Macrolichen Diversity in Noatak National Preserve, Alaska

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28 May 2007

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***Abstract*.**

We sampled Noatak National Preserve with a stratified random sample to allow unbiased park-wide diversity estimates, along with an intensive sample in a limited area. The purpose of the intensive sample was to allow us to calculate a correction from diversity estimates based on a single person in a time-constrained method to a value that more closely approximates the "true" diversity of a plot.

Our 88, 0.38-ha plots averaged 26 species of macrolichens in the sample, while our best estimate of the true average was 42 species per plot. Our raw estimate of gamma diversity (park-wide macrolichen species richness) was 209 species, with jackknife estimates adjusting this to 255 or 290 species, depending on the estimator. Overall beta diversity was rather high at 7.1, reflecting the considerable variation in lichen communities among topographic positions, rock chemistry, soil development, climate, and vegetation. The richest lichen communities were in conifer forests, low birch/ericaceous vegetation, dwarf shrub, and talus lichen cover. Sparse vegetation was the cover type with lowest lichen species richness, reflecting the frequency of bare rock in that cover type. The herbaceous cover type was the most heterogeneous in lichen communities, having a high gamma diversity, high beta diversity, but averaging rather low alpha diversity.

Floristic work revealed several notable species among the 364 taxa reported here. *Leucocarpia biatorella*(Arnold) Vezda is reported as new to the American Arctic. *Cladonia libifera* Savicz is newly reported for North America. A second location for *Rhizocarpon cumulatum* J. W. Thomson beyond the type locality was found.

INTRODUCTION

The 2.6 million hectare Noatak National Preserve is dominated in diversity by nonvascular species which have yet to be enumerated. This is an International Biosphere Reserve. Studies in adjacent Gates of the Arctic National Park have shown that as much as 75% of the flora is nonvascular, with approximately 45% of the species represented by lichens (Neitlich and Hasselbach, 1998). We estimated that less than 10% of the probable lichen flora in Noatak had been documented, based on the list of 59 species in the National Park Service lichen database (Bennett and Wetmore 2007). Lichens face threats of injury and/or extirpation from a variety of anthropogenic sources including air pollution, snowmachine and ATV use, and overuse of fragile areas by human visitors. Managers do not currently know what taxa or communities are most at risk or at what scale. Our objective was to provide a park-wide inventory for macrolichens. A second objective, to collect data from baseline lichen community plots for future monitoring and to describe the relationships between lichen communities and major landscape variables, are reported elsewhere (Holt et al. 2007d).

The lichen flora of Noatak National Preserve is of particular interest not only because it has been little studied, but also because it occupies an intermediate position in the subarctic between the relatively oceanic Seward Peninsula (Holt et al. 2007 a, b, c) and more continental areas, such as Gates of the Arctic (Neitlich and Hasselbach 1998, 2002). It also includes a regional transition between nearly pure tundra and forested areas. oceanic species of the Seward Peninsula, such as *Cladonia subfurcata*, might penetrate inland.

STUDY AREA

Noatak National Preserve includes most of the Noatak River watershed, spanning tundra to forest habitats on a regional climatic gradient. The Noatak River runs west at about 68°N, draining the south slope of the western Brooks Range. The suboceanic western end is 60 km from the Chuckchi Sea. The east end approaches Gates of the Arctic National Park and Preserve and has a more continental climate. The gradient in continentality is rather subtle, with a January to July difference in average temperature ranging from 36°C in the west to 40°C in the upper Noatak valley (Manley and Daly 2005). Noatak is thus intermediate in geography, climate, and floristics between the Bering Land Bridge Preserve on the Seward Peninsula (Holt et al. 2007a, b, c) and Gates of the Arctic (Neitlich and Hasselbach 1998, 2002). The Noatak Valley is rimmed by mountains of both calcareous and noncalcareous rock. Most of the area was glaciated.

