediate area of Kelly Bar at the confluence of the Kelly and Noatak Rivers in Noatak National Preserve. Individual sections discuss terrestrial vegetation, trace element and nutrient analysis of selected plant and soil materials and of stream and lake water, periphyton, and potential whole-catchment sites (watersheds) for long-term environmental monitoring.

---

[1] United Nations Educational, Scientific and Cultural Organization - Man and the Biosphere Programme (UNESCO/MAB)

For the pilot study, a multidisciplinary team was formed from the College of Forestry at Oregon State University, Corvallis, Oregon, the U.S. Forest Service Institute of Northern Forestry at Fairbanks, Alaska, and the Idaho National Engineering Laboratory, Environmental and Earth Sciences Group, Idaho Falls, Idaho.

SETTING

The Noatak National Preserve comprises more than 80% of the watershed of the Noatak River (Figures 1 and 2). It covers a total area of more than 10,600 square miles. The 12,600 square mile drainage basin is entirely north of the Arctic Circle, with the center of the basin at 68 N, 160 W. It lies at the limit of the northern boreal forest--at the forest-tundra transition in the western Brooks Range. A relatively complete description of the Noatak National Preserve, its landscape, natural and cultural resources, and resource uses was prepared by the National Park Service (NPS) (1985). The geography, climate, and vegetation of the watershed were briefly described by Childers and Kernodle (1981).

Fire history in the Noatak has been documented by Racine, et al. (1985), who demonstrated that fire regime varies with elevation (reflecting limits on vegetation growth and fuel buildup), physiographic sector within the basin, and seasonal (summer) climate. A wildfire "recurrence interval" or "natural fire rotation" of 988 years was estimated for the entire Noatak watershed; however, a more realistic estimate is 395 years for the land area below 450 m elevation (the approximate elevational limit of shrub-tussock vegetation) (Racine, et al., 1985).

TERRESTRIAL AND AQUATIC SITE ESTABLISHMENT AND DESCRIPTION

Terrestrial Sites

The following section addresses the third stated objective of our pilot study--collecting ecosystem data to help plan a full-scale

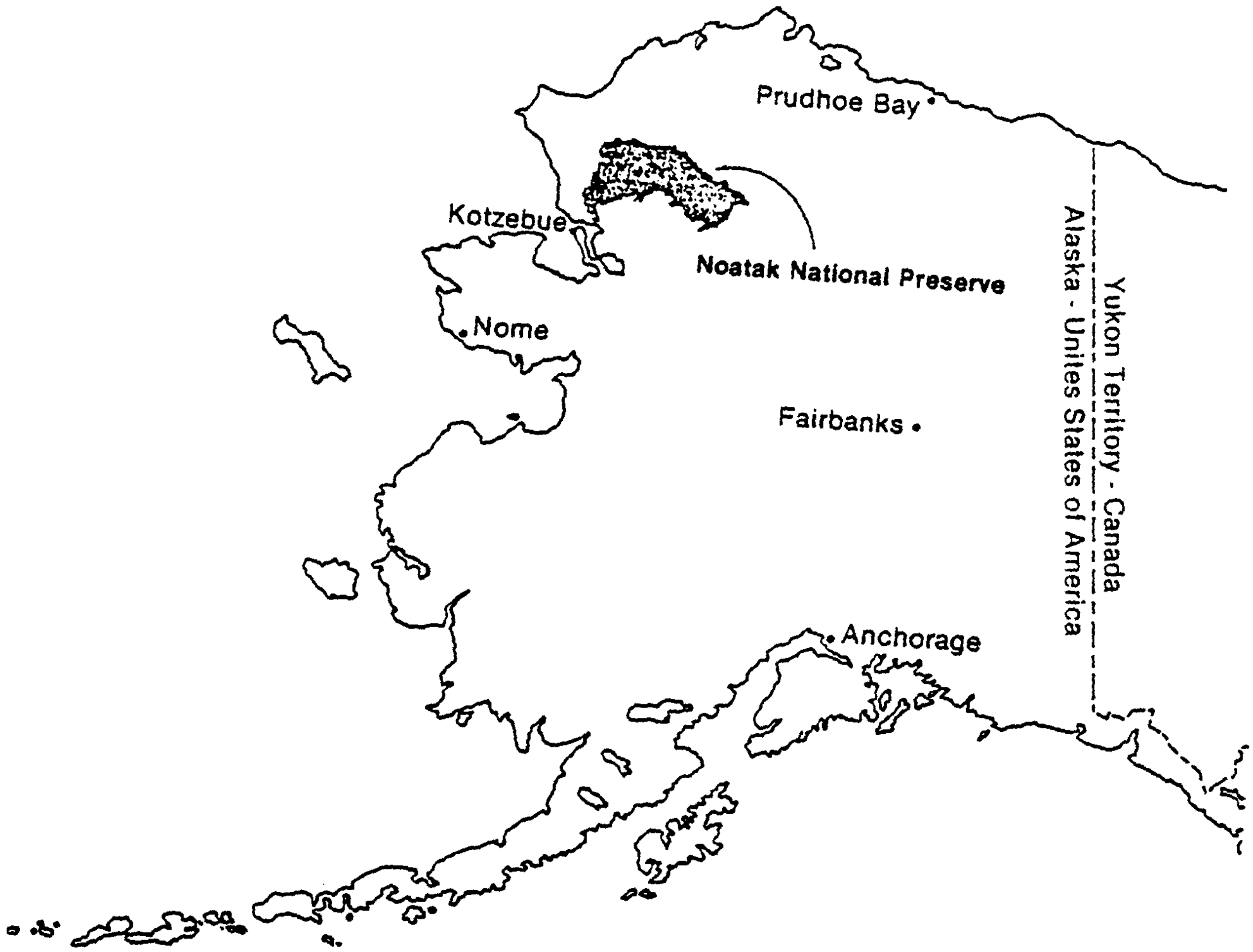


Figure 1. Location of Noatak National Preserve.

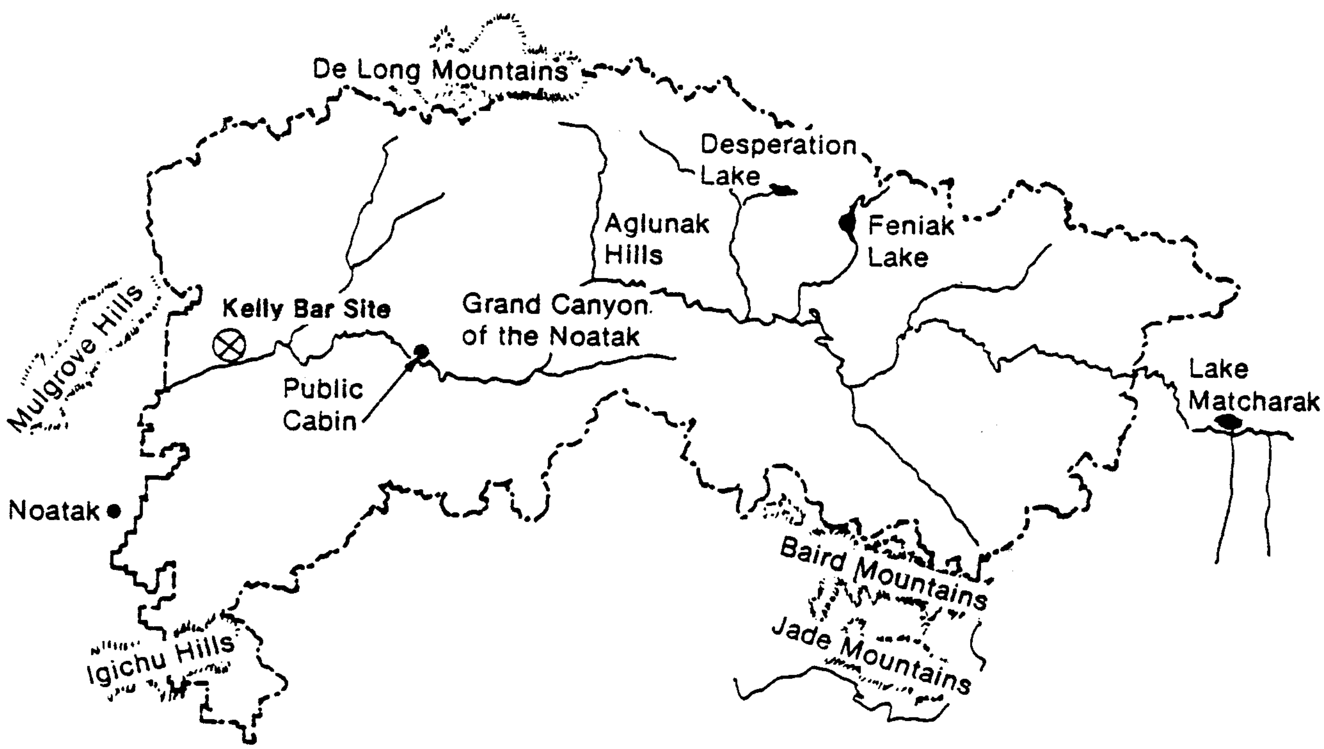


Figure 2. The Noatak National Preserve, showing the relative location of the Kelly Bar sampling site.

monitoring program. The first portion describes the permanent plots installed for terrestrial vegetation sampling, while the second section describes the sampling from aquatic systems. Two permanent vegetation plots were established near the confluence of the Kelly and Noatak Rivers in the western portion of the Preserve (Figures 2 and 3). Although they occupy a relatively small proportion of the total landscape, stands of white spruce were selected because they probably represent the maximum rates of local ecosystem production, and have long-lived tree and shrub individuals. Both population and ecosystem level processes can be tracked by repetitive measurements on permanent vegetation plots to detect changes that might be the result of increased pollutant levels. The results presented provide a context for the levels of pollutants and their variability within the study area at the current time.

Methods

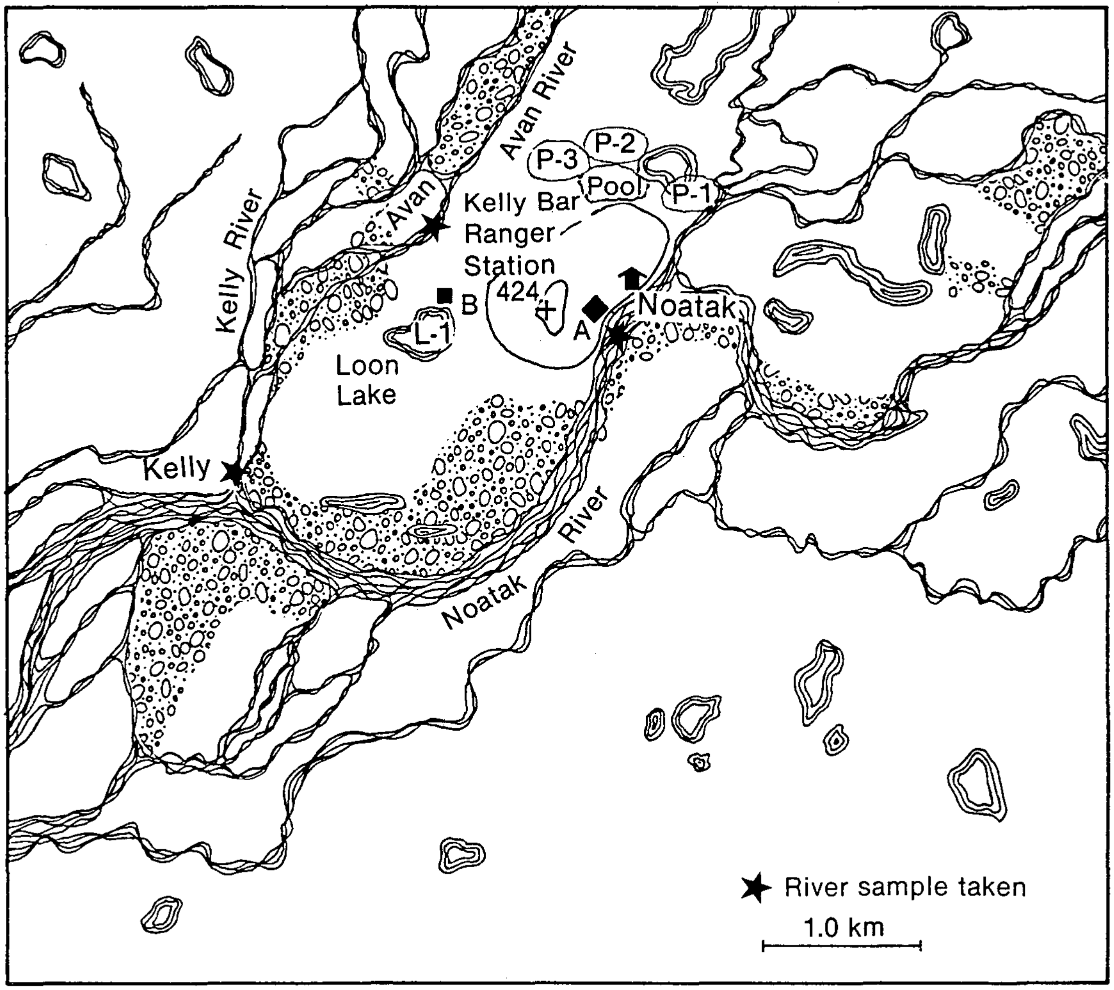
Forest Stand Selection

Two forest stands were selected to represent the observed variation of white spruce (Picea glauca) density within the study area (Figures 2 and 3). Permanent plots were at first located by subjectively picking a "typical" site within the stand and then the initial corner was determined by throwing a stake vigorously backwards over the shoulder to minimize bias in actual location. The baseline for the X-coordinates was placed on the contour so that the Y-axis was oriented up and down slope.

The boundaries of the 25 x 25 m permanent plots were surveyed by hand-compass without slope correction. Error of closure was less than 0.5 m. Five-meter points were marked along the perimeter and 2 x 2 inch wooden stakes were driven in to mark the corners. String was run between the five meter points to establish a grid for stem mapping.

Field Sampling

Trees were measured for height and diameter at breast height (dbh) (1.4 m). The heights at the Loon Lake plot were estimated from height



Legend

P-1	=	Pond #1
P-2	=	Pond #2
P-3	=	Pond #3
L-1	=	Lake #1

Figure 3. Location of sampling sites in the confluence of the Kelly and Noatak rivers.

over diameter regressions developed from the Kelly Bar plot data. The regression used was height (meters) = 1.504 + 0.4125 dbh (cm), r^2 = 0.73. The X, Y-coordinates of each tree were recorded, ocularly interpolating within the grid established. Standing dead trees were also tallied and mapped and the size and locations of downed trees noted. Increment cores were taken at approximately 0.3 m height from selected overstory dominants as well as several smaller individuals to determine growth rates and approximate ages.

The shrub stratum was sampled by line intercept. Five 5-meter long transects were installed at each site. A 5 x 5 m subplot was picked randomly within each grid column and the line intercept was run from right to left across the middle of the selected subplot. Starting coordinates were the same for both sites (5, 17.5; 10, 7.5; 15, 7.5; 20, 17.5; 25, 22.5). Intercepts of moss cover as well as that for individual shrub species were measured to the nearest centimeter. Estimates of percent species cover were calculated by summing intercept length over all 5 transects and dividing by 25 meters.

The herb, moss, and lichen cover was sampled using a .2 x .5 m plot frame. Ten microplots were sampled along both the upper and lower boundaries at 2-meter intervals starting at 2.5 m for a total of 20 samples per plot. The center of the short side of the microplot frame was placed at the sampling interval (e.g., 2.5, 4.5, 6.5 m, ...) with the frame just inside the overall plot boundary. Cover for each species was ocularly estimated to the nearest percent. Cover for total herb, moss, and lichen was also estimated. Mean cover and frequency were then calculated for each species and growth-form. Nomenclature for vascular plant species follows Hulten (1968). Nomenclature for mosses follows Lawton (1971).

Black-and-white photographs were taken with a 2 1/4 x 2 1/4 in. format camera with a 50 mm wide-angle lens. Photos were taken at the 5-meter points along the perimeter of the plot, facing into the stand along the grid lines at right angles to the boundary (Figures 4a and b and 5a and b).

Figure 4a. White spruce forest at the Kelly Bar permanent reference stand, Noatak National Preserve, Alaska. Striped pole is 1 m tall.

Figure 4b. White spruce forest at the Kelly Bar permanent reference stand, Noatak National Preserve, Alaska. Note the density of tall shrubs as compared with Loon Lake (Figs. 5a and b).

Figure 5a. White spruce forest at the Loon Lake permanent reference stand, Noatak National Preserve, Alaska.

Figure 5b. White spruce forest at the Loon Lake permanent reference stand, Noatak National Preserve, Alaska. Note the lower density of trees as compared with Kelly Bar.

Data Reduction and Analysis

Tree stem maps were generated for each reference stand based upon the coordinate assignments of live, dead, and downed trees. The maps exaggerate diameter by a factor of 2. Diameter and height distributions for white spruce were plotted for both sites with size classes presented as the mid-points of 1.0 cm diameter classes and 1 m height classes, respectively.

Biomass estimates were obtained by using equations developed by Yarie and Van Cleve (1983). These equations were derived from stands at approximately the same latitude as the Noatak plots but located near the Porcupine River in eastern interior Alaska.

Tree age at coring height and ten-year-growth increments were measured under a 10 power dissecting microscope with optical micrometer. Growth data are presented as mean annual growth increment per decade vs. years before present.

Results

Tree Stratum

Stand Maps

The maps of the two stands graphically show the greater density of live trees and downed coarse woody debris at the Kelly Bar stand (Figures 6 and 7). Both stands show the wide spacing of live trees and the spatial heterogeneity that is typical of white spruce stands in this locale. At several places within both stands there is a suggestion of a linear pattern of establishment, for example, in the northwestern corner of the Kelly Bar stand and the eastern central portion of the Loon Lake stand.

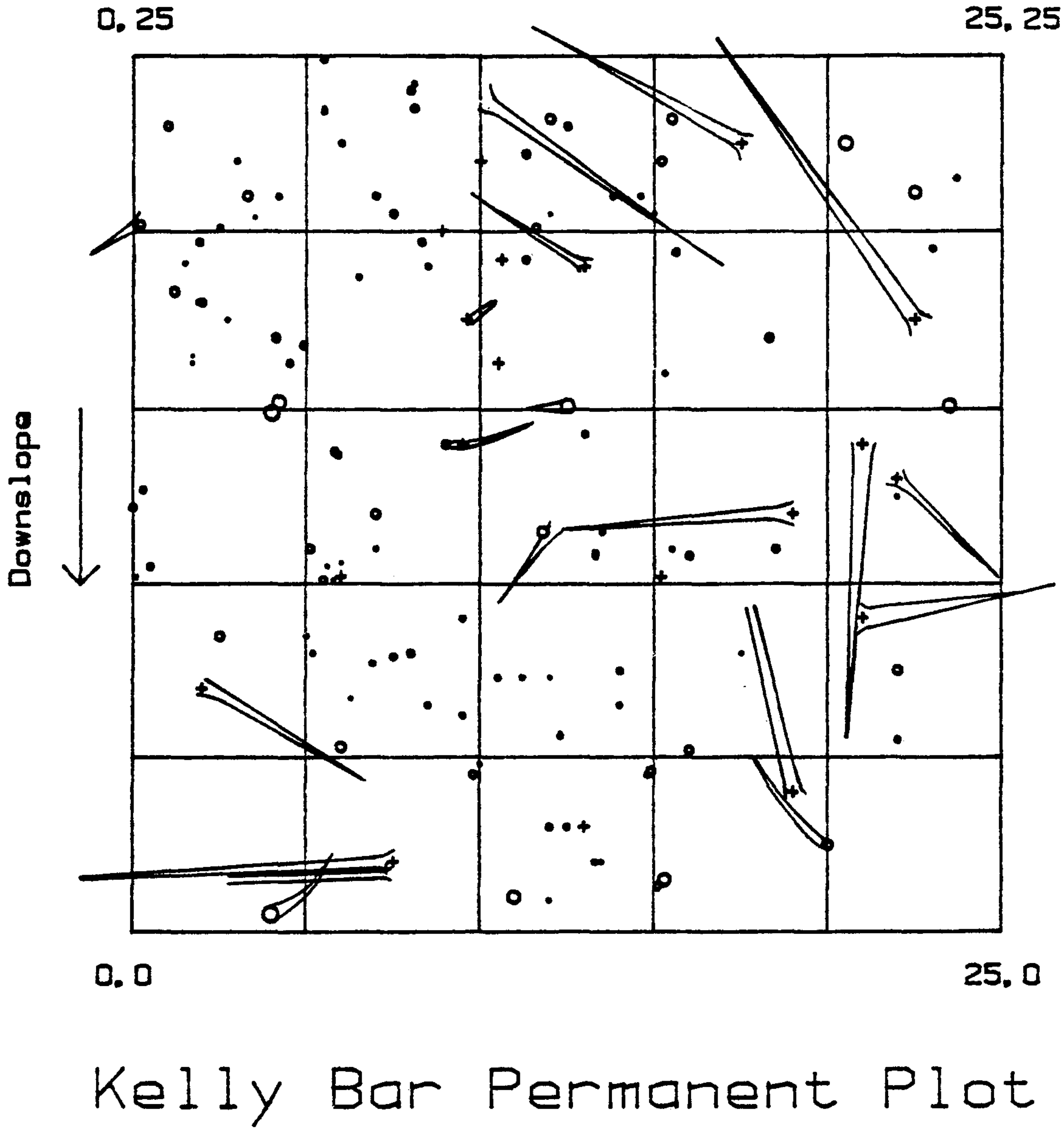
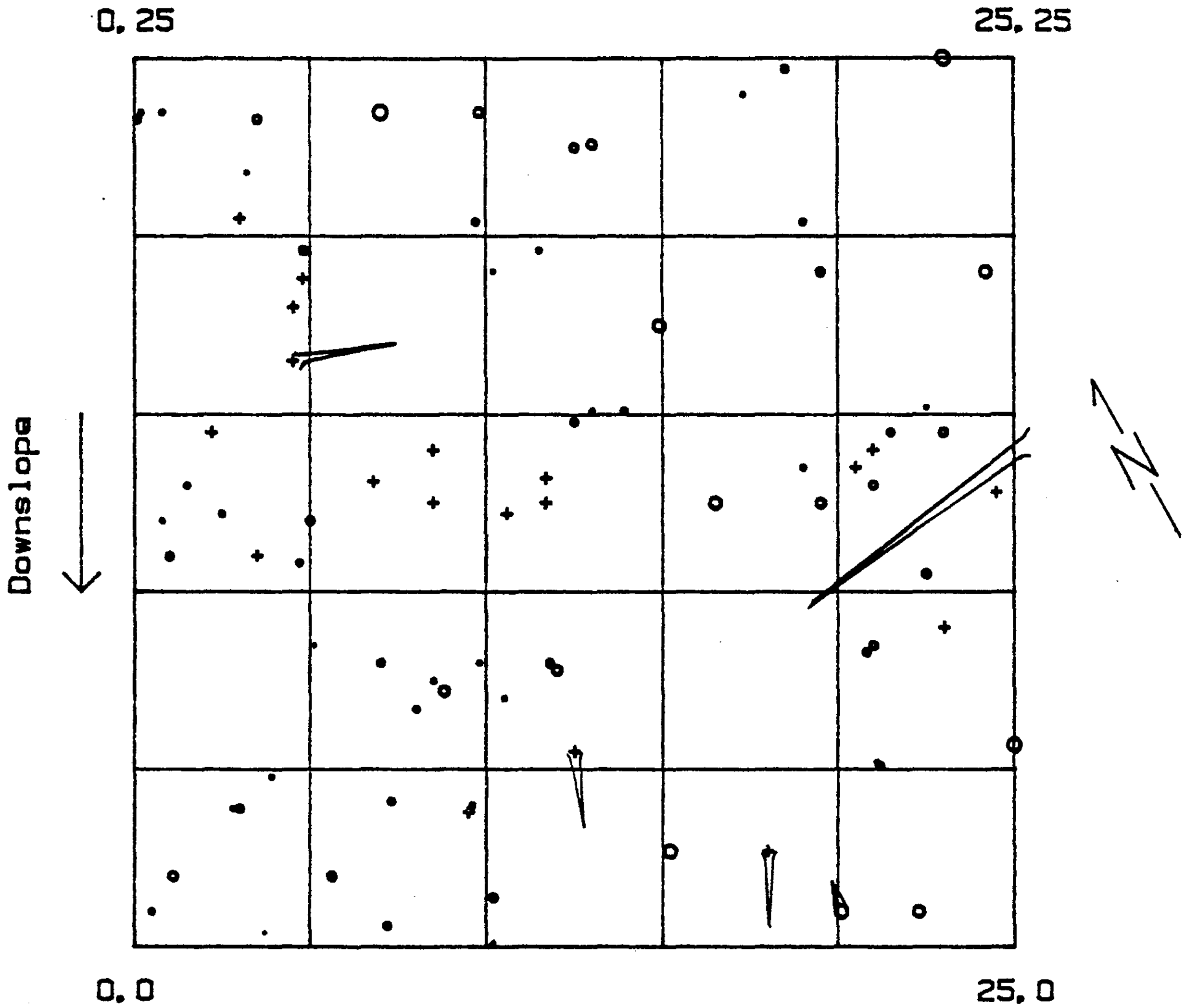