METHODS

Sampling

Two basic kinds of sampling provided different kinds of data: an intensive sample in a limited area and a park-wide stratified random sample. The purpose of the intensive sample was to allow us to calculate a correction from diversity estimates based on a single person in a time-constrained method to a value that more closely approximates the “true” diversity of a plot. To do this, a group of five lichenologists sampled a diversity of cover types near a basecamp near Copter Peak (68.4734°N, 161.4845°W). One lichenologist (Holt), the person who sampled all of the remaining plots, read the seven intensive plots independent of the other four lichenologists. Those four divided the lichen flora into four sections, each focusing on only one section. Holt’s data were then compared with our best estimate of the true lichen flora in each of the seven plots. This best estimate was made as the combination of Holt’s data with the four others. These data were gathered over a five-day period in 2004. In addition microlichens were collected incidentally by the group. Though not part of the formal plot sampling, these microlichen collections contributed to our understanding of the lichen flora of Noatak (see Floristic Sampling below).

We used two-stage adaptive sampling to attempt to focus our efforts on lichen-rich habitats in Noatak, while also providing coverage in other habitats. The first stage of sampling gave crude estimates of average macrolichen species richness in each cover type, the cover types based on remote sensing data. This stage included the 7 plots by the group of lichenologists, as well as 13 other plots by a single observer. The second stage of sampling added 68 more sample units such that the effort within a cover type was approximately proportional to lichen richness estimated in the first stage.

Table 1. Reclassification of 15 land cover types determined by remote sensing into 7 sampling strata, with the percentage of area of Noatak National Reserve in each cover type.

Original Cover Types		Reclassified Cover Types		
Name	Area, %	No.	Reclassified Name	Area, %
Closed needleleaf forest	1.8	1	Conifer forest	9.9
Open needleleaf forest	4.5			
Needleleaf woodland	3.7			
Tall open and closed alder/willow	2.6	2	Alder-willow	18.0
Closed low shrub-alder/willow	4.5			
Open low shrub-alder/willow	11.0			
Closed low shrub-birch/ericaceous	1.8	3	Low birch/ericaceous	19.7
Open low shrub-birch/ericaceous	17.9			
Open low and dwarf shrub tussock tundra	18.9	4	Dwarf shrub	26.1
Dwarf shrub tundra/dwarf shrub peatland	7.2			
Open dwarf shrub-talus/lichen	3.9	5	Talus lichen	3.9
Moist or dry herbaceous	8.7	6	Herbaceous community	10.5
Wet herbaceous	1.8			
Sparsely vegetated	4.5	7	Sparse vegetation	11.9
Barren	7.3			

Table 2. Sampling intensity for cover types based on average rarity scores, *S*, calculated from a preliminary sampling in 2004, assuming 60 plots to be sampled in 2005.

Stratum (Cover Type)	2004 No. plots	*S*	Expected plots in 2005	Total plots
1. Conifer Forest	2	18.2	9	11
2. Alder-Willow	3	15.4	8	11
3. Low Birch/Ericaceous	2	17.1	9	11
4. Dwarf Shrub	3	13.7	7	10
5. Talus Lichen	4	20.1	11	15
6. Herbaceous Community	3	28.6	15	18
7. Sparse Vegetation	3	1.6	1	4

The original GIS land cover type map of Noatak contained 15 total land cover types. Based on previous knowledge of the area, experience in nearby Bering Land Bridge National Preserve (Holt et al. 2007a, b, c), and similarity or overlap in cover type labels, we reclassified the cover types into seven strata (Table 1).

Based on our preliminary data from Noatak in 2004, we adapted the sampling intensity for sampling each of the seven cover types for 2005. Sampling intensity was determined by a "rarity score". The rarity score, $S_{i,}$ is a rarity-weighted species richness for plot *i*.

With a presence-absence data matrix **A** containing *j* = 1 to *p* species and *i* = 1 to *n* plots, and a rarity weight w_j for species *j*, the rarity score S_i for a plot is:

$$S_i = \sum_{j=1}^{p} a_{ij} \bullet w_j$$

where $w_j = 1 - \text{freq}_j / N$

and freq_j is the frequency of species *j*,

In other words, freq_j is the fraction of plots in which species *j* occurs. The lowest possible value of S_i is zero, for a plot with no species, while the maximum possible is the sum of rarity weights of all species in a particular data set. For this data set the highest possible rarity score was 106.35.

Strata were then sampled in proportion to the average S_i in that stratum. In this way, strata with high species richness and high frequency of rare species were sampled more intensively.

In the 2004 data, the lowest rarity weight for a species was 0.25 and the highest was 0.95. The highest rarity score, S_i, for a plot was 36.5 and the lowest was 0.9. Averaging the scores of plots within the same stratum produced overall scores for each of the seven strata, these ranging from 1.6 to 28.6 (Table 2). Based on the rarity scores and planning for 60 plots for 2005, we calculated the number of plots to sample in each stratum (Table 2).

To improve the spatial balancing of the sampling we divided the Preserve into four roughly equal-area geographic blocks. The boundaries of these blocks coincided with Preserve boundaries and physiographic regions. Within each geographic block, points from each of the seven cover type were randomly located with a random point generator script in ArcGIS. Points of a particular cover type were retained if they were surrounded by a minimum of 8 cells of the same cover type. The number of plots was roughly equal in each geographic block, with each cover type represented proportionate to the total number of plots from that cover type. Including the 20 plots sampled in 2004, a total of 80 plots were selected. The formal stratified randomization scheme allows us to make inferences about park-wide values of species diversity.

plots were circular and fixed-area with a 34.7-meter radius. We used thin layer chromatography for identification of some *Bryoria*, *Cladonia*, *Hypogymnia*, *Parmelia omphalodes* group, and *Stereocaulon*. All *Cladonia* identifications were based on voucher specimens with podetia, and strictly squamulose thalli were not recorded. UV light distinguished the two chemical species of *Thamnolia*, which was also collected from every site at which it occurred. Vouchers were deposited at OSC, H, the NPS Herbarium in Anchorage, Alaska, and the research herbaria of Rosentreter and Holt.

Diversity measures

We separated alpha, beta, and gamma diversity of macrolichens, following Whittaker (1972) and McCune and Grace (2002), using only the data collected in formal lichen plots while excluding opportunistic floristic sampling. Calculations were made for individual cover types (Table 2) as well as for the all cover types combined. Alpha diversity was measured as species richness per plot. Because our abundance scale for plot sampling (Holt et al. 2007d) had only a few coarse intervals, use of evenness-weighted alpha diversity measures, such as the Shannon index, were inappropriate. Beta diversity expresses the amount of community variation among plots and was measured with Whittaker's beta = (gamma/alpha) – 1. Gamma diversity was measured as the total number of macrolichen species observed in our plots in the study area. Because gamma diversity is always underestimated by such sampling (Palmer 1990, 1995), we used nonparametric resampling (jackknife) methods in PC-ORD (McCune and Mefford 2006) to attempt to estimate the "true" park-wide macrolichen species richness. Both the first-order jackknife (Heltshe and Forrester 1983) and the second-order jackknife (Burnham and Overton 1979, Palmer 1991) are based on the number of rare species encountered, and are thus very sensitive to sampling error (Palmer 1990, 1995).

Species area curves were generated with PC-ORD 5 (McCune and Mefford 2006). Our sample of plots was subsampled to determine the average number of species as a function of size of the subsample. Subsampling was repeated 500 times for each subsample size.

Floristic sampling

Three sources of data were combined to provide a first inventory of the lichen flora of Noatak National Preserve: (1) sampling of macrolichens and microlichens by five lichenologists near a basecamp near Copter Peak, (2) a park-wide stratified random sample of macrolichens by Holt, and (3) incidental sampling of lichens along the Noatak River by two National Park Service employees, Tracy Wiese and Bruce Carter (Table 3). In all 3678 collections or species observations were made.

Several localities received special attention by the team of lichenologists (Table 4). These locations are referred to by name in the Results; otherwise plots are referred to by plot names in an Access database available from McCune, Holt, or the National Park Service.

Table 3. Contributions to the floristic database for Noatak National Preserve.

Observer	Count	Observation source	Range in collection numbers
Ahti	310	Copter peak area collections	63269 to 64002a
Holt	456	Noatak collections, park-wide	21451b to 22493
Holt	2266	Macrolichen community matrix entries (nonzero values only)	n.a.
McCune	157	Copter peak area collections	27497 to 27594b
Neitlich	146	Copter peak area collections	2649 to 3204
Rosentreter	219	Copter peak area collections	15700 to 15921
Wiese	124	Noatak River collections	AK-1-01 to WBK-09
Total	3678	Noatak National Preserve	

Table 4. Localities that are frequently mentioned in the floristic list, each sampled by a team of five lichenologists. "Q" designates plots part of the intensive lichen "quest" by the team. A, D, H, L, and S designate cover types used in the stratified sampling of Noatak as a whole.