Figure 6. Tree stem map of the Kelly Bar permanent reference stand, Noatak National Preserve, Alaska. Grid represents 5 X 5 m units. Circles represent live white spruce individuals (2 X actual size). +'s represent standing dead and the bases of downed trees. Horizontal projections of leaning trees are drawn adjacent to circular bases.



Loon Lake Permanent Plot

Figure 7. Tree stem map of the Loon Lake permanent reference stand, Noatak National Preserve, Alaska. Grid represents 5 X 5 m units. Circles represent live white spruce individuals (2 X actual size). +'s represent standing dead and the bases of downed trees. Horizontal projections of leaning trees are drawn adjacent to circular bases.

The causes of this linearity are not known, but it suggests the importance of downed trees in providing shelter or a more optimal seedbed. This could also be the results of some interaction of small mammals or birds with the downed logs through processes involving dispersal mechanisms or creation of more favorable vertebrate habitat.

Diameter and Height Distributions

Size distributions of white spruce in both reference stands appeared fairly similar. Both diameter and height distributions approximated bell-shaped or normal curves with varying amplitude and range (Figures 8 and 9).

Maximum tree heights were 9.7 m at Loon Lake and 12.3 m at Kelly Bar. Diameters for trees greater than 1.4 m tall ranged from 1.3 to 19.9 cm at Loon Lake and from 1.5 to 21.5 cm at Kelly Bar. Greater than 70% of the trees in both stands were less than 6.0 m tall. Similarly, 73 and 79% of the individuals at Loon Lake and Kelly Bar, respectively, had diameters smaller than 12.0 cm. Because of a greater proportion of individuals in the low- to mid-size class range, both the height and diameter distributions for the Kelly Bar stand were more peaked and skewed than those of Loon Lake. Small numbers of individuals in the lowest diameter and height classes suggest a recent regeneration regime quite different from that expressed by the modal size class trees.

Biomass and Density

The aboveground biomass estimates for the two permanent plots are given in Table 1, along with density, mean diameter at breast height, and total height.

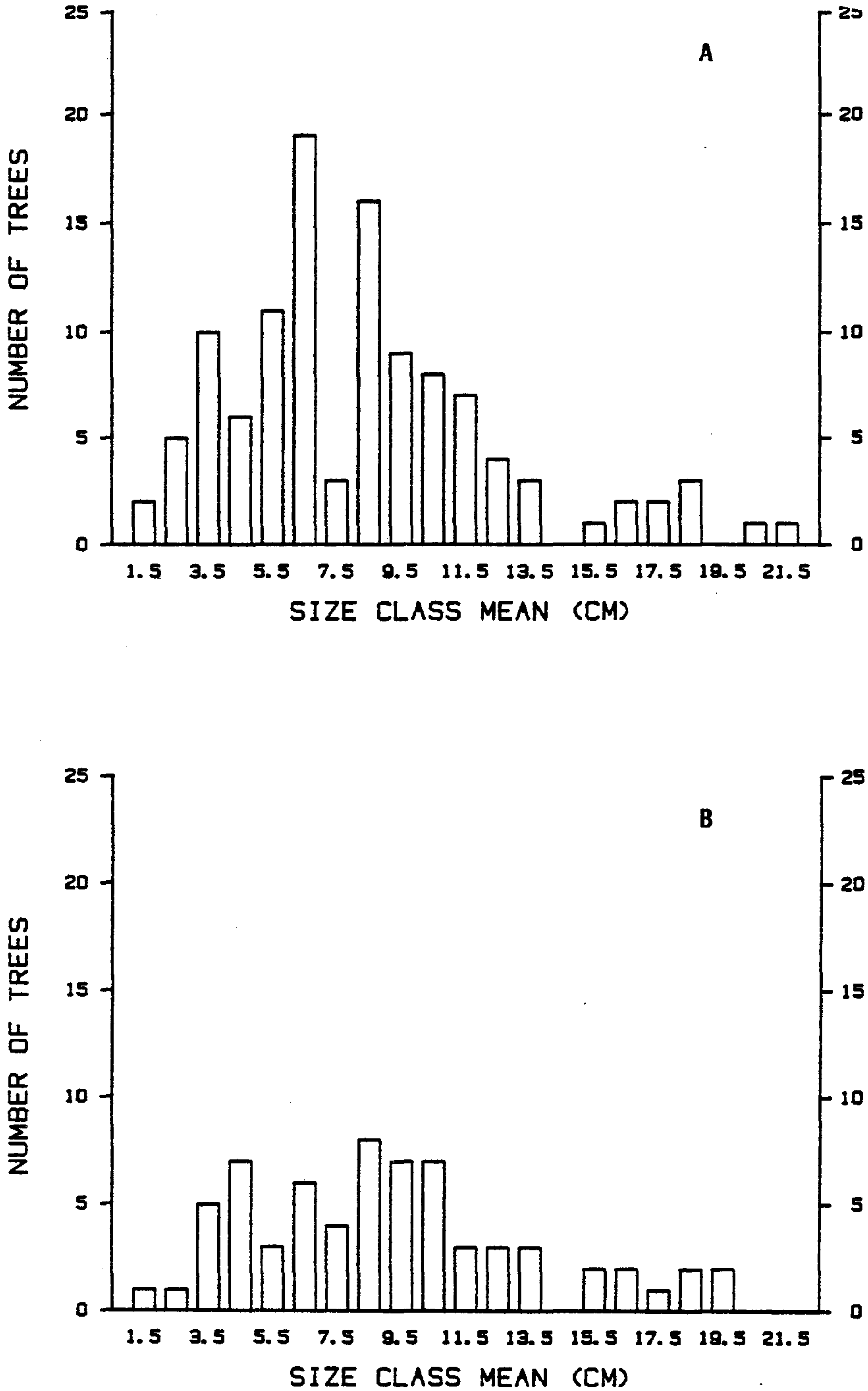
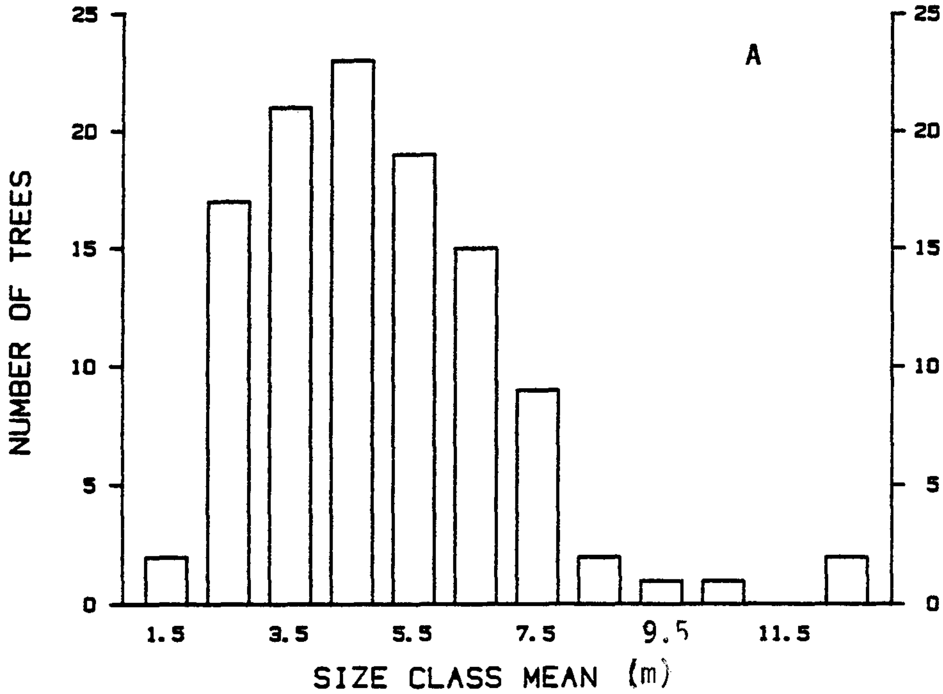


Figure 8. Diameter distributions for white spruce in the Kelly Bar (A) and Loon Lake (B) reference stands. Diameters are expressed as the means of 1.0 cm size classes measured at diameter breast height (1.4 m).



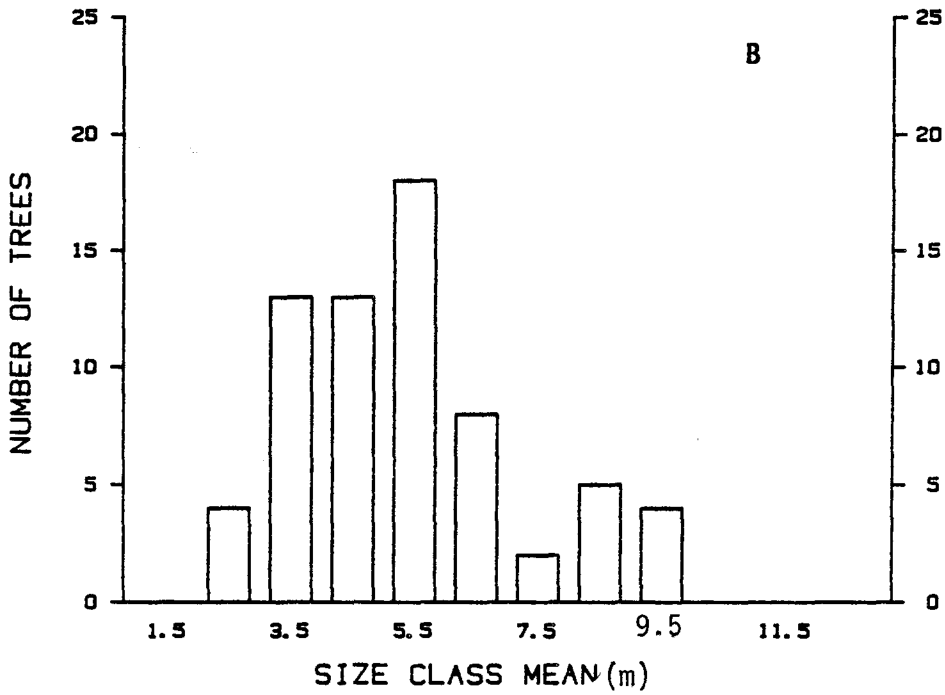


Figure 9. Height distributions for white spruce in the Kelly Bar (A) and Loon Lake (B) reference stands. Heights are expressed as the means of 1.0 m size classes.

Table 1. Density, mean diameter at breast height, and aboveground biomass estimates for permanent plots (625 m^2) established in September 1985 near Loon Lake and Kelly Bar Guard Station, Noatak National Preserve, Alaska.

Site	Dead: Standing (No.)	Dead: Standing (kg)	Dead: Down (No.)	Dead: Down (kg)	Live (No.)	Live: Mean (cm)	Live: Mean (m)	Live: Foliage (kg)	Live: Total aboveground (kg)	Plot total (kg)
Loon	16	190	3	40	67	9.2	5.2	250	1600	1800
Kelly	8	70	12	620	113	8.2	4.9	350	2200	2900
Mean	12	130	7.5	330	90	8.6	5.0	300	1900	2350

An overall mean for both plots is also given since the plots are relatively small (625 m^2) and the stands are quite open and appear to be quite heterogeneous in their spacing pattern. While the mean diameters and heights are similar, the two plots have quite different densities of live and standing dead and downed trees. The Loon Lake stand is more open with fewer total live trees and a larger proportion of standing dead. The Kelly Bar stand, on the other hand, has quite a few more downed trees, many of which are relatively large in size. The proportion of biomass in downed trees is much higher at the Kelly bar stand.

The plot totals of 1800 and 2900 kilograms at Loon Lake and Kelly Bar, respectively, equal 14.5 and 23 metric tons per hectare. These are extremely low values for stands where the overstory dominants are 250+ years in age. Typical mature temperate forests are an order of magnitude higher (Whittaker, 1975; O'Neill and Reichle, 1979). The old-growth forests of the Pacific Northwest are two orders of magnitude greater (Franklin and Waring, 1979; Grier and Logan, 1977).

The proportion of estimated biomass in foliage (about 16%) is much higher than in temperate forests, however. The values are admittedly suspect since the equations are not locally derived, but even if overestimated by a factor of two, they are still extremely high values. In the old-growth forests of the Pacific Northwest, foliar biomass is typically 1.5-2% of the aboveground total--an order of magnitude less.

Foliage is retained for many years on the trees at the Noatak plots. Observations of length of needle retention ranged from 15 to 22 years. This is quite unusual for the genus Picea and may represent an example of a nutrient conserving adaptation to an extreme environment. It might be possible to sample needles for the last two decades to see if any trend in anthropogenic materials is evident.

A comparison of stand characteristics of the two plots at Noatak with some plots near the Porcupine River in eastern interior Alaska is shown in Table 2.

Table 2. Selected stand parameters for two plots in the Noatak National Preserve and three plots near the Porcupine River in interior Alaska.

	Sites: Plots				
	Noatak		Porcupine [1]		
	Loon	Kelly	334	22	4
Stand Description					
Age of dominant trees	250+	250+	85	--	75
Basal area (m^2/ha)	8.63	12.1	3.28	17.0	8.14
Mean diameter (cm)	9.2	8.2	7.8	9.5	9.0
Stems/ha	1072	1808	688	2408	1285
Stand Biomass (kg/m^2)					
Foliage	0.4	0.6	0.15	.78	.37
Total tree	2.5	3.5	0.92	4.40	2.20

[1] Values from Yarie, J. and K. Van Cleve (1983).

The Porcupine plots shown in Table 2 are selected from a table in Yarie and Van Cleve (1983) and represent the stands from that study with very low biomass and density values. The values for density, basal area, and biomass of the Noatak plots are similar to, or within the range of, those of the Porcupine plots. One revealing difference, however, is the age of the overstory dominants. The Noatak plots have much older trees, indicating that the productivity of white spruce stands in the Noatak is very low even by interior Alaska standards. The Noatak plots are near the very limits of tree growth, and the biomass values reflect that.

Tree Ages and Growth Rates

Increment core samples from white spruce individuals at Loon Lake and Kelly Bar reference stands indicate a fairly wide distribution of tree ages. Maximum annual ring counts were 239 and 243 at Loon Lake and Kelly Bar, respectively. Absolute tree ages were not determined because of our uncertainty of tree age at coring height (approximately 0.3 m). Data from Gasbarro and Zasada (1984) suggest a large range of possible ages at that height--from 15 to 50+ years. We estimate that the oldest trees at Loon Lake and Kelly Bar undoubtedly exceed 250 years.

Growth increments by decade of white spruce showed a large variation (Figures 10-14). Individuals exhibited asymmetrical growth patterns (not related to reaction wood) and decade-length increments showed little relation to tree age. Annual growth increments derived from decade-length measurements ranged from 0.13 - 1.82 and from 0.10 - 1.72 mm/yr at Kelly Bar (Figures 10-12) and Loon Lake (Figures 13 and 14), respectively. Growth rate patterns of individuals varied considerably within both reference stands. However, one fairly consistent trend appeared for both sites. A recent decline in growth increment spanning the last 50-60 years was exhibited by all five cored individuals at Loon Lake and five of eight individuals at Kelly Bar. Causes for the decline are not known.

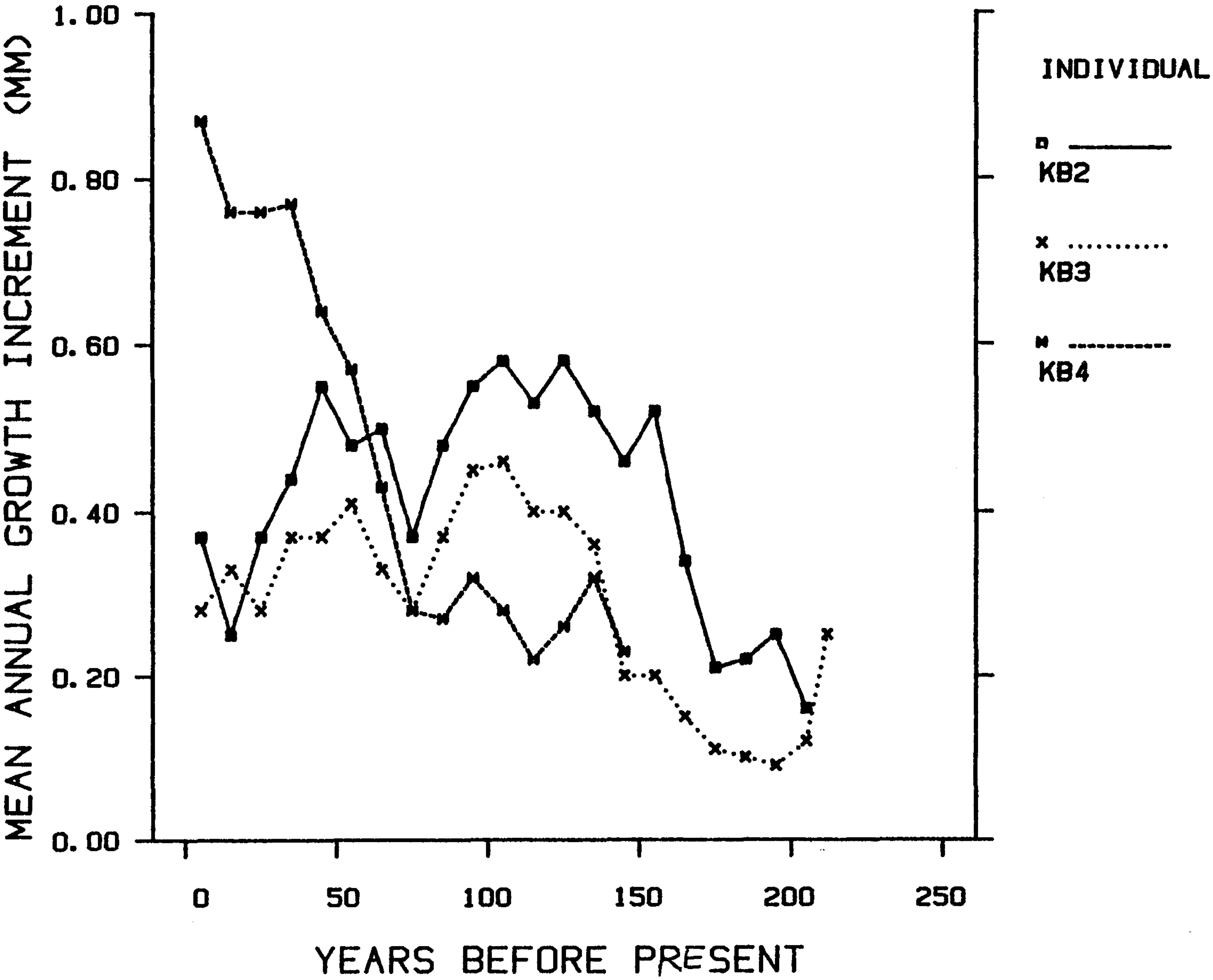


Figure 10. Mean annual growth increment per decade for three white spruce individuals in the Kelly Bar reference stand.