Name	Description	Lat. °N	Long. °W	Elev., m
plot Q3-D2	Open low-and dwarf shrub (*Betula*) tundra, valley bottom	68.4727	-161.4745	433
plot Q3-S4	Barren talus slope with a few small *Salix*, mid slope	68.4808	-161.4833	688
plot Q3-H3	Dwarf shrub tundra, upper west slope, near ridgetop	68.4605	-161.4515	729
plot Q3-A5	Tall *Salix alaxensis* thickets, moist tundra, and creek bottom	68.4645	-161.4901	437
plot Q3-L2	*Dryas* – low birch tundra on flats of valley floor, heavily used by caribou	68.4735	-161.4640	423
plot Q3-L5	Patches of dwarf shrub tundra on talus, steep NE slope	68.4892	-161.5215	608
plot Q1-L2	Open dwarf shrub tundra on alluvial terrace, valley bottom	68.4725	-161.4496	442
Camp Copter	Campsite near informal airstrip, dwarf shrub and low shrub (*Betula*) tundra on alluvial terraces and valley bottom	68.4739	-161.9625	450
Low Rock Ridge	Low siliceous outcrop ridge protruding from alluvial terrace	68.4685	-161.4775	432
Outcrops Near Q3-H3	Outcrops near barren talus slope, mid slopek	68.4808	-161.4833	688
Cyano-tundra near Q3-H5	Dwarf shrub tundra rich with cyanolichens on N facing slope	68.4633	-161.4546	640

RESULTS AND DISCUSSION

Estimates of total diversity

Species richness estimates from the single observer (Holt) sampling throughout the park were analyzed both unadjusted and adjusted to a "true" value. These adjustments were made by the strongly linear relationship ($r^2 = 0.98$) between estimates of the single observer in a time-limited sample and the "true" value for a subset of plots, as determined by a 5-person team of lichenologists. This allowed a simple correction factor between the single observer (x) and true species richness (y), $y = 1.67x$ (Figures 1 and 2).

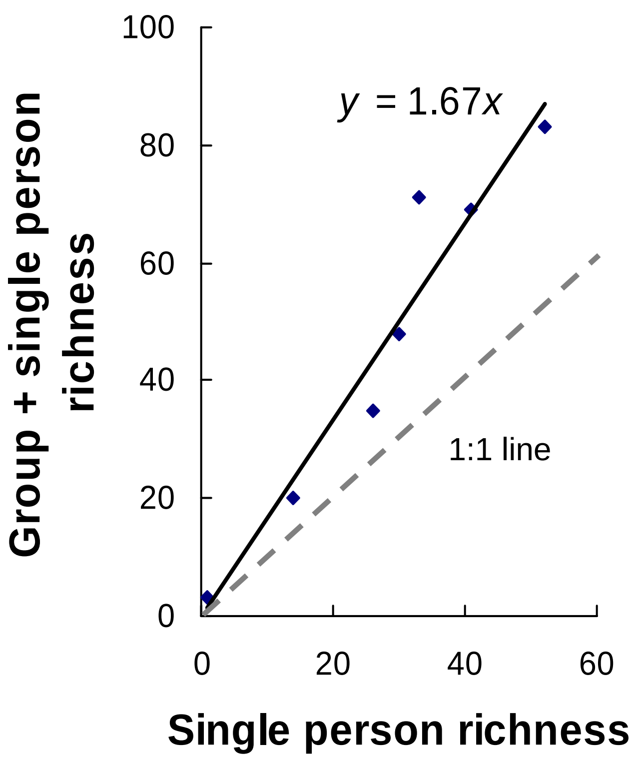

Figure 1. Relationship between macrolichen species richness estimates from a single observer versus that from our best estimate of the true species richness, combining the results of the single observer with those of four other lichenologists (Group + single person richness). The regression line (adjusted $r^2 = 0.98$, $N = 7$) was forced through the origin because an empty plot will have no species observations, regardless of the number of observers.

plots averaged 25 species of macrolichens in the sample with our best estimate of the true average being 41 species per plot (Table 5), including the adjustment given by the regression in Figure 1. These estimates apply to the whole park, based on stratified random sampling and weighting plot richness in particular cover types by the land area occupied by those cover types. Our raw estimate of gamma diversity from the single observer was 209 species, with jackknife estimates adjusting this to 255 or 290 species, depending on the estimator (Table 5, Fig. 2).

Overall beta diversity was rather high at 7.1, reflecting the considerable variation in lichen communities among topographic positions, rock chemistry, soil development, climate, and vegetation.

The richest lichen communities were in conifer forests, dwarf shrub, low birch/ericaceous vegetation, and talus lichen cover types, each averaging an estimated 47-50 macrolichen species per plot. (Table 5). Sparse vegetation was the cover type with lowest lichen species richness, reflecting the frequency of bare rock in that cover type. The herbaceous cover type was the most heterogeneous in lichen communities, having a high gamma diversity, high beta diversity, but averaging rather low alpha diversity (Table 5). The rather low average species richness in the herbaceous cover type contrasts with its relatively high species in our preliminary sample, meaning that our preliminary sample led us to "oversample" the herbaceous type, relative to the conifer forest, low birch, and dwarf shrub cover types.

Table 5. Estimates of total number of macrolichen species in Noatak National Preserve broken down by cover type and for the Preserve overall; *N* = number of plots. "Area weighted" estimates represent park-wide averages across cover types, weighted by their areas (Area%). Alpha diversity is measured by species richness; adjusted estimates incorporate the correction from single observer estimates to multiple-expert estimates. Whittaker's beta diversity (gamma/alpha – 1) expresses community heterogeneity among plots. Gamma diversity is the total number of species observed; Jack1 and Jack2 are jackknife estimates of the true gamma diversity, based on first-order and second-order jackknife estimators.

			Alpha diversity		Beta	Gamma diversity		
Cover type	*N*	Area%	raw	adjusted	diversity	Raw	Jack1	Jack2
Conifer forest	11	1.5	28.7	48.0	2.8	109	136	160
Alder-willow	12	19.3	23.4	39.1	3.1	96	125	135
Low birch/ericaceous	12	18.9	28.8	48.2	2.3	96	130	152
Dwarf shrub	11	28.5	28.3	47.3	2.2	91	119	131
Talus lichen	16	5.0	30.1	50.4	3.3	128	171	196
Herbaceous	18	11.7	22.4	37.5	4.0	111	147	162
Sparse vegetation	8	15.2	15.9	26.6	3.5	72	110	132
Overall	88	100.0	25.7	43.0	7.1	209	255	290
Area weighted			25.0	41.8				