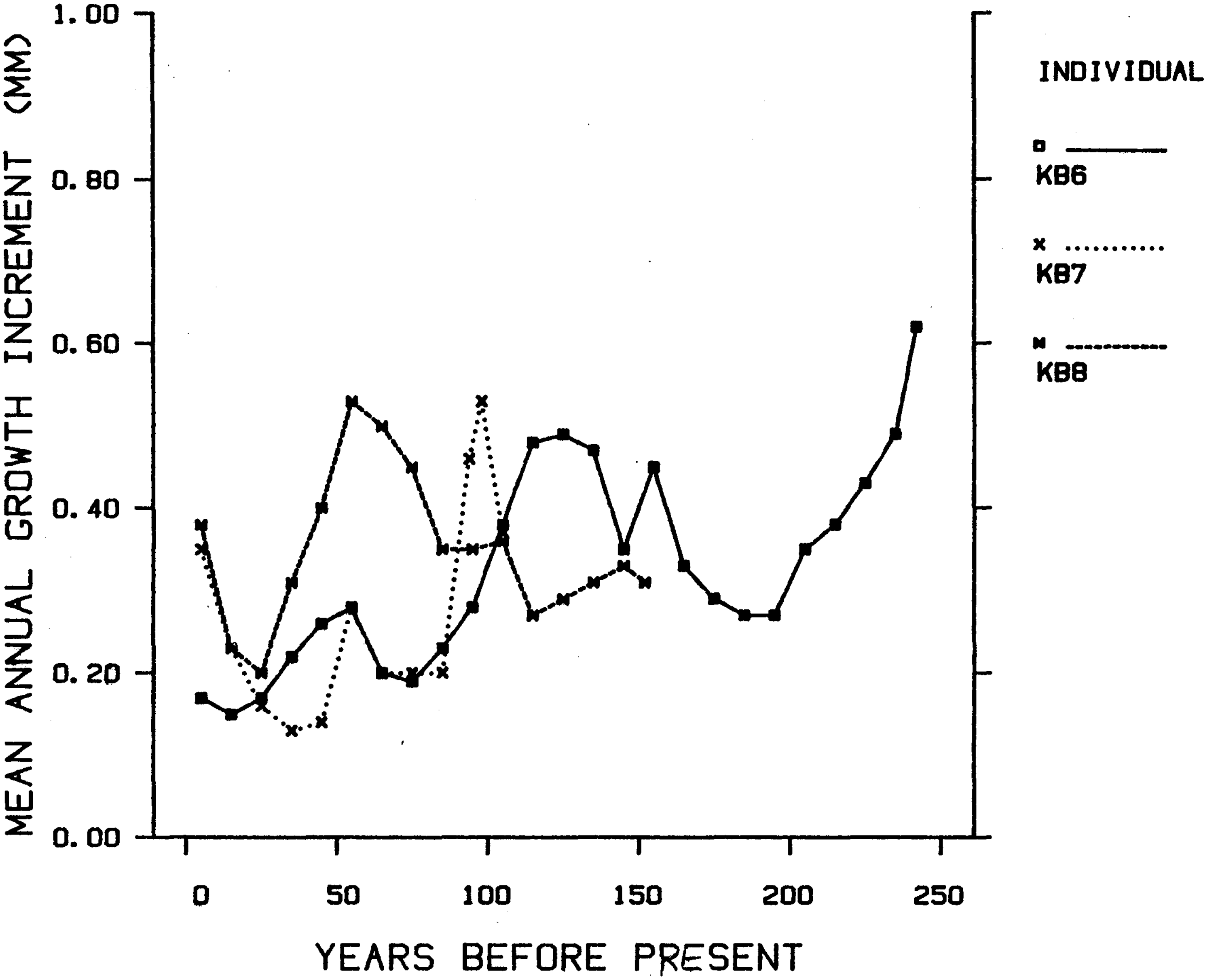


Figure 11. Mean annual growth increment per decade for three white spruce individuals in the Kelly Bar reference stand.

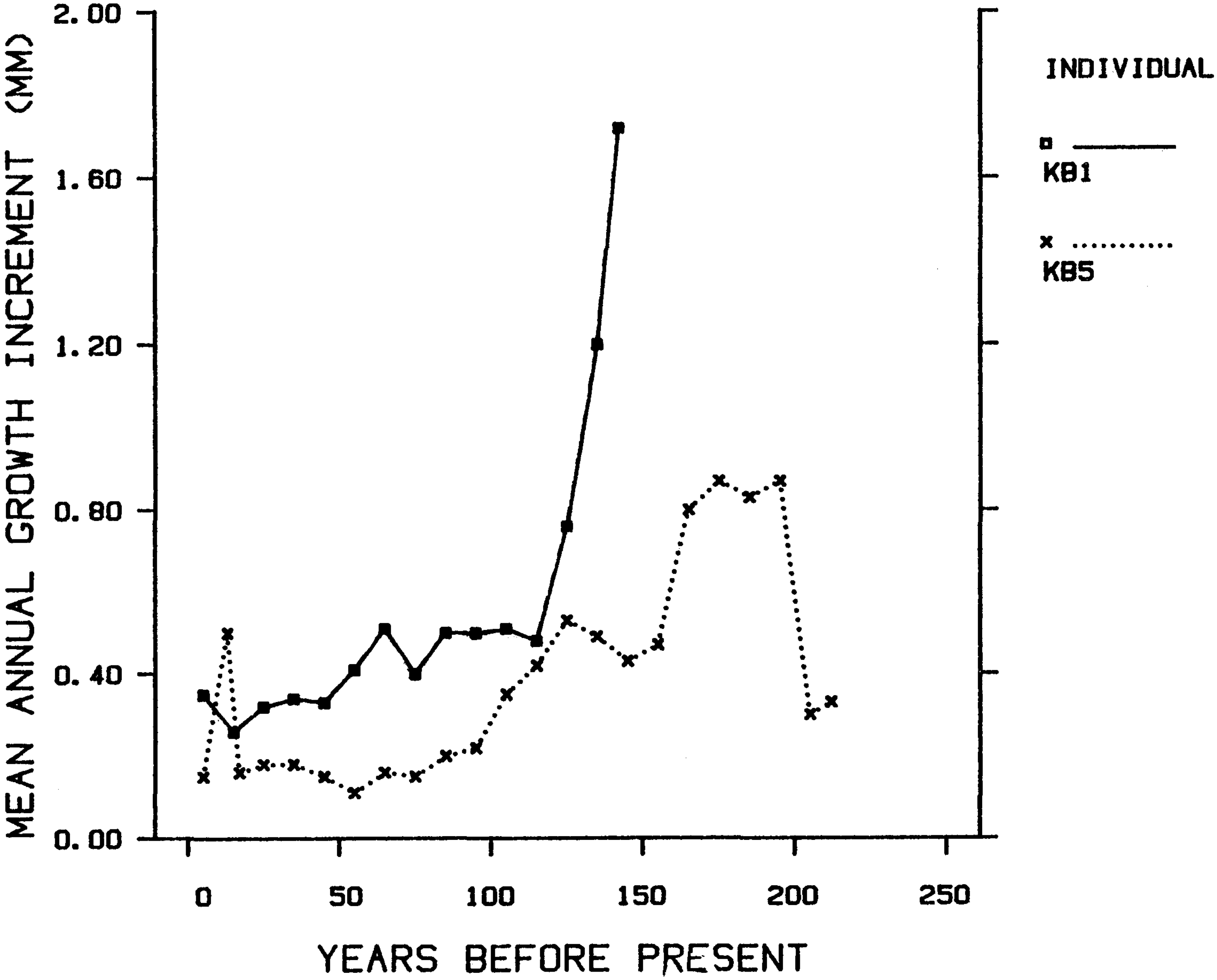


Figure 12. Mean annual growth increment per decade for two white spruce individuals in the Kelly Bar reference stand. Note change in scale from Figure 11.

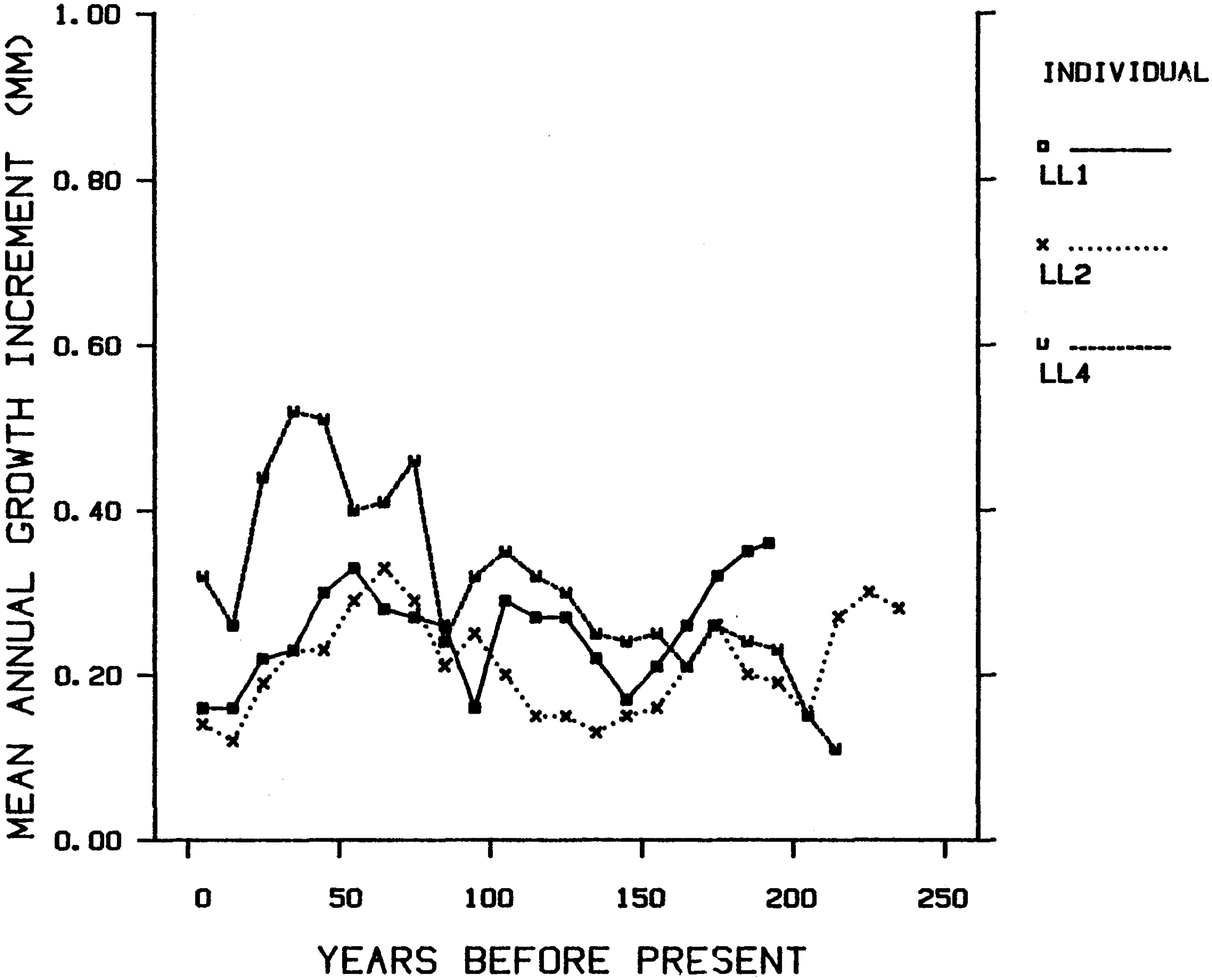


Figure 13. Mean annual growth increment per decade for three white spruce individuals in the Loon Lake reference stand.

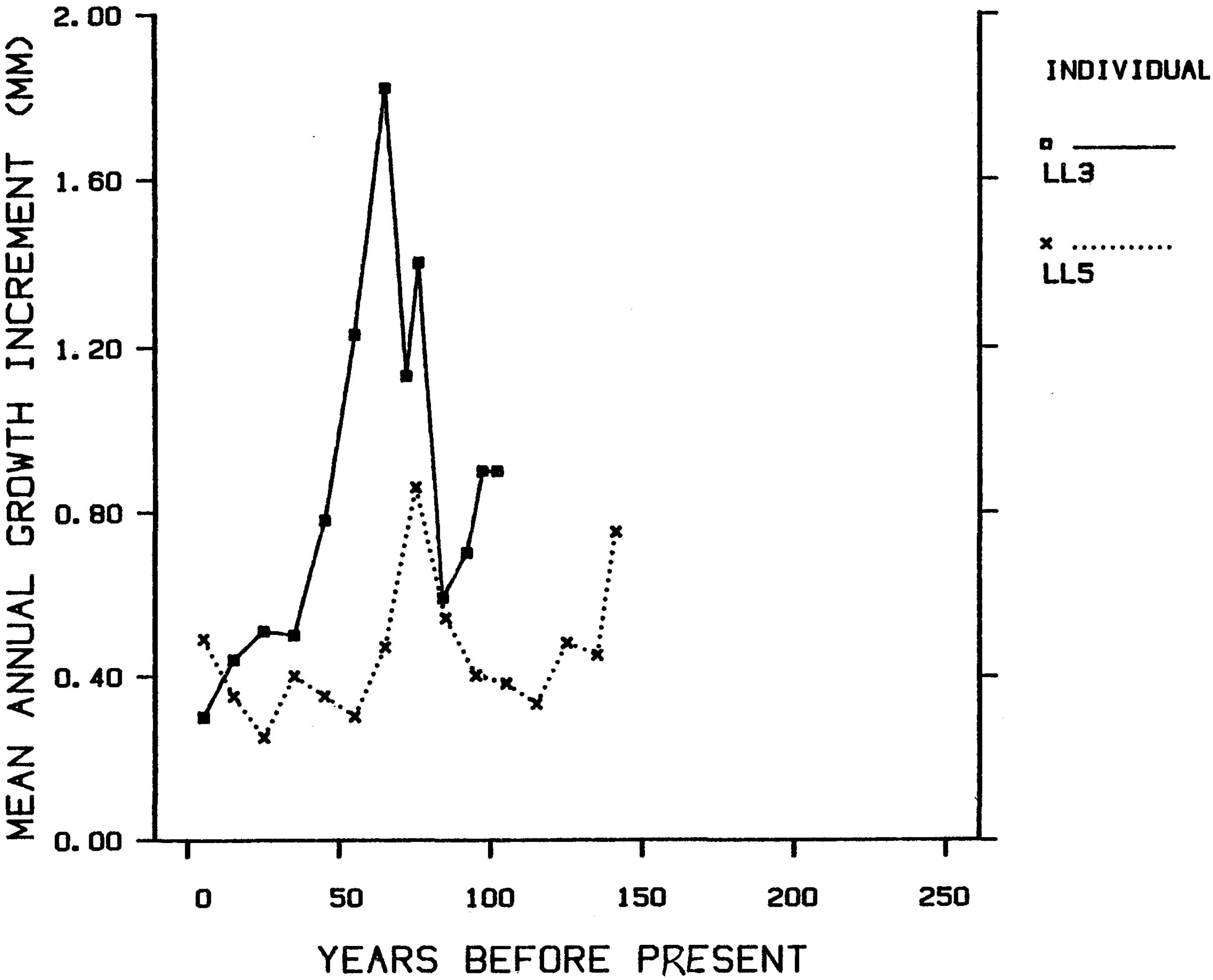


Figure 14. Mean annual growth increment per decade for two white spruce individuals in the Loon Lake reference stand. Note change in scale from Figure 13.

Estimates of absolute incremental growth and total ages, and comparisons of growth patterns remain rather limited at present. Asymmetrical growth rings, high incidence of wood decay, and uncertainty of tree age at coring height prevent us from making anything more than general statements.

Shrub Cover and Density

Because of the open nature of the forests, the shrub layer is well developed. Cover values are quite high with the Kelly Bar stand dominated by *Alnus crispa* and *Arctostaphylos alpina*, and the Loon Lake stand dominated by *Vaccinium uliginosum* and an unknown *Salix* (Table 3).

Table 3. Moss and shrub percent cover and frequency in permanent plots established in September 1985 near Loon Lake and Kelly Bar Guard Station, Noatak National Preserve, Alaska.

Species/Taxon	Cover (%)		Frequency (No. of Transects)	
	Kelly	Loon	Kelly	Loon
Mosses	74.9	80.1	5	5
Alnus crispa	31.6	4.6	4	1
Arctostaphylos alpina	23.1	1.5	5	1
Empetrum nigrum	15.0	6.9	4	3
Vaccinium uliginosum	13.3	30.8	5	5
Ledum (*decumbens* ?)	12.5	3.3	2	4
Vaccinium vitis idaea	9.6	7.1	5	5
Salix reticulata	2.7	0.9	2	2
Potentilla fruticosa	1.8	---	1	---
Salix spp.	1.3	13.1	2	3
Linnea borealis	0.9	---	2	---
Dryas integrifolia	0.5	---	1	---
Betula nana	---	0.1	---	1
Sum of shrub cover (%)	112.3	68.3		
Vascular species richness (No.)	11	9		
Vascular diversity (H') ($H' = - \sum pi \log_e pi$)	2.2	1.8		

The two stands differ quite a bit in the relative abundances of the common shrub species they share, and the total cover at the Kelly Bar stand is greater. The species richness at the two sites is similar, but the diversity, as measured by the Shannon index (H'), is quite a bit greater at the Kelly Bar stand.

The shrub stratum of the two sites is also similar in shorter species structure--multilayered with taller deciduous species that are often evergreen. Approximately one-half of the cover at both sites is comprised of evergreen species. The distribution of species tends to be quite clumped with several layers of shrubs occupying short sections of the transects. The moss cover tends to be nearly continuous at both sites, absent only in areas of dense shade or on rocks and downed trees.

The high cover and mixture of deciduous, evergreen and moss species could provide an opportunity for monitoring the accumulation of anthropogenic substances. The three different groups of organisms have quite different life histories, nutrient retention capacities, and decomposition patterns. Ratios of accumulation and turnover among the three groups might prove to be a very sensitive index.

Herb Stratum

Vegetation of the herb stratum was generally well-developed although of low stature. Total herb-layer cover averaged 134% at Loon Lake and 89% at Kelly Bar (Tables 4 and 5). Moss dominated both sites contributing 88% and 61% cover at Loon Lake and Kelly Bar, respectively--estimates from the line intercept sampling also showed the Loon Lake stand to have higher moss cover. Herb and graminoid cover was of secondary importance and fairly similar at both sites--32% and 28%. The most distinctive site difference with regard to the herb stratum was the prominence of lichen at Loon Lake (14% cover and 85% constancy) and its relative scarcity at Kelly Bar (trace cover and 30% constancy).

Table 4. Frequency and average cover for the herb stratum of the Kelly Bar permanent reference stand, Noatak National Preserve, Alaska. COV represents mean canopy cover. T represents trace cover (<0.5%). Nomenclature for vascular plant species follows Hulten (1968). Nomenclature for mosses follows Lawton (1971).

			MICROPLOT NUMBER																				
			LOWER LINE										UPPER LINE										
SPECIES	FREQ(%)	COV(%)[1]	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
Total Moss	95	61	10	100	100	100	100	80		40	8	10	90	98	70	15	20	25	100	80	75	100
Total Lichen	30	T			T	1							2						2	2	1	
Total Herb	100	28	3	10	5	30	75	40	13	70	40	25	25	T	20	40	2	28	5	25	60	45
Moss and Lichen Species																						
Hylocomium sp.	85	43	10	100	75		30	70		15		1	90	80	65	15	20	20	95	10	40	100
Aulacomnium sp.(?)	55	15		1	15	100	70	10		25	1	3						6	5	70		
Polytrichum sp. 1	5	T									2											
Polytrichum sp. 2	10	T																	1		5	
Moss sp. 1	20	1			10	1	2														5	
Moss sp. 2	15	1									5	3			5							
Moss sp. 3	10	1										3									10	
Moss sp. 4	10	1																	T		10	
Cladonia sp.	5	T											2									
Lichen Sp. 1	10	T			T	1																
Lichen sp. 2	15	T																	2	2	1	
Graminoid Species																						
Carex bigelowii	80	15	1	10	3	20	70	35	5	25	T	10	5		10	10		25		10	60	
Arctagrostis latifolia	25	1			T								2			5				1		20
Grass sp.	50	6				10	2	T	3	40	15		15					T	2			25
Herbaceous Species																						
Equisetum sp.	70	6	1		1		10	3	4		25	7	5	6	10	25	2	3		15		
Aster sp.	30	1			1		T	3	2	1		7										
Papaver sp.	15	T				5	T						1									
Pyrola sp.	25	T									1		1	T	1				2			
Herb sp. 1	50	1	1			T	1	1	3	2					1				1	2	2	
Herb sp. 2	5	T	1																			

Table 5. Frequency and average cover for the herb stratum of the Loon Lake permanent reference stand, Noatak National Preserve, Alaska. COV represents mean canopy cover. T represents trace cover (< 0.5%). Nomenclature for vascular plant species follows Hulten (1968). Nomenclature for mosses follows Lawton (1971).

			MICROPLOT NUMBER																			
			LOWER LINE										UPPER LINE									
SPECIES	FREQ(%)	COV(%)[1]	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
Total Moss	95	88	80	85	95	100	90	100	90	100	100	100	90		70	100	100	100	80	95	95	95
Total Lichen	85	14	2	3	T[2]	40	50			5	5	1	1		60	7	6	3	48	3	27	15
Total Herb	100	32	50	T	20	25	70	7	50	30	37	30	25	3	40	10	40	50	20	38	45	11
Moss and Lichen Species																						
Hylocomium sp.	95	62	80	85	85	60	5	50	30	50	60	90	90		70	90	95	98	75	85	15	20
Aulacomnium sp.(?)	70	24			10	40	85	50	60	50	40	10				10	5	2		1	40	75
Moss sp.	15	3																	5	10	40	
Peltigera sp.	50	1		3							2	1			1	3	5	T	5		2	1
Lichen sp. 1	55	7		T		25					1				60	4	1	2	20	T	10	10
Cladonia	30	3				1	40			5	1								3		T	
Cladina sp.(?)	35	4				15	10				1								28	2	15	2
Lichen sp. 2	10	T											1									1
Graminoid Species																						
Carex bigelowii	80	8		T	10	5	10	3		5	10	30	20		T	2	6		10	25	20	3
Eriophorum vaginatum	5	1	25																			
Arctagrostis latifolia	10	3							35									15				
Poa sp.	15	T									2						1			3		
Catamagrostis sp.	5	T						T														
Grass sp.	10	1						4										10				
Herbaceous Species																						
Equisetum sp.	85	15	1		10	20	60		15	25	25	1	5	1	35	5	25	25		10	25	7
Polemonium acutiflorum	5	T																				
Papaver sp.	20	T			2										3			T	3			
Petasites frigidus	5	T																5				
Dryas integrifolia	10	T																	5			1
Tofieldia pusilla	5	T																	1			
Saxifrage sp.	5	T											2									
Polyogonum sp.(?)	35	T	3			T	T		1									T	1			T
Herb sp.	5	T												2								

Compositionally, the herbaceous vegetation at the two sites was fairly similar. Species of Hylocomium and Aulacomium comprised 95-98% of the moss cover in both stands. The remaining species of moss were fairly uncommon (less than 20% constancy). Carex bigelowii and Equisetum sp. totaled between 72% and 78% of the herbaceous cover on both sites, the former of greater abundance at Kelly Bar, the latter, of greater abundance at Loon Lake. Additionally, Arctagrostis latifolia and an unknown grass were fairly important. The remaining herbaceous species were fairly infrequent and had low abundances.

Species richness in the herb stratum at Loon Lake greatly exceeded that at Kelly Bar (15 vs. 9 vascular plant species) which was the reverse of the pattern for shrub species. Moss and lichen richness, however, were more comparable (8 vs. 11 species) at the two sites. The values for the herbaceous component are a little low compared with the herb layers of temperate forest systems we are familiar with.

The herbaceous component of the vegetation resembles the Carex bigelowii high center polygon vegetation type described by Johnson et al. (1966). Unfortunately our vegetation data were collected at the end of the growing season and many species may be poorly represented. Early and mid-summer composition and structure may be significantly different. Relative abundance and diversity estimates should be assessed accordingly.

Summary

The plots at Loon Lake and Kelly Bar probably represent much of the variation found in white spruce stands near the confluence of the Kelly and Noatak Rivers. Both stands are open with well developed shrub layers and low statured, moss-dominated herb layers. Tree spacing appears quite heterogeneous, but an occasional linear pattern of seedlings suggests the importance of downed logs or nurse trees for regeneration. The shrub stratum is actually multi-layered with a taller layer of deciduous species and lower layers of both deciduous and evergreen species. The latter evergreen species. The latter constitutes about 50% of the total shrub cover. Because deciduous and evergreen shrub species are quite different in their nutrient retention and decomposition patterns, ratios of accumulation and turnover of anthropogenic substances between the two groups might be a sensitive index. The herb stratum appears fairly depauperate, with a major portion of the cover attributed to a few species of moss. A rather simple vegetation structure and composition would suggest that potential anthropogenic influences might be more easily assessed than in more complex systems.

Diameter and height distributions of white spruce approximate bell-shaped curves with greater than 70% of the individuals with diameters smaller than 12.0 cm and heights less than 6.0 m. Nevertheless, the forest stands are fairly old with individuals ranging from 100-250+ years of age.

The estimated biomass for the two plots is very low, 1 to 2 orders of magnitude lower than for temperate coniferous forests. The proportion in foliage is quite high, however, because of prolonged retention of needles up to 20 or more years. Such needles may provide a way of sampling changes in certain types of pollutant loadings over the past two decades. Although density, basal area, and biomass estimates seem comparable with other estimates reported from eastern interior Alaska, the Noatak sites are significantly older and may reflect an existence near the limits of tree growth under the most extreme environmental conditions.

Aquatic Sites

The aquatic environment is a particularly important habitat in the Noatak Preserve. In appreciation of this, a number of aquatic sites were surveyed during this study including the Kelly, Avan, and Noatak Rivers and a number of small lakes. It should be pointed out that, at the time the turbidity and temperature measurements were made, the Noatak River was at a high flow.

Algal Species Composition

A total of 136 algal taxa were observed in samples collected from three ponds, one lake, a series of small pools, and a periphyton scrape from a riffle within the Avan River (Table 6). Ponds were dominated by diatoms and green algae in the periphyton (Tables 7 through 10), while the Loon Lake sample was dominated by desmids and blue-green algae (Table 11). The periphyton from the Avan River (Table 12) was dominated by pennate diatoms, many taxa of which typify river and stream periphyton from interior (Hilgert 1984) and north coastal Alaska (Patrick and Freese, 1961).

Table 6. Summary of number of algal taxa by major algal groups from each collection site.

	Cyanophyta	Chlorophyta Desmids	Chlorophyta All taxa	Crysophyta Diatoms	Crysophyta All taxa	Total taxa
Pond #1	1	3	4	14	16	23
Pond #2	3	8	13	13	15	32
Pond #3	4	6	15	10	10	29
Loon Lake	9	19	23	12	12	45
Pools	5	6	11	10	12	30
Avan R.	5	2	4	20	20	30

Most taxa found in this survey are typical of collections made on the north slope of Alaska, including many desmid taxa (Prescott and Vinyard, personal communications). A series of small, shallow pools on the "tundra" area between ponds #2 and #3 were covered with a thin ice layer and water temperatures were 0 C. Thick growths of mucilaginous algae (accompanied by many gas bubbles) were observed under the ice. These growths (Table 13) were predominantly large colonies of Nostoc pruniforme, found to be common on the north slope tundra by Prescott and Vinyard (1965), "...common in the tundra, often forming a 'pebbled' bottom in shallow pools, especially on bare ground." Submerged mosses and Utricularia vulgaris from the three ponds and Loon Lake were often

Table 7. Algal species composition from pond #1, periphyton collected from squeeze of Utricularia vulgaris.

CHLOROPHYTA
  Zygnematales
    Desmidiaceae
      Closterium kuetzingii
      Closterium sp.
    Zygnemataceae
    Mougeotia sp.

CHRYSOPHYTA
  Chrysophyceae
    Ochromonadales
      Synuraceae
        Mallomonas spp. (2)
  Diatomaceae
    Achnanthaceae
      Achnanthes minutissima
    Cymbellaceae
      Cymbella cuspidata
    Eunotiaceae
      Eunotia sp.
    Fragilariaceae
      Fragilaria sp.
      Tabellaria fenestrata
      Tabellaria flocculosa
    Naviculaceae
      Navicula sp.
      Pinnularia sp.

Table 8. Algal species composition from pond #1, benthic flocculent.

CYANOPHYTA
- Nostocales
  - Nostocaceae
    - _Anabaena_ sp.

CHLOROPHYTA
- Zygnematales
  - Desmidiaceae
    - _Cosmarium_ sp.

CHRYSOPHYTA
- Diatomaceae
  - Centrales
    - Coscinodiscaceae
      - _Cyclotella kutziningiana_?
  - Pennales
    - Achnanthaceae
      - _Achnanthes minutissima_
    - Cymbellaceae
      - _Cymbella cuspidata_
      - _Cymbella_ sp.
    - Eunotiaceae
      - _Eunotia_ sp.
    - Fragilariaceae
      - _Tabellaria fenestrata_
      - _Tabellaria flocculosa_
    - Naviculaceae
      - _Navicula_ spp.
      - _Pinnularia_ spp. (2)
      - _Stauroneis_ sp.
    - Nitzschiaceae
      - _Hantzschia amphioxys_
    - Surirellaceae
      - _Surirella angusta_?

CRYPTOPHYTA
- Cryptophyceae
  - Cryptomonadaceae
    - _Cryptomonas erosa_

Table 9. Algal species composition from pond #2, periphyton collected from squeeze of *Utricularia vulgaris*.

CYANOPHYTA
- Chroococcales
  - Chroococcaceae
    - *Merismopedia glauca*
- Nostocales
  - Nostocaceae
    - *Anabaena* sp.
- Oscillatoriales
  - Oscillatoriaceae
    - *Oscillatoria* sp.

CHLOROPHYTA
- Chlorococcales
  - Oocystaceae
    - *Ankistrodesmus spiralis*
    - *Oocystis eremosphaeria*
    - *Quadrigula closteriodes*
- Oedogoniales
  - Oedogoniaceae
    - *Oedogonium* sp.
- Zygnematales
  - Desmidiaceae
    - *Closterium* sp.
    - *Cosmarium* spp. (6)
    - *Euastrum* sp.
  - Zygnemataceae
    - *Mougeotia* sp.

CRYPTOPHYTA
- Cryptophyceae
  - Cryptomonadaceae
    - *Cryptomonas ovata*

CHRYSOPHYTA
- Chrysophyceae
  - Ochromonadales
    - Dinobryaceae
      - *Dinobryon divergens*
    - Synuraceae
      - *Mallomonas* sp.
- Diatomaceae
  - Achnanthaceae
    - *Achnanthes minutissima*
  - Cymbellaceae
    - *Cymbella* sp.
  - Epithemiaceae
    - *Epithemia* sp.
  - Eunotiaceae
    - *Eunotia* sp.

Table 9 (Continued). Algal species composition from pond #2, periphyton collected from squeeze of *Utricularia vulgaris*.

CHRYSOPHYTA
- Diatomaceae
  - Pennales
    - Fragilariaceae
      - *Meridion circulare*
      - *Synedra* spp.
      - *Tabellaria fenestrata*
      - *Tabellaria flocculosa*
    - Gomphonemaceae
      - *Gomphonema truncatum*
      - *Gomphonema* sp.
    - Naviculaceae
      - *Navicula* sp.
    - Nitzschiaceae
      - *Nitzschia* spp. (2)

Table 10. Algal species composition from pond #3, periphyton collected from mosses and attached *Nostoc* balls.

CYANOPHYTA
- Chroococcales
  - Chroococcaceae
    - *Chroococcus limneticus*
- Oscillatoriales
  - Oscillatoriceae
    - *Oscillatoria hamelii*
    - *Phormidium mucicola*
- Nostocales
  - Nostocaceae
    - *Nostoc paludosum*

CHLOROPHYTA
- Chlorococcales
  - Oocystaceae
    - *Ankistrodesmus falcatus*
    - *Oocystis crassa*
    - *Oocystis eremosphaeria*
    - *Oocystis gigas*
  - Micractiniaceae
    - *Golenkinia radiata*
  - Scenedesmaceae
    - *Scenedesmus bijuga*
- Zygnematales
  - Mesotaeniaceae
    - *Netrium digitus*
  - Zygnemataceae
    - *Mougeotia* sp.
    - *Spirogyra* sp.
  - Desmidiaceae
    - *Cosmarium simplicus*
    - *Cosmarium* spp. (3)
    - *Euastrum* sp.
    - *Staurastrum* sp.

CHRYSOPHYTA
- Diatomaceae
  - Pennales
    - Cymbellaceae
      - *Cymbella cuspidata*
      - *Cymbella* sp.
    - Epithemiaceae
      - *Epithemia* sp.
    - Eunotiaceae
      - *Eunotia arcus*
    - Fragilariaceae
      - *Synedra* sp.
      - *Tabellaria fenestrata*
      - *Tabellaria flocculosa*
    - Naviculaceae
      - *Navicula* spp. (2)
      - *Pinnularia* sp.

Table 11. Algal species composition from Loon Lake, periphyton collected from squeeze of submerged mosses covered with *Nostoc* balls.

CYANOPHYTA
- Chroococcales
  - Chroococcaceae
    - *Chroococcus limneticus*
    - *Chroococcus minutus*
    - *Merismopedia punctata*
- Nostacales
  - Nostocaceae
    - *Anabaena affinis*
    - *Cylindrospermum stagnale*
    - *Nostoc paludosum*
  - Scytonemataceae
    - *Scytonema archangelii*
- Oscillatoriales
  - Oscillatoriceae
    - *Lyngbya* sp.
    - *Oscillatoria* sp.

CHLOROPHYTA
- Chlorococcales
  - Oocystaceae
    - *Oocystis eremosphaeria*
- Oedogoniales
  - Oedogoniaceae
    - *Bulbochaete* sp.
    - *Oedogonium* sp.
- Zygnematales
  - Desmidiaceae
    - *Cosmarium contractum*
    - *Cosmarium* spp. (5)
    - *Euastrum* spp. (2)
    - *Hyalotheca mucosa*
    - *Spondylosium planum*
    - *Staurastrum arctiscon* ?
    - *Staurastrum* spp. (8)
  - Zygnemataceae
    - *Mougeotia* sp.

CHRYSOPHYTA
- Diatomaceae
  - Pennales
    - Achnanthaceae
      - *Achnanthes minutissima*
      - *Achanthes* sp.
    - Cymbellaceae
      - *Cymbella* spp. (3)
    - Eunotiaceae
      - *Eunotia arcus*

Table 11 (Continued). Algal species composition from Loon Lake, periphyton collected from squeeze of submerged mosses covered with *Nostoc* balls.

CHRYSOPHYTA
- Diatomaceae
  - Pennales
    - Fragilariaceae
      - *Fragilaria crotonensis*
      - *Synedra* sp.
      - *Tabellaria fenestrata*
      - *Tabellaria flocculosa*
    - Gomphonemaceae
      - *Gomphonema* sp.
    - Naviculaceae
      - *Navicula* sp.

PYRROPHYTA
- Dinophyceae
  - Dinokontae
    - Peridiniaceae
      - *Peridinium cinctum*

Table 12. Algal species composition from periphyton growing on submerged rocks in a riffle of the Avan River.

CYANOPHYTA
- Chroococcales
  - Chroococcaceae
    - *Coelosphaerium naegelianum*
- Oscillatoriales
  - Oscillatoriceae
    - *Oscillatoria subbrevis*
    - *Oscillatoria* spp. (3)

CHLOROPHYTA
- Tetrasporales
  - Gloecystaceae
    - *Gloeocystis* sp.
- Zygnematales
  - Desmidiaceae
    - *Cosmarium* sp.
    - *Staurastrum* sp.
  - Zygnemataceae
    - *Mougeotia* sp.

CHRYSOPHYTA
- Diatomaceae
  - Centrales
    - Coscinodiscaceae
      - *Melosira* sp.
  - Pennales
    - Achnanthaceae
      - *Achnanthes minutissima*
      - *Achnanthes* sp.
    - Cymbellaceae
      - *Amphora* sp.
      - *Cymbella minuta*
      - *Cymbella* spp. (4)
    - Fragilariaceae
      - *Diatoma tenue* v. *elongatum*
      - *Hannaea arcus*
      - *Fragilaria* sp.
      - *Meridion circulare*
      - *Synedra ulna*
      - *Synedra* sp.
    - Gomphonemaceae
      - *Didymosphenia geminata*
    - Naviculaceae
      - *Navicula* spp. (2)
      - *Pinnularia* sp.
    - Nitzschiaceae
      - *Nitzschia* sp.

EUGLENOPHYTA
- Euglenales
  - Euglenaceae
    - *Lepocinclis sphagnophila*?

Table 13. Algal species composition from very small pools of standing water among "polygons" between ponds #2 and #3.

CYANOPHYTA
- Chroococcales
  - Chroococcaceae
    - _Merismopedia elegans_
- Nostocales
  - Nostocaceae
    - _Nostoc paludosum_
    - _Nostoc pruniforme_
- Oscillatoriales
  - Oscillatoriceae
    - _Oscillatoria subtillisima_
    - _Phormidium retzii_

CHLOROPHYTA
- Chlorococcales
  - Coccomyxaceae
    - _Elakatothrix gelatinosa_
  - Palmellaceae
    - _Palmella mucosa_
- Oedogoniales
  - Oedogoniaceae
    - _Bulbochaete_ sp.
    - _Oedogonium_ sp.
  - Tetrasporales
    - Gloecystaceae
      - _Gloeocystis vesiculosa_
  - Zygnematales
    - Desmidiaceae
      - _Cosmarium_ spp. (3)
      - _Euastrum_ sp.
      - _Pleurotaenium minutum_
      - _Staurastrum_ sp.

CHRYSOPHYTA
- Diatomaceae
  - Pennales
    - Achnanthaceae
      - _Achnanthes minutissima_
    - Cymbellaceae
      - _Cymbella_ sp.
    - Eunotiaceae
      - _Eunotia_ sp.
    - Fragilariaceae
      - _Synedra_ sp.
      - _Tabellaria fenestrata_
      - _Tabellaria flocculosa_
    - Gomphonemaceae
      - _Gomphonema_ sp.
    - Naviculaceae
      - _Caloneis_ sp.
      - _Navicula_ sp.
      - _Pinnularia_ sp.

Table 13 (Continued). Algal species composition from very small pools of standing water among "polygons" between ponds #2 and #3.

CHRYSOPHYTA
- Chrysophyceae
  - Ochromonadales
    - Dinobryaceae
      - *Dinobryon sertularia*
- Xanthophyceae
  - Mischococcales
    - Characiopsidaceae
      - *Characiopsis cylindricum*

PYRROPHYTA
- Dinophyceae
  - Dinokontae
    - Glenodiniaceae
      - *Glenodinium Kulczynskii*
    - Peridiniaceae
      - *Peridinium cinctum*

covered with extensive growths of Nostoc paludosum, Nostoc pruniforme, and species of Anabaena. These heterocystic taxa have the ability to fix atmospheric nitrogen which may be an important source of biogenic nitrogen to the aquatic system. Terrestrial nitrogen-fixing blue-green algae have been shown to be an important component in the nitrogen cycle of interior Alaskan terrestrial systems (Billington, 1983) and on the north slope region of Alaska (Alexander et al., 1978).

Phytoplankton grab samples were collected from each pond and Loon Lake. Only one small (125 ml) sample was taken from near the shore just under the water surface. The phytoplankton samples were counted at between 25 and 30 times the original concentration to increase cell sightings. In all cases, very few phytoplankters were encountered. Results of cell counts were: 8 cells/ml from pond #1, 22 cells/ml from pond #2, 16 cells/ml from pond #3, and 27 cells/ml from Loon Lake. These counts, although not intended to be comprehensive of the entire sampling area within each water body, indicate that during the late fall when the samples were taken the phytoplankton population appeared to be very sparse. The few cells seen in the phytoplankton were all very small nannoplankton, which are often indicative of lentic systems with low nutrient concentrations as have been seen in the chemical constituents of the ponds and the lake. With such a small sampling size and cell concentration, a listing is not appropriate unless many more sightings are incorporated into a phytoplankton flora; however, all the taxa seen in the plankton showed up in the periphyton samples. Further investigation by more detailed sampling could show that the phytoplankton biomass of the ponds and lake may be insignificant when compared to the periphyton and macrophyte community. This survey is by no means a comprehensive sampling of the plankton of each body of water. A more extensive effort is required to fully collect from different areas of each body of water as well as from varying depths. A raft or small boat would be required along with an appropriate water sampler such as a Van Dorn or Kemmerer sampler.

These listings represent a minimal number of samples from a small and restricted region of the Noatak basin. Many of the algal taxa such as the diatoms are very small (less than 10 micrometers in longest dimension) and difficult to identify with a light microscope (see Table 14). If the opportunity exists to photograph these small taxa with a scanning electron microscope (SEM), many of the unidentified diatoms can be identified to species by Hilgert. This should be a priority if more extensive taxonomic lists are to be generated in the future. Many of the desmids can be identified to species with the SEM also; however, most desmids were seen in these samples in small numbers, often only one cell per sample. Members of the Zygnemataceae such as Mougeotia and Spirogyra must be in the process of producing zygospores in order to be identified to species. Often these filamentous green algae can be induced to sporulate by returning live samples to the laboratory and placing them in stressed cultures. Any future sampling should attempt to more fully characterize the plankton community and return live samples for culture. Specimens from the initial trip, however, could be examined with the SEM to enhance the floral list.

An alphabetical list of the algal flora (Table 15) has been prepared to show the species identified as well as the number of unidentified species within each genus. The number of times each taxa was seen in the seven algal samples is shown as "occ." Diatoms and desmids occurred most commonly. Most notable were the diatom taxa Achnanthes minutissima, Cymbella, Eunotia, Navicula, Pinnularia, Synedra, Tabellaria fenestrata and Tabellaria flocculosa and the desmid genera Cosmarium, Euastrum, and Staurastrum. Many desmids occur in the areas of low acidity such as Sphagnum bogs. The presence of Sphagnum surrounding most of these collection sites may be correlated with the acidity of the habitats. The pHs of the ponds sampled were not inordinately low. Monitoring of algal communities in several habitats may be useful as a tool in the assessment of long-term acid deposition.