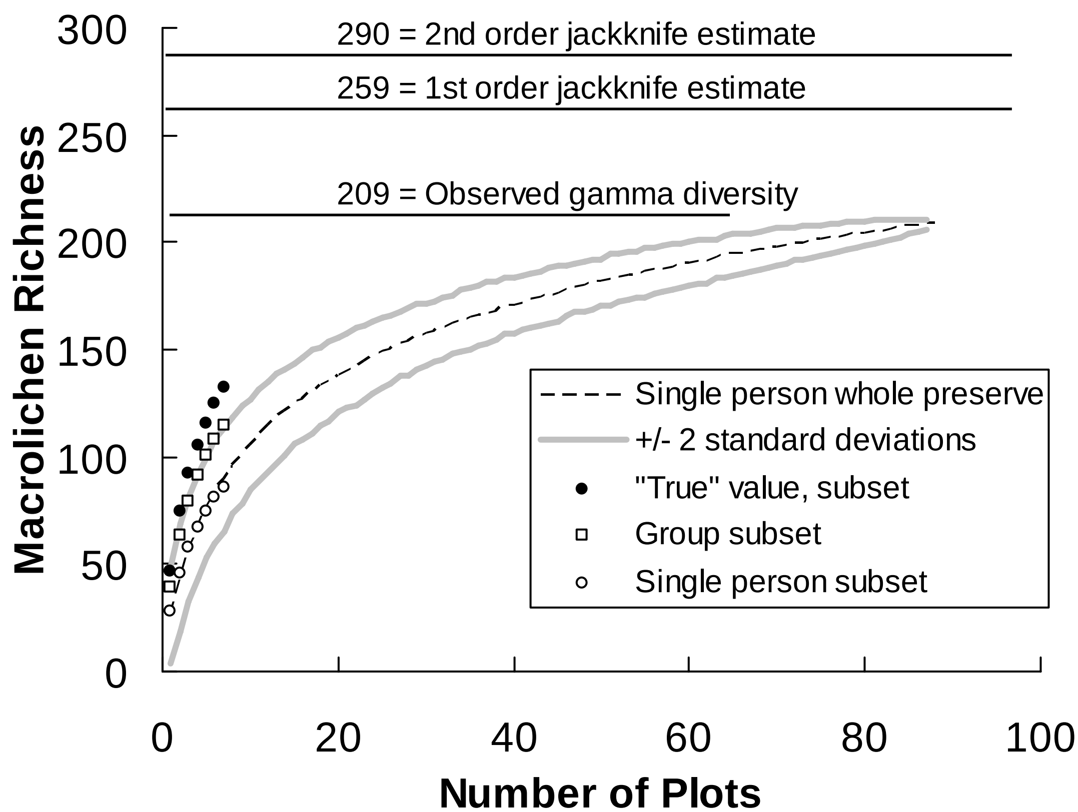

Figure 2. Species-area curve and estimates of gamma diversity for macrolichens in Noatak National Preserve. Curves show species-area relationships for the whole preserve based on repeated subsampling by a single person from a total of 88 plots. Gray lines show ± 2 standard deviations around that curve. Series of points on the left show species area relationships in a subset of plots visited by a team of four lichenologists (“Group subset”), the same single person as for the whole preserve (“Single person subset”), and the combined results from the group and the single person (“True value, subset”).

Species list
We report 364 taxa. Abundance is stated when sufficient information is available to make a statement, based on both the park-wide stratified random sample and the intensive sampling near a basecamp. Our limited sampling of crustose lichens does not allow a statement of abundance in most cases. Individual collection numbers and locations are given when only a few collections were made.

Alectoria nigricans – Common.
Alectoria ochroleuca – Common.

Allantoparmelia almquistii –McCune 27608, Low Rock Ridge. TLC: olivetoric acid.
Allantoparmelia alpicola –Holt 22788, plot SW-5d; medulla P+Y, not confirmed by TLC.

Anzina carneonivea – Tentative identification; Ahti 63466; Low Rock Ridge

Arctoparmelia centrifuga – Occasional.
Arctoparmelia incurva – Infrequent.
Arctoparmelia separata – The most common *Arctoparmelia* in Noatak.

Arthrorhaphis alpina

Asahinea chrysantha
Asahinea scholanderi

Aspicilia sp.— Ahti 63843, plot Q3-A5.
Aspicilia caesiopruinosa – Rosentreter 15797, plot Q1-L2.
Aspicilia candida – McCune 27581, plot Q3-S4.

Aspilidea myrinii? – Wiese NM-1-04d, NM-1.

Bacidia?— Ahti 63947, plot Q3-L5.

Baeomyces carneus – Ahti 63335, plot Q3-D2.
Baeomyces placophyllus
Baeomyces rufus

Biatora vernalis

Brodoa oroarctica – Holt 22968, plot NE-5a; cortex K+Y, medulla K-, KC+R, P+Y, UV+ faint; TLC: atranorin and physodic acid.

Bryocaulon divergens – Common on tundra.

Bryonora castanea – plots Q3-H3 and plot Q3-L5.

Bryoria fuscescens
Bryoria implexa – Holt 23178, plot NW-1e, thallus P+Y
Bryoria lanestris
Bryoria nitidula – Common on tundra.
Bryoria simplicior – Holt 23272, plot SW-2a; Holt 23588b, plot SW-1c; soralia P-.

Bryoria trichodes – Holt 23581, plot SW-1c, Holt 23588a, plot SW-1c; medulla P+O, occurring with *B. fuscescens* and *B. lanestris*.