Table 14. Tabulation of number of algal taxa by species and genera identified, and number of taxa unidentified at this time.

TAXA	GENERA IDENTIFIED	SPECIES IDENTIFIED	SPECIES UNIDENTIFIED
Cyanophyta	10	16	5
Chlorophyta (Desmids only)	8	8	28
Chlorophyta (excluding desmids)	12	11	7
Chlorophyta (All taxa including desmids)	20	19	35
Chrysophyta (Diatoms only)	20	15	29
Chrysophyta (excluding diatoms)	3	3	2
Chrysophyta (All taxa)	23	18	31
Cryptophyta	1	2	0
Pyrrophyta	2	2	0
Euglenophyta	1	1	0
TOTAL	59	59	77

Table 15. Alphabetical listing of algal taxa showing species which were identified and indicating the number of identified species (spp.) in each genus and the number of occurrences of that species or genus (occ.) if it occurred in more than one sample.

Achnanthes minutissima (6 occ.)
Amphora sp. (2 occ.)
Anabaena sp.
Ankistrodesmus spiralis
Caloneis sp.
Chroococcus limneticus (2 occ.)
Closterium kuetzingii
Coelosphaerium naegelianum
Cosmarium simplicus
Cryptomonas erosa
Cyclotella kutzingiana?
Cymbella cuspidata (3 occ.)
Cymbella spp. (6 spp., 5 occ.)
Didymosphenia geminata
Dinobryon sertularia
Epithemia spp. (2 spp., 2 occ.)
Eunotia arcus (2 occ.)
Fragilaria crotonesis
Glenodinium Kulczynskii
Gloecystis sp.
Gomphonema truncatum
Hannaea arcus
Hyalotheca mucosa
Lyngbya sp.
Melosira sp.
Merismopedia elegans
Merismopedia punctata
Navicula spp. (2 spp. 5 occ.)
Nitzschia spp. (2 spp., 3 occ.)
Nostoc pruniforme
Oocystis crassa
Oocystis gigas
Oscillatoria subbrevis
Oscillatoria spp. (3 spp., 3 occ.)
Peridinium cinctum (2 occ.)
Phormidium mucicola
Pinnularia spp. (3 spp., 5 occ.)
Quadrigula closteriodes
Scenedesmus bijuga
Spirogyra sp.
Staurastrum artiscon
Stauroneis sp.
Synedra ulna
Tabellaria fenestrata (6 occ.)
Achnanthes sp. (2 occ.)
Anabaena affinis
Ankistrodesmus falcatus
Bulbochaete sp.
Characiopsis cylindricum
Chroococcus minitus
Closterium (3 spp., 2 occ.)
Cosmarium contractum
Cosmarium spp. (12 spp. 6 occ.)
Cryptomonas ovata
Cylindrosperum stagnale
Cymbella minuta
Diatoma tenue v. elongatum
Dinobryon divergens
Elakatothrix gelatinosa
Euastrum spp. (3 spp., 4 occ.)
Eunotia spp. (3 spp., 4 occ.)
Fragilaria sp. (2 occ.)
Gloecystis vesiculosa
Golenkinia radiata
Gomophonema spp. (2 spp,3 occ)
Hantzschia amphioxys
Lepocinclis sphagnophila?
Mallomonas spp. (2spp., 2 occ.)
Meridion circulare (2 occ.)
Merismopedia glauca
Mougeotia spp. (2 spp., 2 occ.)
Netrium digitus
Nostoc paludosum (3 occ.)
Oedogonium sp. (2 spp., 3 occ.)
Oocystis eremosphaeria (3 occ.)
Oscillatoria hamelii
Oscillatoria subtillisima
Palmella mucosa
Phormidium mucicola
Phormidium retzii
Pleurotaenium minutum
Scenedesmus bijuga
Scytonema archangelii
Spondylosium planum
Staurastrum spp. (10 spp. 5 occ.)
Surirella angusta?
Syendra spp. (3 spp.,5 occ)
Tabellaria flocculosa (6 occ.)

The selection of an appropriate basin, or series, should encompass a creek-to-river system or stream continuum, as well as a series of small shallow ponds progressively grading up to larger and deeper lakes. The habitat diversity and varying physical, chemical, and hydrologic characteristics in such a scheme will aid in the interpretation of long-term effects as well as providing a wider scope of communities from which to choose for long-term monitoring studies.

TRACE ELEMENT AND NUTRIENT ANALYSES

To meet the first and second objectives of this project, vegetation, soil and water samples were collected and analyzed for trace element content. The following section describes the techniques and results of this sampling. The results from soil samples are not available.

Vegetation

Sampling Methodology and Analysis

Seventy samples were collected for trace element analysis. Because of limited resources, the relatively restricted amount of time we had in the field, and the logistical problems, including lack of access to power, sampling for trace element analysis was restricted to those environmental media which have shown potential for accumulating trace elements from atmospheric sources in particular--mosses and lichens--however, soil and water samples were also collected.

Our initial plan was to establish an integrated sampling site near the Kelly Bar Ranger Station and a site near Motpik in the upper tundra country. However, weather and flying conditions precluded the latter. Therefore, two sites were chosen in the vicinity of the Kelly Bar area, primarily between the confluence of the Noatak and Kelly Rivers (see Figure 3).

The Kelly Bar site, located on a south facing slope, represented a mature white spruce forest (see Terrestrial and Aquatic Site Establishment Section and Figure 3). The Loon Lake site represented a more open white spruce forest and was located near an unnamed lake, which for the purpose of this study has been called Loon Lake. Sampling was coordinated with the vegetation site established by the Oregon State University team. Two genera each of mosses, *Hylocomium* and *Alacomnium*, and lichens, *Cladonia* and *Cladina*, were collected. *Hylocomium* and soil samples were collected from both sites. Table 16 summarizes the samples.

Table 16. Summary of samples collected at Noatak National Preserve.

	(Site A) Kelly Bar	(Site B) Loon Lake
Hylocomium splendens	10	10
Alacomnium spp.		10
Cladina spp.		10
Cladonia spp.	10	
Soil	10	10
TOTAL	30	40

In order to minimize disruption of the 25 m x 25 m permanent vegetation sample plot, the sampling points for the pollutant monitoring were placed in 5 x 2 m grids, approximately 25 m apart, adjacent to the permanent 25 x 25 m plot. At each sampling point, 10 subsamples were collected of each moss or lichen species and of soil. Subsamples were chosen equally from around the circumference of a circle approximately 10 m in diameter. Ten subsamples were then combined into one sample for that point. Ten samples of moss, lichens, and soil were collected for the Kelly Bar and Loon Lake sites.

Clean bags were used to contain all samples. Bags were not opened until sampling was begun in the field. A new pair of disposable plastic gloves was used each time a sample was collected. About five grams of moss, wet weight, were picked from each of the subsampling points and combined into one clean bag for a total sample size of about 50-75 g. Slightly smaller amounts of lichens were collected because of the lower abundance of these species. Soil samples were collected by digging a shallow pit approximately 15 cm deep and then collecting the top 5 cm of soil. Samples included the highly decomposed organic material when present. A trowel was used and was cleaned with laboratory towels between each sampling point. Soil samples were placed in clean bags. The bags were sealed and returned as soon as possible to the laboratory.

The vegetation samples were kept under cold conditions and reached the laboratory within two weeks after sampling in the field. In the laboratory, samples were dried for approximately 24 hours at about 50 C. The dried samples were then powdered in a Spex mill and an aliquot of the powdered sample was sent to the Laboratory of Biomedical and Environmental Sciences, Department of Energy, at University of California Los Angeles (UCLA) for trace element analysis using spark source emission spectroscopy. The elements that can be detected and the detection limits for the technique are shown in Table 17.

Table 17. Precision limits for spark source emission spectroscopy.

Elements	Maximum allowable percent deviation from a known value
K, Ca, Mg, Cu, Mn, B, Sr, Ba, Al	20%
P, Na, Zn, Fe, Cr, Ag,	40%
Ti, V, Li, Pb	50%

Element	ppm	Element	ppm	Element	ppm
P	50.0	B	1.0	Sr	0.2
Na	1.0	Al	1.0	Ba	0.2
K	150.0	Si	1.0	Li	0.3
Ca	1.0	Ti	0.5	Ag	0.1
Mg	50.0	V	1.0	Sn	0.3
Zn	5.0	Co	1.5	Pb	1.0
Cu	0.2	Ni	0.5	Be	0.2
Fe	0.6	Mo	0.2	Cd	3.0
Mn	0.1	Cr	0.2	As	1.0

Results and Discussion

Along with the samples collected, we submitted 24 National Bureau of Standards (NBS) pine needle standards. These standards provided a quality control check on some of the elements analyzed. Not all of the elements analyzed by spark source emission spectroscopy are certified in pine needle standards. The results of quality control samples are shown in Figures 16-18 for the elements phosphorus, potassium, calcium, copper, iron, manganese, aluminum, cobalt, nickel, chromium, strontium, lead, cadmium, and arsenic. Prior to submitting samples, we established the percent variation from the known mean for each element which we would accept. We have plotted the acceptable variation around the reported mean value from analytical procedures. Also plotted are the actual certified NBS values.

For most elements, our acceptable spread includes the certified NBS value. The NBS values for calcium and potassium are slightly below the lower acceptable limits but we have reported them here anyway, bearing in mind that the reported values for these two elements may be higher than they really are under field conditions. The value for cadmium falls outside the accepted limit. The cadmium values probably should be viewed with caution. Levels for each element analyzed for each species are shown in Table 18.

The coefficient of variation is plotted for Hylocomium for each element on each site (Figures 19 and 20). This variation reflects the combination of sample and instrument variation. We established a desirable maximum limit for the coefficient of variation of 75%. Most of the samples fell below 75%, except for phosphorus, lead, tin, and beryllium. The mean values for tin and beryllium for Hylocomium were below the detection limit; therefore, these high coefficients of variation reflect data containing mostly zeros with relatively few numbers of detection. The mean lead values exceeded the limits of detection. The high variability probably reflects a majority of values near the limits of detection.

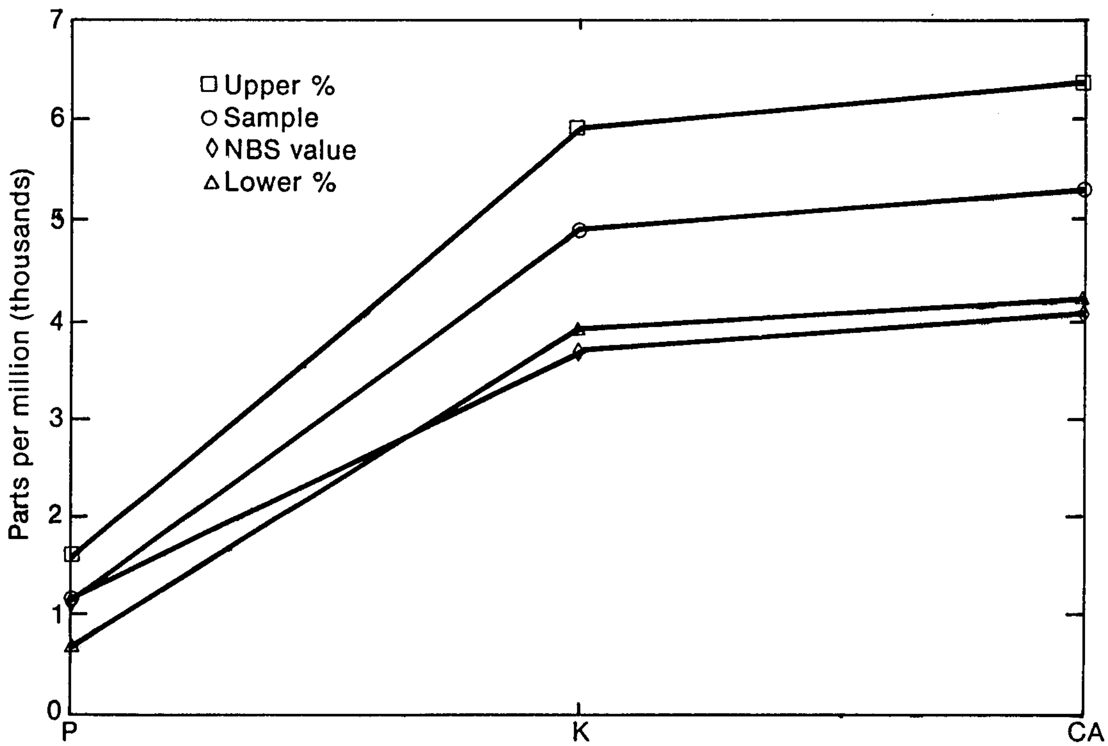


Figure 16. Comparison of quality assurance data for NBS pine needles for Noatak National Preserve, September 1985.

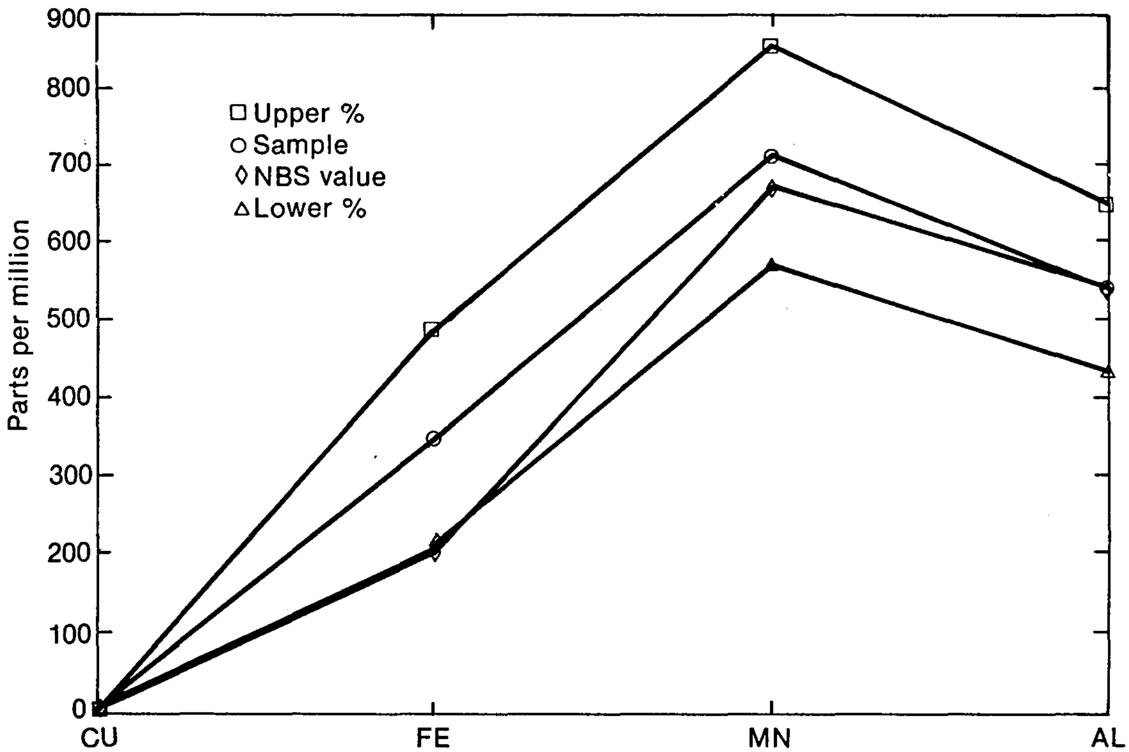


Figure 17. Comparison of quality assurance data for NBS pine needles for Noatak National Preserve, September 1985.

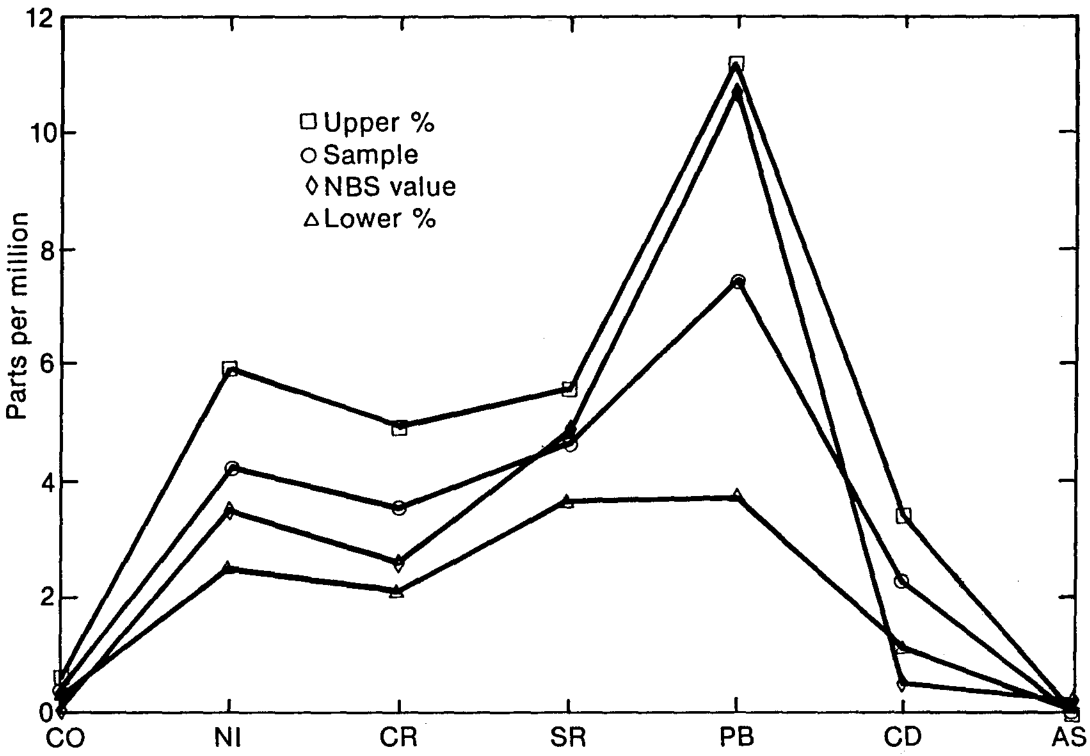


Figure 18. Comparison of quality assurance data for NBS pine needles for Noatak National Preserve, September 1985.

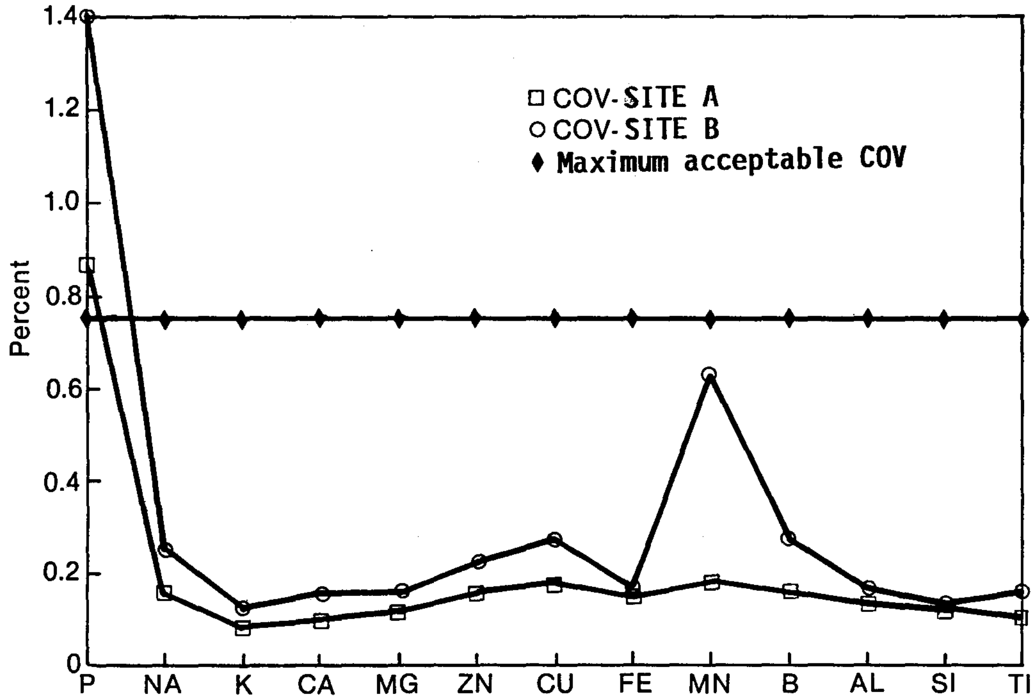


Figure 19. Comparison of coefficient of variation for Hylocomium splendens, Kelly Bar and Loon Lake sites.

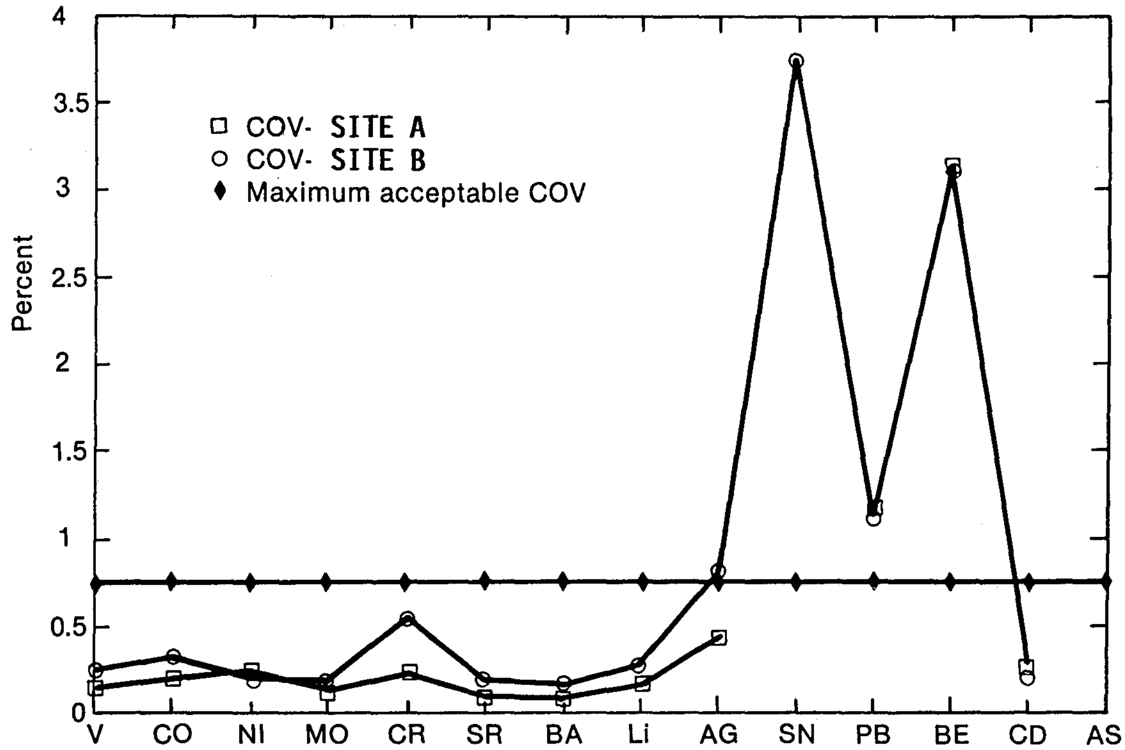


Figure 20. Comparison of coefficient of variation for _Hylocomium splendens_, Kelley Bar and Loon Lakes sites.

Table 18. Summary of trace element values in moss and lichens for Noatak National Preserve (ppm, each value represents the arithmetic mean for 10 different samples, each analyzed 3 times).

	Moss			Lichen	
	Hylocomium splendens		Alacomnium	Cladonia	Cladina
Element	Kelly Bar	Loon Lake	Loon Lake	Loon Lake	Kelly Bar
P	2600	500	790	56	780
Na	2100	980	760	340	2400
K	9600	6700	5800	2800	6600
Ca	11200	9500	12600	4000	17500
Mg	4000	2700	2700	980	3000
Zn	65	58	43	18	46
Cu	15	9	6.5	4	14
Fe	4900	3600	3000	2000	3900
Mn	530	500	250	120	360
B	17	20	17	3.5	6.6
Al	4300	2600	2300	1100	4000
Si	29000	23500	19200	127000	29700
Ti	760	440	400	160	580
V	17	12	9.7	2.3	15
Co	<1.5	1.8	<1.5	<1.5	2.2
Ni	9	6.6	7.1	9.1	21
Mo	11	9.9	7.8	3.6	9.2
Cr	20	14	12	5.4	35
Sr	23	25	38	6.8	20
Ba	200	140	150	49	120
Li	7.6	1.4	2.2	2.1	13
Ag	<0.1	<0.1	<0.1	<0.1	<0.1
Sn	<0.3	<0.3	<0.3	<0.3	<0.3
Pb	6.8	1.9	2.8	1.6	1.7
Be	<0.2	<0.2	<0.2	<0.2	<0.2

As stated earlier, our objectives were to sample vegetation which had the potential of receiving and reflecting atmospheric concentrations of particulates. Mosses and lichens have been identified in the literature as such "indicator organisms" (Ruhling and Tyler, 1970). The elemental concentrations in Hylocomium splendens, collected at Kelly Bar and Loon Lake sites, are plotted in Figures 21 and 22. The values are quite comparable.

The comparison between Hylocomium samples averaged for the Kelly Bar and Loon Lake Sites and Alacomnium samples from Loon Lake only are presented in Figures 23 and 24. The element levels track quite well

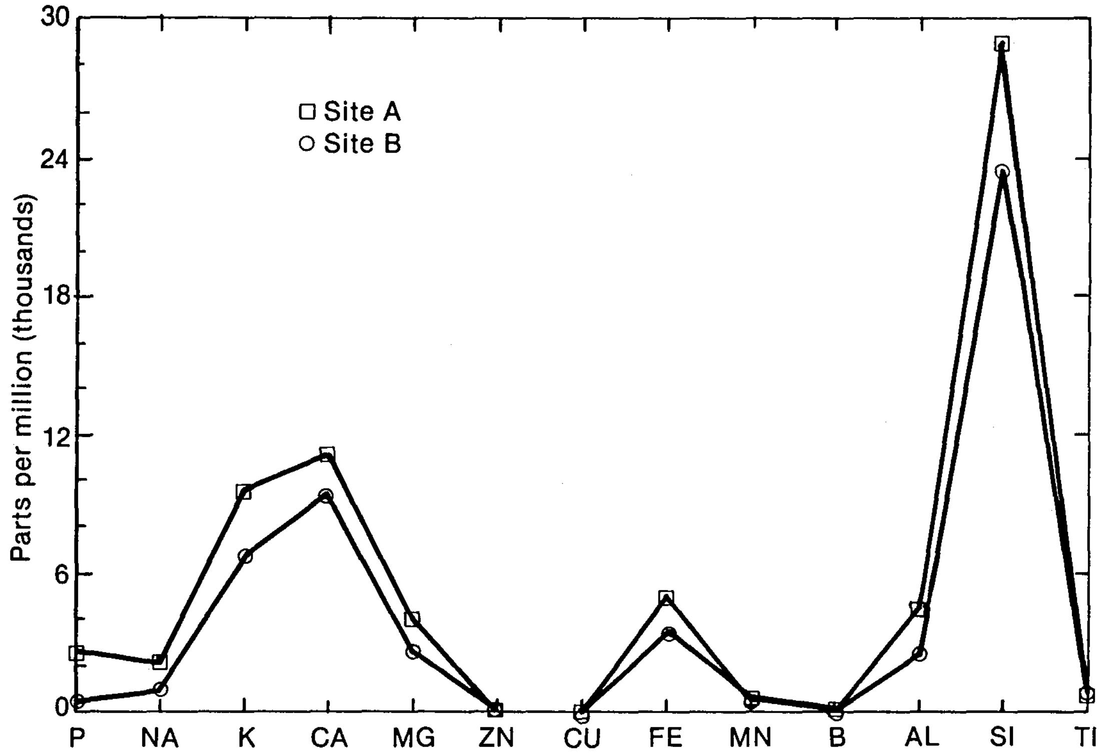


Figure 21. Comparison of elemental levels in Hylocomium splendens, Kelly Bar and Loon Lake sites.

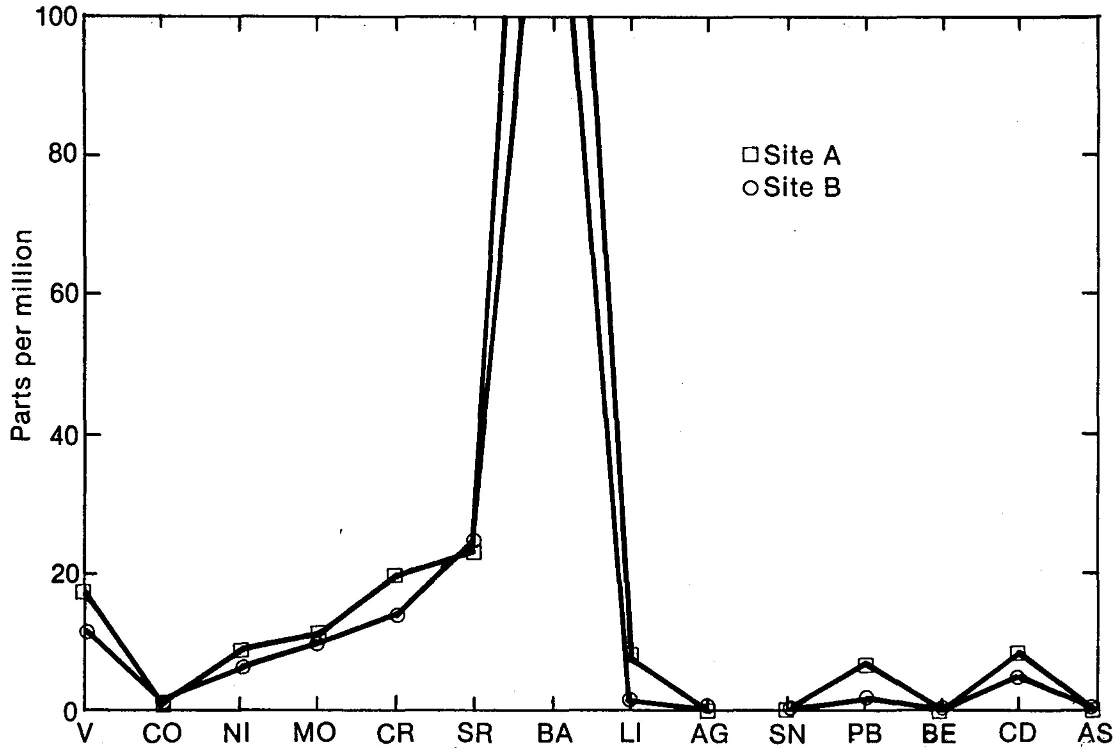


Figure 22. Comparison of elemental levels in Hylocomium splendens, Kelly Bar and Loon Lake sites.

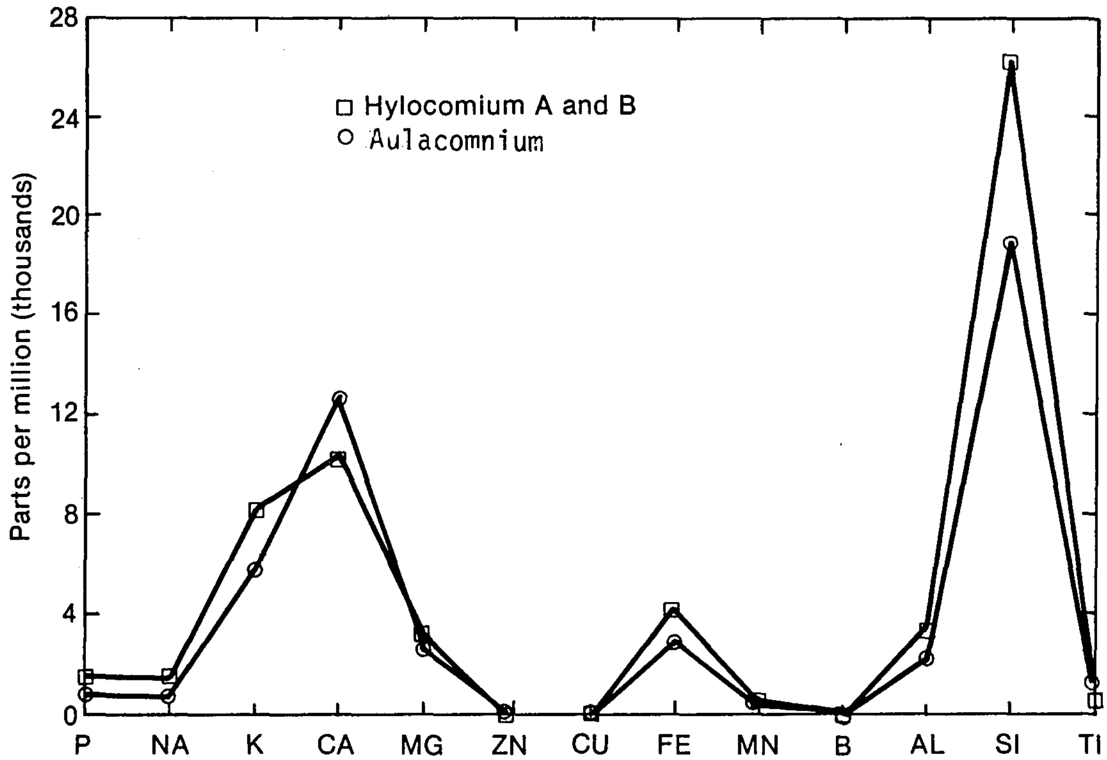


Figure 23. Comparison of elemental levels, Hylocomium and Aulacomnium, Noatak National Preserve.

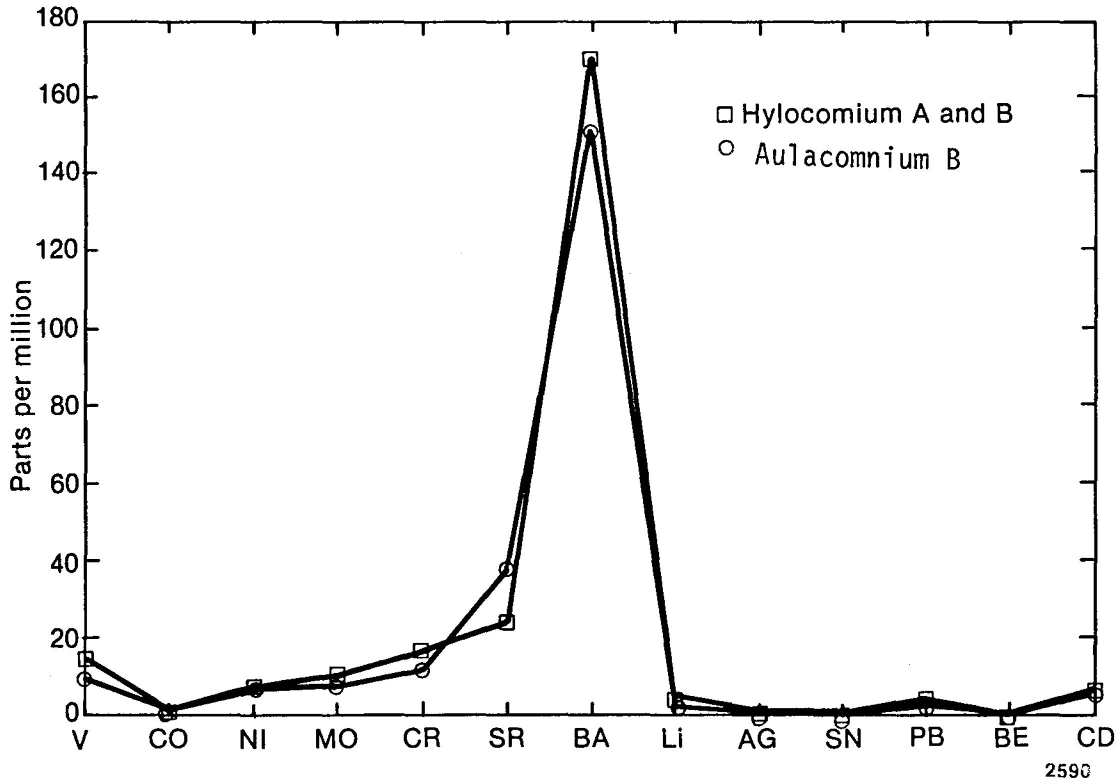


Figure 24. Comparison of elemental levels in Hylocomium and Aulacomnium, Noatak National Preserve.

indicating that the two moss species seem to reflect similar patterns. Figures 25 and 26 compare the two genera of lichens, Cladina and Cladonia, with the Hylocomium splendens samples. The agreement is not as close among these three taxa as it is for the comparison between Aulacomnium and Hylocomium at the Kelly Bar site. Also note that values for the two species of lichen tend to differ more than for the two species of moss.

The premise we started with was that many of these species of lower plants had the potential for absorbing elements from the atmosphere. One way to estimate whether the elements in question in the plant material came from the crustal material or from the atmosphere is by calculating enrichment factors (EF) (Zoller et al., 1974; Wiersma and Davidson, 1986). In this case, we compared the ratio of the element in question, C_x, in the medium (moss or lichen) and the reference element, aluminum, in our study (C_{al}), with the same ratio in an average crustal sample as reported in a geochemical table such as Taylor (1964). The sample formula is as follows:

$$EF = \frac{C_x / C_{al}}{C_{x[crust]}/C_{al[crust]}}$$

As a rule of thumb, if the enrichment factor is greater than 10, the element is considered to be enriched in the medium with reference to the crustal material for the same element (Alkezweeney et al., 1982). This suggests that the element is present in higher concentrations in the medium than it would normally have been if it had received that element from resuspended material from the earth's crust. This, of course, is complicated by the fact that in living material, certain plants have abilities to concentrate elements that are essential to plant life, such as phosphorus and potassium.

We calculated the enrichment factors for all of the elements of the study for Cladina, Cladonia and Hylocomium (Figures 27 and 28). In general, most of the elements were not enriched in any of the species collected at Noatak. There was some variation in the enrichment factor values for

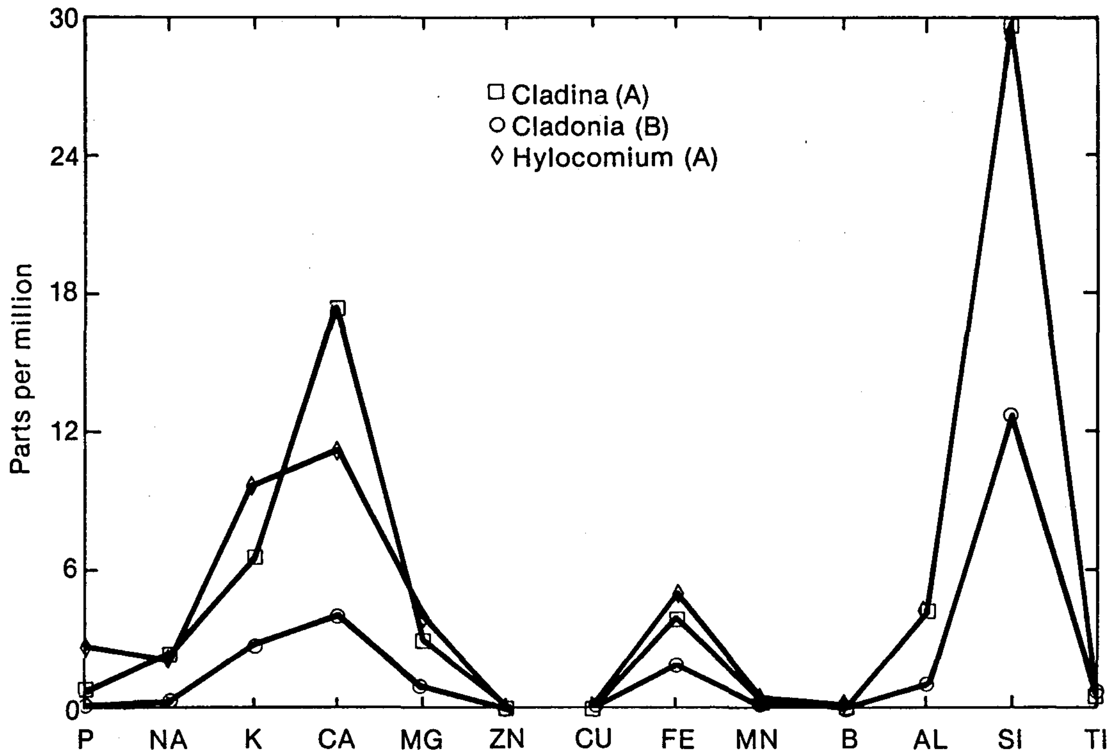


Figure 25. Comparison of Cladina, Cladonia and Hylocomium elemental levels from the Noatak National Preserve.

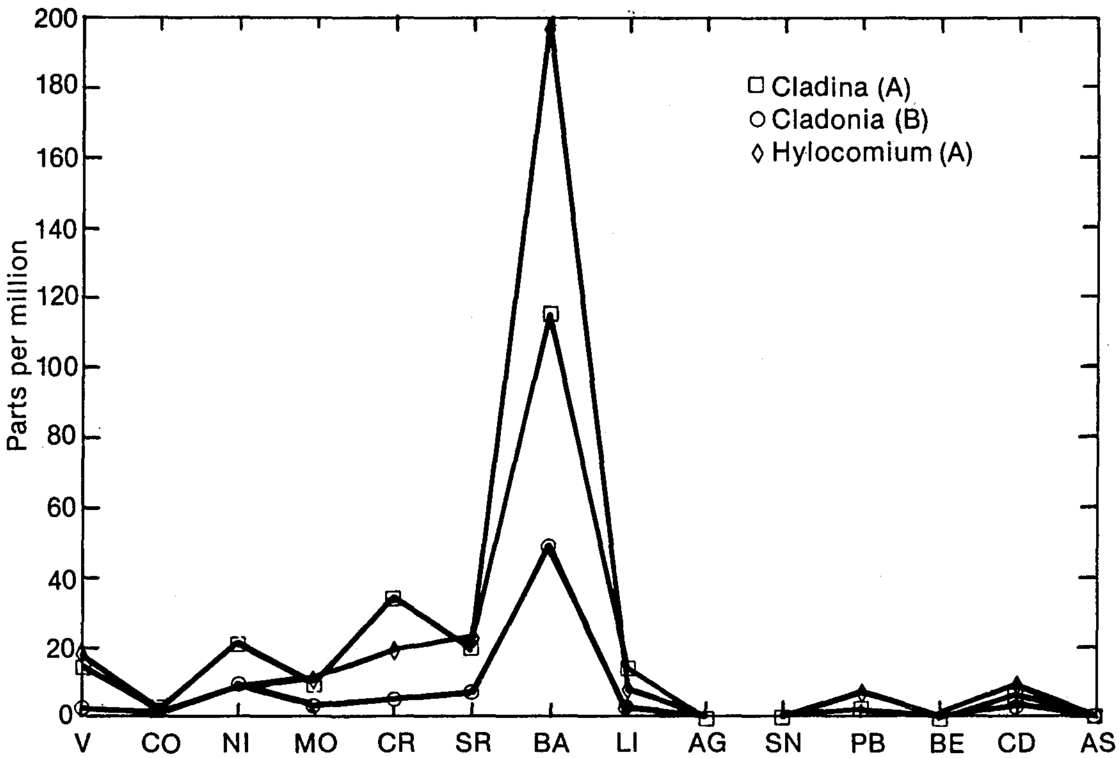


Figure 26. Comparison of Cladina, Cladonia, and Hylocomium elemental levels from the Noatak National Preserve.