Buellia spp.
Buellia erubescens – McCune 27530, plot Q3-A5.
Buellia notabilis – McCune 27500, plot Q3-H3.
Buellia punctata – Rosentreter 1574, plot Q3-L2.

Caloplaca sp. – Ahti 63946, plot Q3-L5; Ahti 63994, plot Q1-L2.
Caloplaca ammiospila – (= *Caloplaca cinnamomea*), Apparently fairly common on tundra sod.
Caloplaca citrina – Ahti 63817b, plot Q3-A5.
Caloplaca holocarpa – McCune 27533, plot Q3-A5.
Caloplaca jungermanniae
Caloplaca phaeocarpella? – Ahti 63919, plot Q3-L2; on *Vaccinium uliginosum*.
Caloplaca saxicola – Wiese AT-1.
Caloplaca stillicidiorum
Caloplaca tetraspora – Ahti 63811a, plot Q3-H3; Ahti 63817, plot Q3-A5; McCune 27546a, plot Q3-L2.
Caloplaca tiroliensis – Ahti 63282a, Camp Copter.

Candelariella sp.

Catapyrenium cinereum

Note: because well-defined genera in *Cetraria* s. l. have proved difficult to establish, we apply a broad view of *Cetraria* here, but excluding *Coelocaulon*.
Cetraria andrejevii– Common.
Cetraria commixta– Holt 22332, plot 04-L2.
Cetraria cucullata – Common.
Cetraria delisei – Common.
Cetraria ericetorum – Common.
Cetraria fastigiata – Holt 23153, plot NW-6a; Holt 23361, plot SE-2a.
Cetraria hepatizon – Common.
Cetraria inermis – Common (one specimen verified by A. Thell).
Cetraria islandica – Both ssp *crispiformis* and ssp. *islandica* are apparently common.
Cetraria kamczatica – Common.
Cetraria laevigata – Common.
Cetraria nigricans – Common.
Cetraria nivalis – Common.
Cetraria orbata – Holt 22937, plot SE-2b.
Cetraria pinastri – Common on woody plants.
Cetraria sepincola – Common on woody plants.
Cetraria subalpina – Neitlich 2683, plot Q3-D2.
Cetraria tilesii – Occasional in calcareous tundra.

Cetrelia alaskana – Uncommon; Holt 21966, Camp Copter; Holt 22897, plot NE-6c; McCune 27518, Neitlich 2759, 2760, 2778, Rosentreter 15859, cyanolichen-rich tundra near plot Q3-H3.

Cladonia sp. *"noatakensis"*– Neitlich 2734, 2735, plot Q1-L2.
Cladonia acuminata – Common; UV-, P+Y, K-, KC-. *Cladonia norrlinii* of North American

authors is the psoromic acid chemotype of *C. acuminata*. But in its original sense, *C. norrlinii* is a homotypic synonym of *C. acuminata*. TLC of Wiese AK-1-05: atranorin, psoromic acid, unknown. Rf 4-5 in solvent B'.

Cladonia alaskana – Ahti 63455, Low Rock Ridge; Ahti 63789, plot Q3-H3; Holt 22336a, plot 04-L2.

Cladonia albonigra – common; eleven specimens verified by TLC.

Cladonia amaurocraea – Common.

Cladonia arbuscula – Abundant.

Cladonia bacillaris – Holt 23310, plot NE-4b; thallus K-, KC-, P-.

Cladonia bacilliformis– Fairly common; thallus P-, K- or faint Y, KC+Y, UV-.

Cladonia bellidiflora – Occasional.

Cladonia borealis – Common.

Cladonia botrytes – Infrequent.

Cladonia cariosa – Infrequent.

Cladonia cenotea – Common.

Cladonia chlorophaea – Common; 18 specimens confirmed by TLC.

Cladonia coccifera – Common; 16 specimens confirmed by TLC.

Cladonia coniocraea – Holt 22353, plot 04-W4; Holt 23558, plot SW-1b

Cladonia cornuta – Common.

Cladonia crispata – Very common; 18 specimens confirmed by TLC.

Cladonia crispata var. *cetrariiformis* – Common; most of *C. crispata* in Noatak is var. *cetrariiformis* (no 'cups').