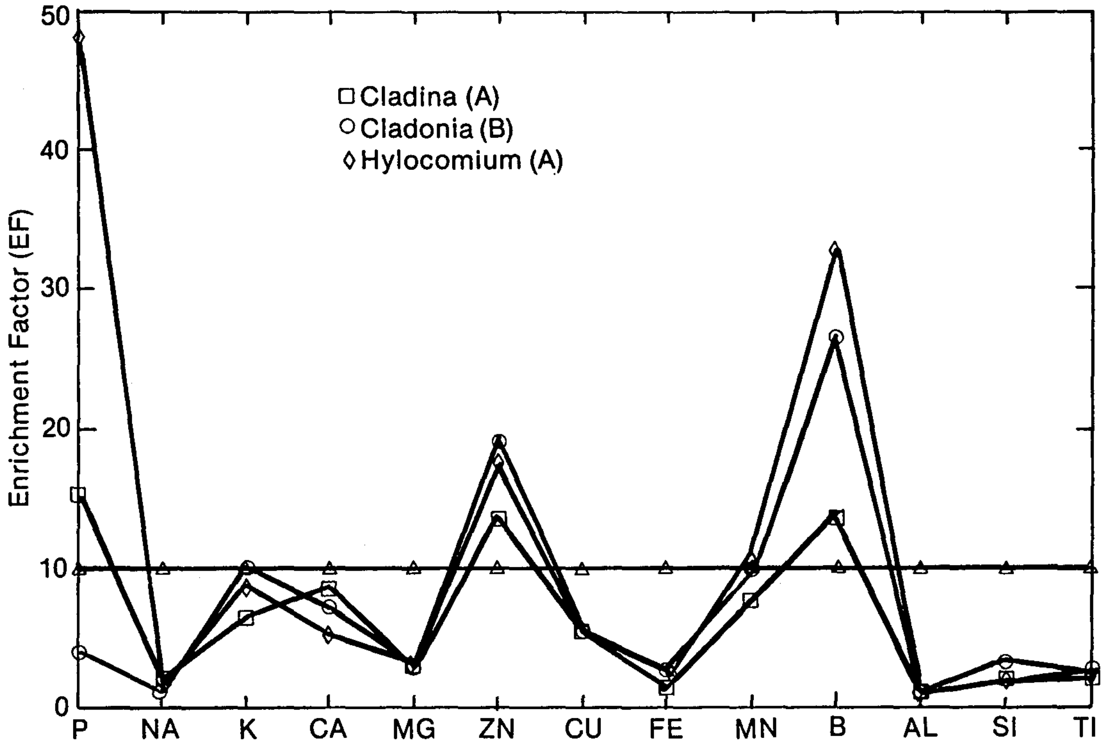


Figure 27. Comparison of Cladina, Cladonia and Hylocomium enrichment factors from the Noatak National Preserve.

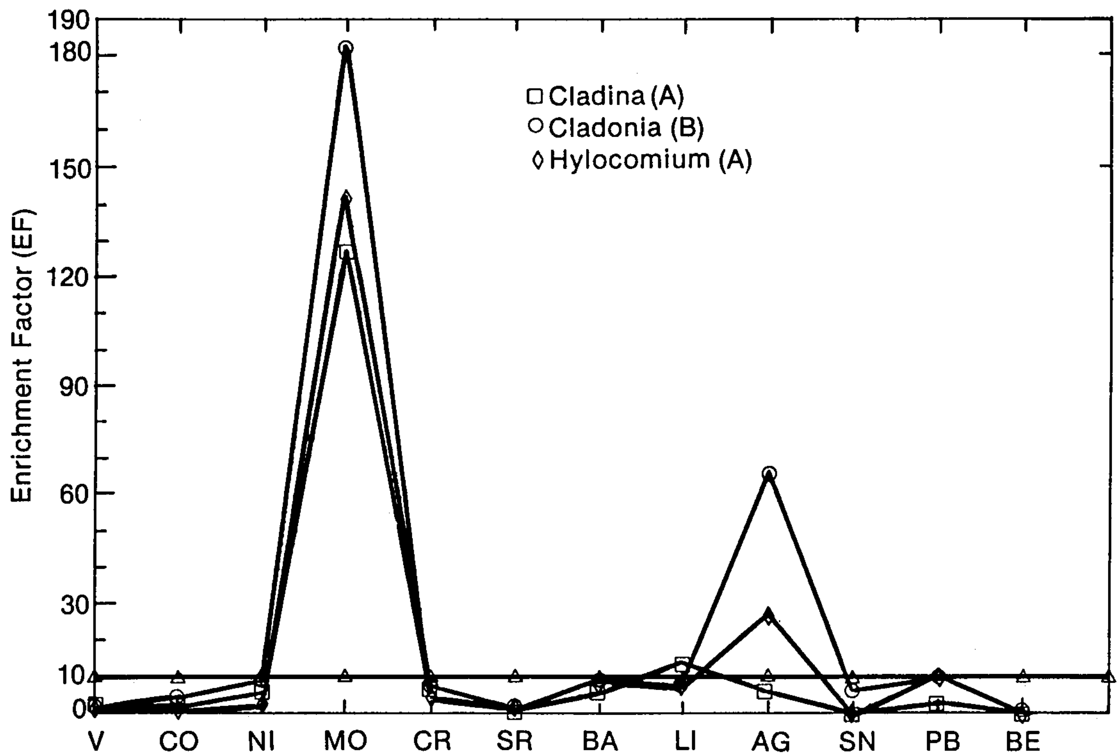


Figure 28. Comparison of Cladina, Cladonia and Hylocomium enrichment factors in the Noatak National Preserve.

phosphorus, an essential plant element. The only elements that were consistently enriched were zinc, boron and molybdenum[1]. Another advantage of the enrichment factor is that it tends to normalize the data somewhat by factoring out samples that would tend to have higher amounts of soil associated with the sample material, i.e., high levels of aluminum. Again, with the exception of phosphorus, enrichment factors for the elements measured in this study appear to track quite well together.

Noatak National Preserve was chosen for integrated global background monitoring because we felt that it represented a location in the world in which very low levels of pollution were likely to occur. In this respect, we hypothesized that it would be similar to two other sites currently in operation, one at Olympic National Park, Washington, USA, which primarily receives westerly winds from the north Pacific, and the second at Torres del Paine National Park in southern Chile, which receives most of its westerly winds from the south Pacific. Moss and lichen samples were collected at all three locations. The moss genus from Noatak and Olympic was Hylocomium. The moss taxa from Chile at this time still remain unidentified, but have growth-forms similar to Aulacomnium.

Examples of elements that are normally enriched over crustal values in the atmosphere are copper, zinc, lead, and cadmium. This may be related to the elemental boiling points of these elements with the more volatile compounds more highly enriched in the atmosphere (Zoller et al., 1974). Since mosses can receive a significant elemental input from the atmosphere, we compared the concentrations of lead, zinc, and copper at four sites and their enrichment factors to see if these elements were enriched in mosses relative to crustal material as they are in the atmosphere (Table 19).

The Wind River site is located in the Bridger Wilderness in the Bridger-Teton National Forest in southwestern Wyoming. It is within 100 km of major energy development located in the southwestern corner of

---

1 Silver enrichment values should be ignored because the mean concentrations of silver were below detection limits.

Wyoming between Soda Springs, Idaho and Rock Springs, Wyoming. The estimated emissions of sulfur dioxide from this area for 1987, for example, are 135,000 tons/yr and the nitrogen oxide emissions are approximately

Table 19. Comparison of lead, copper and zinc concentrations for four sites.

	Lead (ppm)	Copper (ppm)	Zinc (ppm)
Wind River (high elevation site)	139.0	56.0	99.6
Noatak	6.8	14.7	64.9
Torres del Paine	5.4	4.3	50.2
Olympic	13.7	10.6	28.7

108,000 tons/yr. Trace element levels are proportionally enriched in many of these sources. These are significant sources of pollutants. The other three sites, Noatak, Torres del Paine, and Olympic, have no significant pollutant sources upwind. The elemental levels for lead, copper and zinc are quite similar for the three sites. There are striking differences, however, between the lead levels for these three sites and the Wind River site. The average lead level for the three remote sites is 8.6 ppm, whereas the average lead level for the site in the Wind River (high elevation site) is 139 ppm. The average copper value for the three global sites was approximately 10 ppm, whereas it was 56 ppm for Wind River. For zinc, the differences were substantial, although not quite as large. The average zinc concentration for the high elevation site in the Wind River was almost 100 ppm and the average concentration for Noatak, Torres del Paine, and Olympic was 48 ppm. This indicates that 1) for trace elements in mosses, the three remote sites are relatively similar, although they are separated by thousands of miles and 2) that the three sites have the potential for representing background conditions for certain trace elements (Table 20).

Although the levels for copper and zinc were higher in Wind River than in the three background sites, the actual enrichment factors for the former are equal to or lower than for the latter. This indicates, perhaps that we have a higher soil component inherent in our samples from the Wind River. This is possible, since the moss was a different growth-form and was found growing on rock surfaces. The enrichment factor for lead is still quite high in the Wind River site and relatively low in the Noatak, Torres del Paine and Olympic National Park sites.

Table 20. Enrichment factors for lead, zinc, and copper in moss. (parts per million)

	Lead	Copper	Zinc
Wind River (high elevation site)	64.7	5.9	8.3
Noatak	10.4	5.1	17.8
Torres del Paine	20.3	3.7	33.8
Olympic	28.0	5.5	10.5

Water Chemistry and Physical Characteristics

Methods

Ambient air and water temperatures were measured with calibrated thermometers at each site at the time of water quality and algal sampling. Samples for turbidity, pH, alkalinity, and specific conductance were collected in 500 ml Nalgene wide-mouthed bottles pre-washed with distilled water. Samples were kept in a closed cooler in the dark and transported to the Institute of Northern Forestry, Fairbanks,for measurement in the water quality laboratory. Turbidity was measured in Nephelometric Turbidity Units (NTU) with a Hach model 2100 Hephelometer and in Formazine Turbidity Units (FTU) with a Hellige Turbidimeter. pH was measured with a calibrated Digi-Sense pH meter, alkalinity was determined by titration (Hach Chemical Co.) to a pH end point of 5.1 with the Digi-Sense pH meter, and specific conductance was measured with a calibrated Beckman Solubridge meter.

Each site was sampled for chemical constituents using an acid-washed 500 ml Nalgene bottle. Bottles were placed in a cooler and transported as above. Upon arrival at the water quality laboratory, each sample was filtered through a Gelman Micro-Quartz glass fiber filter (0.45 um) which had been pre-rinsed with 250 ml of distilled water. Samples for dissolved Ca, Fe, Na, Si, K, Mg, Mn, and As were acidified to a pH of 2 with nitric acid and stored in the dark at 5 C until analyzed with atomic absorption spectrophotometry (American Public Health Association, 1985). Samples for dissolved Kjeldahl ("total") nitrogen, "available" nitrogen, nitrate, "available" phosphorus, and "total" phosphorus were filtered as above, stored, frozen, and analyzed with a Technicon Auto-Analyzer (American Public Health Association, 1985).

Results and Discussion

Physical characteristics of water samples are shown in Table 21. Water temperatures were lowest in river and seep samples (2-4 C) and highest in ponds and Loon Lake. Pond #3 had lower water temperatures than the other lentic sites, possibly because it appears to be shallower and smaller than ponds #1 and #2. Only temperatures and algal samples were taken at pond #3, no chemical samples were obtained. Specific conductance was highest in the lotic samples (158-196 umhos/cm), while the values for lentic samples ranged from 61-83 umhos/cm. (Solute concentrations, particularly Ca, Na, and Mg, were higher in the rivers, which can contribute towards higher specific conductance). Turbidity was measured using two methods. The nephelometric method measures turbidity as a function of light scattering at a 90 angle to the light source, expressed as NTU's. The Hellige turbidimeter measures turbidity as a function of direct line light transmittance. Both methods yielded comparable values. In terms of algal productivity, however, the Hellige method may be more useful as an indication of how much light penetrates the water column for use by algae and aquatic macrophytes. All sites had relatively clear water (although slightly colored brown in the ponds) except for the Noatak River which had turbidity levels of 24 and 25 FTU's and NTU's, respectively.

Table 21. Physical characteristics of water samples, Noatak National Preserve, 1985.

Site	Date	Air Temperature (degrees C)	Water Temperature (degrees C)	Specific Conductance (umhos/cm)	Turbidity (FTU)	(NTU)
Seep, Pond #1	9-10-85	2	2	83	0.52	0.46
Pond #1	9-10-85	2	8	65	0.70	0.67
Pond #2	9-10-85	3	8	61	0.88	0.68
Pond #3	9-10-85	4	4	---	---	---
Loon Lake	9-10-85	4	7	75	0.66	0.33
Avan River	9-11-85	2	3.5	158	0.52	0.20
Kelly River	9-11-85	12	2	172	0.46	0.27
Noatak River	9-13-85	2	4	196	24	25

pH and alkalinity concentrations are listed in Table 22. Similar pH values which characterized the ponds (6.71-6.77) were lower than Loon Lake value (7.03). The rivers appeared similar, with a range of 7.43 to 7.52. Concentrations of alkalinity were lowest in the ponds (22-28 mg/l, expressed as bicarbonate alkalinity), and slightly higher in Loon Lake (34 mg/l). The river samples were generally higher, with the Kelly River highest at 78 mg/l and the Noatak River lowest at 63 mg/l.

Table 22. pH and alkalinity of water samples, Noatak National Preserve, 1985.

Site	pH	Alkalinity (mg/liter)
Seep, Pond #1	6.71	22
Pond #1	6.75	28
Pond #2	6.77	24
Loon Lake	7.03	34
Avan River	7.43	73
Kelly River	7.49	78
Noatak River	7.52	63

Concentrations of dissolved nitrogen and phosphorus compounds are listed in Table 23. Loon Lake had the lowest concentrations of nitrogen compounds of the lentic sites sampled. Total phosphorus was highest in Loon Lake, however. The seep into pond #1 had higher "available" nitrogen and "total" phosphorus concentrations than the pond itself, possibly indicating nutrient uptake of these compounds into the extensive aquatic macrophyte and periphyton communities within the pond. The Avan River had a higher concentration of "total" nitrogen than either the Kelly or the Noatak Rivers. The Noatak River had higher concentrations of "available" nitrogen than the Kelly or Avan Rivers, possibly because the silty and turbid nature of the Noatak during high flows restricts periphyton and macrophyte growth evident in the Kelly and Avan Rivers.

Table 23. Concentrations of dissolved nitrogen and phosphorus compounds in water samples, 1985.

	Kjeldahl ("total") Nitrogen	"Available" Nitrogen	NO_3-N	"Total" Phosphorus	"Available" Phosphorus
	milligrams per liter				
Seep, Pond #1	0.132	2.095	0.008	0.045	0.004
Pond #1	0.132	0.748	0.016	0.005	0.007
Pond #2	0.106	0.541	0.016	0.005	0.004
Loon Lake	0.000	0.358	0.000	0.047	0.002
Avan River	0.057	0.358	0.000	0.036	0.002
Kelly River	0.000	0.179	0.047	0.052	0.007
Noatak River	0.000	0.541	0.032	0.100	0.002

Concentrations of dissolved cations are listed in Table 24. The seep into pond #1 had higher concentrations of calcium, silicon, potassium, magnesium, and arsenic than the pond itself. Iron was lowest in Loon Lake among the lentic sites and arsenic was lowest in pond #1; otherwise cation concentrations appeared relatively similar in the ponds and Loon Lake. Cation concentrations also appeared relatively similar in the river samples. Calcium, iron, potassium, and to an extent, arsenic, were somewhat higher in the Noatak River than the Kelly or Avan Rivers. The Avan River had the lowest concentration of manganese.

Table 24. Concentrations of dissolved cations in water samples, 1985.

	Ca	Fe	Na	Si	K	Mg	Mn	As
	milligrams per liter							
Seep, pond #1	9.768	0.037	0.052	1.716	1.134	2.187	0.052	0.084
Pond #1	7.294	0.062	0.119	0.513	0.824	1.706	0.053	0.003
Pond #2	7.030	0.070	0.045	0.524	0.746	1.699	0.055	0.207
Loon Lake	9.790	0.002	0.110	0.218	0.649	1.706	0.055	0.030
Avan River	16.870	0.000	0.364	2.716	0.228	12.360	0.000	0.134
Kelly River	13.990	0.000	0.206	2.222	0.190	10.350	0.053	0.122
Noatak River	23.900	0.100	0.294	1.411	0.343	5.275	0.056	0.166

POTENTIAL MONITORING SITES (Watershed Emphasis)

Because of poor weather, we were unable to sample anywhere other than the Kelly Bar area. We suggest that, in future studies, a complete watershed or catchment should be the basic unit within which measurements are made. The following section expands upon the use of watersheds for study areas and also reviews potential future sampling sites.

Hydrologic Setting

Knowledge of water resources and hydrologic regime for high-latitude regions is cursory at best. Dingman (1973) provided a comprehensive survey of hydrologic information available for Arctic regions; the sources reviewed did not refer to the Noatak. Streamflow data (summer only) are available for a now-discontinued U.S. Geological Survey streamgage in the Lower Noatak Canyon, for the period 1965-1971. Based on those data and two "reconnaissance" trips to the basin, Childers and Kernodle (1981) developed initial estimates of several basic hydrologic parameters for the Noatak. A river system profile (Figure 29) shows river gradient development from headwaters to salt water, and is useful in depicting the relative position of primary tributaries. The river gradient is approximately 4 ft/mile for the entire main stem upstream from Noatak Village. A markedly shallower gradient from Noatak Village to Kotzebue

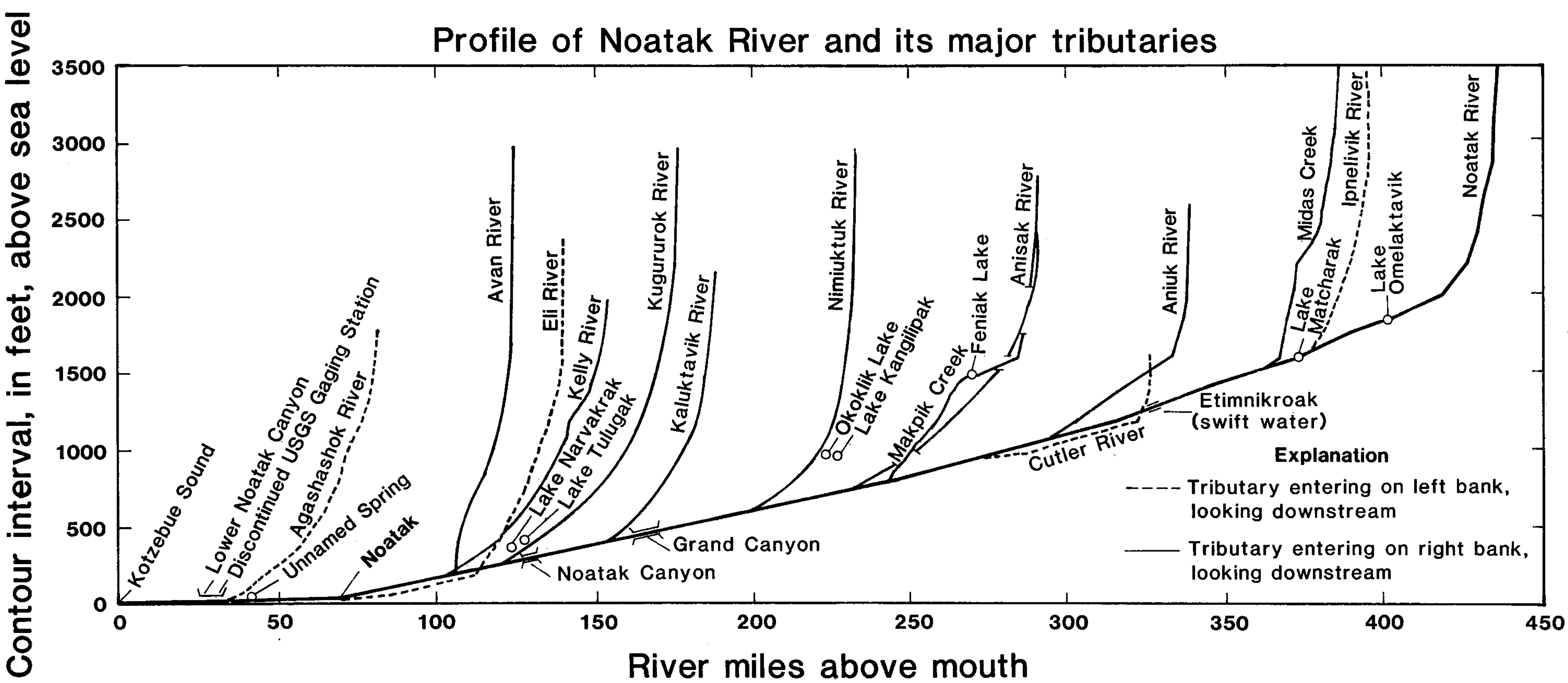

Profile of Noatak River and its major tributaries
Contour interval, in feet, above sea level
0
500
1000
1500
2000
2500
3000
3500
River miles above mouth
0
50
100
150
200
250
300
350
400
450
Kotzebue Sound
Lower Noatak Canyon
Discontinued USGS Gaging Station
Agashashok River
Unnamed Spring
Noatak
Avan River
Eli River
Kelly River
Lake Narvakrak
Lake Tulugak
Kugururok River
Kaluktavik River
Noatak Canyon
Grand Canyon
Nimiuktuk River
Okoklik Lake
Lake Kangilipak
Makpik Creek
Feniak Lake
Anisak River
Cutler River
Aniuk River
Etimnikroak
(swift water)
Midas Creek
Lake
Matcharak
Ipnelivik River
Lake
Omelaktavik
Noatak River
Explanation
Tributary entering on left bank, looking downstream
Tributary entering on right bank, looking downstream

Figure 29

Sound is reflected by salt water intrusion upriver to near Noatak Village in winter. Mean summer streamflow was estimated at 1.0 cfs/mi^2 for the entire Noatak basin, equivalent to a point discharge of 460,000 cfs in the Lower Noatak Canyon (Childers and Kernodel, 1981). The 2-year and 50-year recurrence interval floods were also estimated for the Noatak at Lower Noatak Canyon; these estimates are 172,000 and 312,000 cfs, respectively.

Watersheds for monitoring

This generalized hydrologic description provides a framework for proposing long-term environmental monitoring within the conceptual setting of representative catchments. The watershed or catchment is now widely recognized as an appropriate landscape unit for many "environmental" or "ecosystem" investigations. Cobb and Biesecker (1971) described a national system of "hydrologic bench mark" watersheds, selected stream basins "...which are expected to remain in their present or natural condition." Their initial objectives concentrated on streamflow measurements for analysis of the hydrological regime of natural catchments, statistical analysis of hydrological time series, and as reference sites for noting changes in the regime of streams whose catchment or flow are developed for use. The value of such basins for long-term pollution monitoring was also stressed: "Data collected at the hydrologic bench marks offers a basis for evaluating...changes. For example, radioactive fallout has occurred over most of the earth, and pesticides discharged into the atmosphere often travel great distances. Water-quality data from benchmark basins will aid in determining the distribution and magnitude of these contaminants...data should be obtained as soon as possible even on the remote streams in order to document natural conditions" (Cobb and Biesecker, 1971). The USGS hydrologic benchmark network does not include an Alaskan or high-latitude basin.

The use of representative and experimental basins for research into questions of hydrologic regime, ecosystem functioning, and resource management practices has received attention from many quarters (e.g., Jeffrey, 1964; Toebes and Ouryvaev, 1970; Anderson et al., 1976). Odum (1969), discussing ecosystem development and eutrophication of natural water bodies, noted that "...it is the entire drainage or catchment basin, not just the lake or stream, that must be considered the ecosystem unit if we are to deal successfully with our water pollution problems..." He also stated that, at least at that time, "...it is proving surprisingly difficult to get tradition-bound scientists and granting agencies to look beyond their specialties toward the support of functional studies of large units of the landscape."

The value of natural areas in establishing environmental baselines was documented by Jenkins and Bedford (1973). More recently, the National Science Foundation has supported establishment of a national network of Long-Term Ecological Research (LTER) sites (Callahan, 1984). Many of these sites are centered on or include established research watersheds such as H.J. Andrews Experimental Forest in Oregon and Coweeta Hydrologic Laboratory in North Carolina (Halfpenny and Ingraham, 1983). There is not an LTER site in either arctic or subarctic Alaska.

Likens (1983) has emphasized the value of long-term monitoring in such diverse areas as precipitation chemistry, avian and salamander populations, lake eutrophication (Lake Washington, Lake Tahoe), and biogeochemical cycling, often in the context of complete watershed analysis. While the international Global Environmental Monitoring System (GEMS) program is oriented toward long-term environmental monitoring, rather than active experimental research, it is appropriate to consider a discrete watershed(s) within the Noatak River Basin for long-term monitoring and study.

The September, 1985 reconnaissance was planned to allow at least aerial inspection of possible monitoring sites away from Kelly Bar. Adverse weather and river conditions precluded that work. Nevertheless, map inspection and discussions with NPS personnel allow suggesting several whole-catchment sites which might prove suitable for multi-media monitoring (Wiersma, 1984), and which might also serve as the equivalent of the "hydrologic bench mark" (Cobb and Beisecker, 1971) or "representative basin" (Toebes and Ouryvaev, 1970).

Informal criteria for such a watershed in the Noatak include:

- a well-defined drainage network and watershed boundaries;
- maximum elevational contrast, to allow transition from river valley environment (white spruce community) to alpine environment in one catchment;
- less than 50 mi^2 drainage area; and
- access by fixed-wing aircraft and/or riverboat

<u>Candidate watersheds</u> - Figure 30

Knapp Creek headwaters, in Igichuk Hills. Located in parts of T 21, 22 N, R 16, 17 W Kateel River Meridian; shown on Noatak A-1, B-1 map sheets; this catchment is the furthest downstream of the candidate sites, and therefore closest to Kotzebue (and closest to salt-water influence of Kotzebue Sound); Knapp Creek is a tributary to the Noatak River on the left bank; the monitoring site would have a drainage area of less than 15 mi^2, and elevation range from 200 to 1700 ft MSL.

Catchment tributary to Agashoshok River on right bank, on east side of Asik Mountain; two small drainages in Sections 19, 20, 21, 29, 30, 31, 32, T 24 N, R 16 W, and Sections 24, 25, T 24 N, R 17 W, Kateel River Meridian; shown on Noatak B-2 map sheet; the monitoring site would have a drainage area less than 10 mi^2, and elevation range from 300 to over 2000 ft MSL.

Wrench Creek headwaters, west and northwest flanks of Ampitheatre Mountain and east of Wulik River, in extreme northwest Noatak National Preserve; located in T 34 N, R 17 W, Kateel River Meridian, and T 12 S, R 45 W, Umiat Meridian; shown on Delong Mountains B-1, B-2 map sheets; the monitoring site would have a drainage area of less than 50 mi^2, and elevation range from 1000 to over 3000 ft MSL.

Candidate Watersheds for long-term monitoring and research

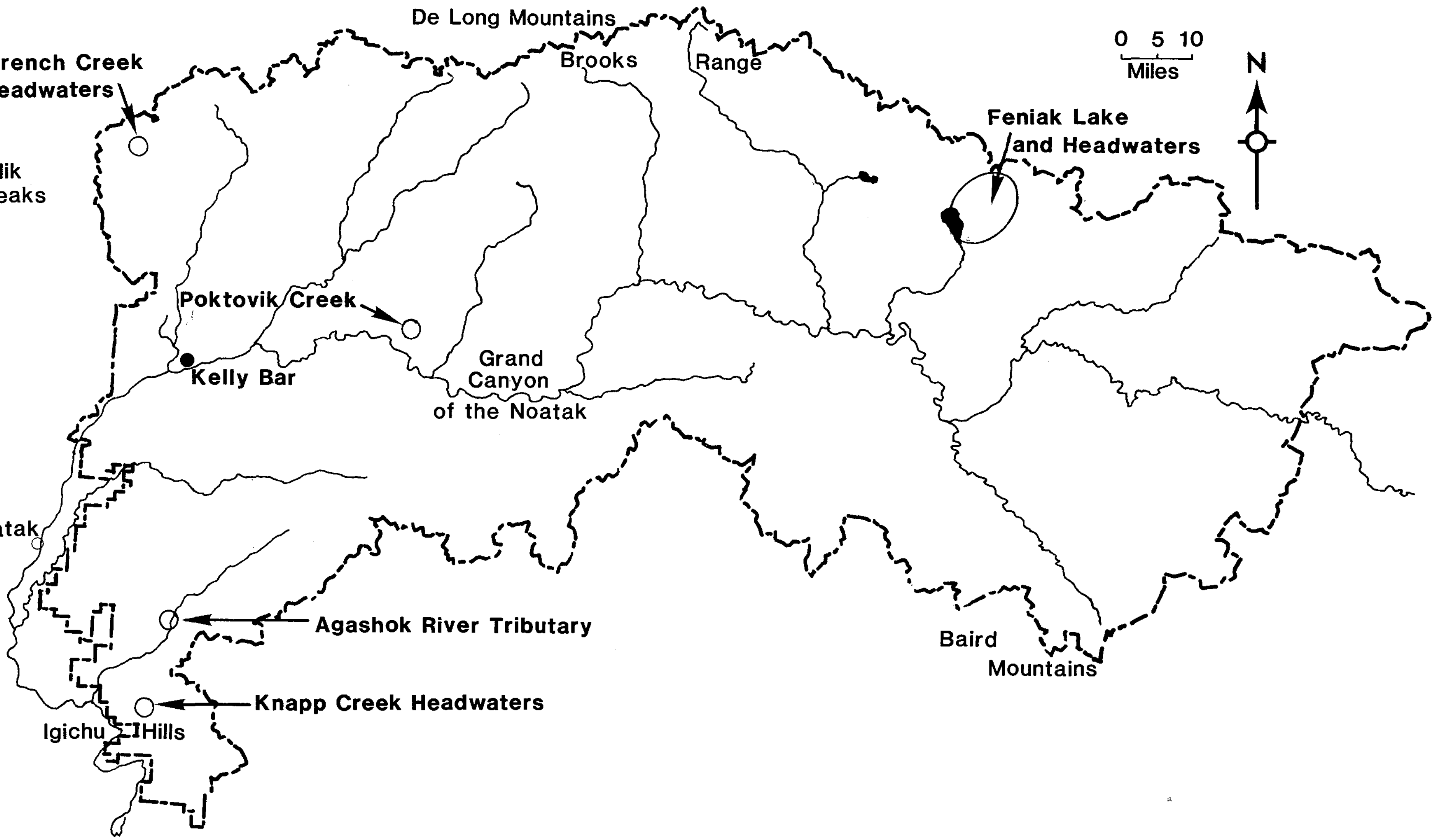


Figure 30

East branch of Poktovik Creek, in Poktovik Mountains, tributary to Noatak River on right bank, upstream from Kelly Bar; includes parts of Sections 21, 22, 23, 24, 26, 27, 28, 33, 34, 35, 36, T 31 N, R 11 W, Kateel River Meridian; shown in Misheguk Mountain A-4 map sheet; the monitoring site would have a drainage area less than 15 mi^2, and elevation range from 500 to 2700 ft MSL.

Feniak Lake and headwaters tributaries, northeast sector of Noatak National Preserve; located in T 33 N, R 23 E, Kateel River Meridian; shown on Howard Pass 1:250,000 map sheet; Feniak Lake is tributary to Matpik Creek, about 20 river miles north of the Noatak River. This pristine Arctic lake is very close to the continental divide, adjacent to NPR-4 and the North Slope Borough; the monitoring site would have a drainage area less than 100 mi^2, and elevation range from 1400 to over 4000 ft MSL. This is north of treeline, and would not include a northern boreal forest component, but is the only proposed site which includes a major freshwater lake.

SUMMARY AND RECOMMENDATIONS

The concensus of the field team is that the Noatak National Preserve is a good potential baseline site for monitoring of ecoystem parameters and certain kinds of pollutants.

1. Trace element levels for compounds that have suspected long-range transport such as lead, zinc, and copper are low in the moss and lichen samples collected at the preserve.

2. The comparison of trace elements (not considered nutrients in mosses) within Noatak National Preserve, Olympic National Park, and Torres del Paine National Park show similarities.

3. Based upon this, from the point of view of trace element analysis, the three sites have potential for representing background areas.

4. Forest communities exist near the extreme limit of tree growth; certain tree and shrub species which are near their physiological limits might show rapid response to increasing levels of atmospheric pollutants within this high stress environment.

5. The vegetation is short in stature, simple in vertical structural development, and rather depauperate in species--attributes which may be helpful in evaluating potential changes from anthropogenic sources.

6. All sites had abundant moss and lichen; plants generally considered to respond to change in atmospheric pollution levels.

7. Vegetation gradients exist over very short distances.

8. Prolonged--up to 20 years-- needle retention of white spruce was observed and this may serve as a biological tool for assessing recent historical changes in atmospheric pollutants.

9. The logistical problems of working in the Noatak National Preserve are formidable, but they can be overcome with adequate agency support.

10. Totally pristine catchments or watersheds are available in each of the major environmental settings of Noatak National Preserve, offering the potential for integrated landscape/stream system analysis and long-term monitoring.

11. Additional sampling should be carried out on watersheds in different locations in the preserve before a final decision regarding Noatak's suitability as a global baseline monitoring site is made.

LITERATURE CITED

Alexander, V., M. M. Billington, and D. M. Schell. 1978. "Nitrogen fixation in arctic and alpine vegetation." In Vegetation and Production Ecology of an Alaskan Arctic Tundra. (Edited by L. L. Tieszen). Springer-Verlag, New York, pp. 539-558

Alkezweeney, A. J., N. S. Laulinen, and J. M. Thorp. 1982. "Physical, chemical and optical characteristics of a clean air mass over Northern Michigan." Atmospheric Environment 16(10):2421-2430

American Public Health Association. 1985. "Standard methods for the examination of water and wastewater." Amer. Public Health Assoc., Washington D. C., 1268 pp.

Anderson, H. W., M. D. Hoover, and K. G. Reinhart. 1976. "Forests and water: effects of forest management on floods, sedimentation, and water supply." GTR PSW-18, Pacific Southwest Forest and Range Experiment Station, U.S.D.A. Forest Service, Berkeley, California., 115 pp.

Billington, M. M., and V. Alexander. 1983. "Site-to-site variations in nitrogenase activity in a subarctic black spruce forest." Can. J. For. Res., Vol. 13, pp. 782-788

Callahan, J. T. 1984. "Long-term ecological research." Bioscience 34(6):363-367

Childers, J. M., and D. R. Kernodle. 1981. "Hydrologic reconnaissance of the Noatak River Basin, Alaska, 1978." Water-Resources Investigations Open-File Report 81-1005, U. S. Geological Survey, U.S.D.I., Anchorage, Alaska. 38 pp.

Cobb, E. D., and J. E. Biesecker. 1971. "The national hydrologic bench-mark network." Geological Survey Circular 460-D, U. S. Geological Survey, Washington, D. C. 38 pp.

Dingman, S. L. 1973. "The water balance in Arctic and subarctic regions." Special Report 187, U.S.A. Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire. 134 pp.

Franklin, J. F., and R. H. Waring. 1979. "Distinctive features of the northwestern coniferous forest: development, structure and function." In R. H. Waring (ed.), Forests: Fresh Perspectives from Ecosystem Analysis. Proceedings of the 40th Annual Biology Colloquium. Oregon State University, Corvallis, Oregon. pp. 59-85

Gasbarro, T., and J. Zasada. 1984. "Forest regeneration assessment and preliminary forest management guidelines for the Kobuk and Ambler village forest lands." Cooperative Extension Service, University of Alaska. Unpublished report.

Grier, C. C., and R. S. Logan. 1977. "Old-growth Pseudotsuga menziesii communities of a western Oregon watershed: biomass distribution and production budgets." Ecological Monographs 47(4):373-400

Halfpenny, J. C., and K. P. Ingraham (editors). 1983. "Long-term ecological research in the United States: A network of research sites." Long-Term Ecological Research Network, Division of Biology, Kansas State University, Manhattan, Kansas. 27 pp.

Hilgert, J. W. 1984. "Periphyton inventory and monitoring for water quality characterization in subarctic streams." In Proceedings of the International Conference on Inventorying Forest and Other Vegetation of the High Latitude and High Altitude Regions, Fairbanks, Alaska. pp. 271-280

Hulten, E. 1968. "Flora of Alaska and neighboring territories." Stanford University Press, Stanford. 1008 pp.

Jeffrey, W. W. 1964. "Watershed research in the Saskatchewan River headwaters." Forestry Research Branch, Department of Forestry, Canada. Calgary, Alberta. 51 pp. plus app.

Jenkins, R. E., and W. B. Bedford. 1973. "The use of natural areas to establish environmental baselines." Biological Conservation 5(3): 168-174

Johnson, A. W., L. A. Viereck, R. E. Johnson, and H. Melchior. 1966. "Vegetation and flora." In N. J. Wilimovsky and J. N. Wolfe (eds.), Environment of the Cape Thompson region, Alaska. United States Atomic Energy Commission, Division of Technical Information, Oak Ridge, Tennessee. 277 pp.

Lawton, E. 1971. "Moss flora of the Pacific Northwest." The Hattori Botanical Laboratory, Nichinan, Japan. 362 pp.

Likens, G. E. 1983. "A priority for ecological research." Bulletin of the Ecological Society of America 64, 234 pp.

National Park Service. 1985. Noatak National Preserve, Alaska. Draft General Management Plan/Environmental Assessment. Alaska Regional Office, National Park Service, U.S.D.I., Anchorage, Alaska.

Odum, E. P. 1969. "The strategy of ecosystem development." Science 164, 262 pp.

O'Neill, R. V., and D. E. Reichle. 1979. "Dimensions in ecosystem theory." In R. H. Waring (ed.), Forests: Fresh Perspectives from Ecosystem Analysis. Proceedings of the 40th Annual Biology Colloquium. Oregon State University, Corvallis, Oregon. 11 pp.

Patrick, R., and L. R. Freese. 1961. "Diatoms (Baccillariophyceae) from Northern Alaska." Acad. Nat. Sci. Phila. 112(6), 301 pp.

Prescott, G. W., and W. C. Vinyard. 1965. "Ecology of Alaskan freshwater algae V. Limnology and flora of Malikpuk Lake." Trans. Amer. Micros. Soc. 84(4):427-478

Racine, C. H., J. G. Dennis, and W. A. Patterson. 1985. "Tundra fire regimes in the Noatak River Watershed, Alaska." Arctic 38(3):194-200

Ruhling, A., and G. Tyler. 1970. "Sorption and retention of heavy metals in the woodland moss Hylocomium Splendens (HEDW)." BR et Sch. Olkos 21, pp 92-97

Taylor, S. R. 1964. "Abundance of chemical elements in the continental crust: a new table." Geochim. Cosmochim. Acta 28:1273-1285

Toebes, C., and V. Ouryvaev (editors). 1970. "Representative and experimental basins - an international guide for research and practice." Studies and Reports in Hydrology 4, UNESCO, Paris. 348 pp.

Whittaker, R. H. 1975. "Communities and ecosystems." MacMillan Publishing Co., Inc., New York. 387 pp.

Wiersma, G. B. and C. I. Davidson. 1986. "Trace metals in the atmosphere of remote areas." In Toxic Metals in the Atmosphere. John Wiley & Sons. New York, New York. 635 pp. J. O. Nriagu and C. I. Davidson (eds.)

Wiersma, G. B. 1984. "Integrated global background monitoring network." Presented at symposium: Research and Monitoring in Circumpolar Biosphere Reserves. Northern Science Network, UNESCO-MAB, Waterton Lakes, Alberta, Canada (in press).

Yarie, J., and K. Van Cleve. 1983. "Biomass and productivity of white spruce stands in interior Alaska." Canadian Journal of Forest Research 13(5):767-772

Zoller, W. H., E. S. Gladney and R. A. Duce. 1974. "Atmospheric concentrations and sources of trace metals at the South Pole." Science 183:198-200

APPENDIX I

Trip Summary

Objective: Evaluate potential of Noatak National Preserve/Biosphere Reserve for establishing a long-term, interdisciplinary environmental monitoring station as one component of the world-wide Global Environmental Monitoring System network.

Procedures: The reconnaissance team met in Kotzebue on Monday, September 9, 1985. An introductory briefing was conducted with Ms. Kate Roney, National Park Service (NPS) Resource Specialist, and Mr. Mack Shaver, Superintendent of Noatak National Preserve. In the afternoon, the team flew in NPS planes (Cessna 206 and Cessna 185, wheels) to Kelly Bar at the confluence of the Kelly and Noatak Rivers; a NPS summer ranger is stationed at that location, normally accessible by wheel plane. Camp was established near the NPS station.

September 10 was devoted to reconnaissance of the immediate area, including a low forested ridge and two small lakes. A 25 m x 25 m vegetation sample plot was established in a southwest-facing closed spruce forest near the NPS station. McKee and Halpern, assisted by Slaughter, collected soil and vegetation material for future trace metal analysis, and Hilgert visited three ponds and one lake northwest of the NPS site to collect water samples for chemical analysis, and phytoplankton and periphyton samples. McKee and Halpern established a second vegetation analysis plot, adjacent to a small lake west of the NPS station, in an open spruce forest on a west-aspect slope. Hilgert and Slaughter inspected riverine and riparian aspects of the Avan/Kelly rivers confluence and collected water samples.

A flight over the upper Noatak basin to inspect discrete watersheds for long-term monitoring, planned for September 11, was cancelled due to poor flying weather. The day was devoted to further work on the previously-established vegetation plots, and discussions with NPS personnel.

Rain, snow, low clouds and rising river level curtailed travel on September 12 and 13. The team completed sampling in previously established spruce forest plots, and devoted much of the time to planning future activities. Hilgert collected water samples from the Noatak River.

The feasibility of a long-term environmental monitoring effort in Noatak National Preserve is obviously constrained by logistics considerations. The Kelly Bar site is considered one of the most accessible locations in the entire Preserve, yet still offers access problems under some conditions. Logistics aside, requirements for a comprehensive multi-media monitoring effort might be better met at other locations within Noatak National Preserve, but inclement weather precluded even aerial reconnaissance of such sites.