Cladonia crispata var. *crispata*

Cladonia cryptochlorophaea – Occasional; 5 specimens confirmed by TLC.

Cladonia cyanipes– Common.

Cladonia decorticata – Fairly common.

Cladonia deformis– Occasional.

Cladonia digitata – Holt 23418, plot NE-6b; Holt 23529, plot NW-3b

Cladonia ecmocyna ssp. *intermedia* – Holt 21719, plot Q3-D2. TLC: atranorin and fumarprotocetraric acid.

Cladonia fimbriata – Common.

Cladonia furcata – Common.

Cladonia gracilis – Abundant.

Cladonia gracilis ssp. elongata

Cladonia grayi– Occasional; five specimens confirmed by TLC.

Cladonia kanewskii – Fairly common.

Cladonia libifera Savicz – Occasional; new to North America.

Cladonia luteoalba – Occasional.

Cladonia macroceras – Common.

Cladonia macrophylla – Common.

Cladonia macrophyllodes – Holt 23577, plot SW-1c. TLC: atranorin and fumarprotocetraric acid.

Cladonia metacorallifera – Infrequent; confirmed by TLC.

Cladonia mitis – Common.

Cladonia nipponica – Infrequent..

Cladonia "nitens" Ahti ined.– Holt 23025, plot NE-2a.

Cladonia phyllophora – Common.

Cladonia pleurota – Common.

Cladonia pocillum – Abundant.

Cladonia rangiferina – Occasional

Cladonia scabriuscula – Occasional

Cladonia "scotteri" Ahti ined.– Occasional.

Cladonia squamosa – Occasional.
Cladonia stellaris – Common.
Cladonia stellaris var. *aberrans*
Cladonia stricta – Common.
Cladonia stygia – Common.
Cladonia subfurcata – Common.
Cladonia sulphurina – Common.
Cladonia symphycarpa. – Occasional. Three specimens with TLC: atranorin, fumarprotocetraric and protocetraric acids.
Cladonia thomsonii – Infrequent. Ahti 63324x, 63347c, plot Q3-D2; Ahti 63912, 63913, plot Q3-L2.
Cladonia trassii – Infrequent; previously reported from North America by Ahti (1998).
Ahti 63315, 63334, 63345, 63918, plot Q3-D2; Holt 22274, plot 04-H2; Holt 23044, plot NE-4a.
Cladonia uliginosa (Ahti 1998) – Ahti 63341a, plot Q3-D2.
Cladonia uncialis – Common.
Cladonia verticillata (including Holt specimens under *C. cervicornis*). – Fairly common.
Cladonia wainioi – Infrequent.

Coccocarpia erythroxyli – Apparently rare. Holt 21801, plot Q3-H3; Holt 23120, plot SW-4b; cyanolichen rich tundra near plot Q3-H3, McCune 27521, Neitlich, 2756, 2757, Rosentreter 15858, 15862.

Coelocaulon aculeatum – Holt 21791, plot Q3-H3; ?Neitlich 2743, plot Q3-H3.
Coelocaulon muricatum – Much more common than *C. aculeatum* in Noatak.

Collema bachmanianum – McCune 27544b, plot Q3-L2.
Collema callopismum – Wiese K-01-09c, K-01.
Collema ceraniscum – Ahti 63931e, plot Q3-L2.
Collema cristatum – Holt 23336, plot SE-5a.
Collema furfuraceum – Holt 23566, plot SW-1b.
Collema fuscovirens – Common in calcareous areas.
Collema polycarpon – McCune 27579, plot Q3-S4.
Collema tenax – Common, especially in calcareous areas.
Collema undulatum

Dactylina arctica –Both subspecies *arctica* and subspecies *beringica* are very common on tundra.
Dactylina ramulosa – Common on tundra.

Dibaeis baeomyces

Diploschistes muscorum
Diploschistes scruposus

Ephebe hispidula – Holt 23476, plot NE-5c.

Epilichen scabrosus – Common on *Baeomyces*.

Evernia divaricata – Occasional in tundra; Holt 22692, 22733, 23415
Evernia mesomorpha – Common in forested areas.
Evernia perfragilis – Occasional.

Farnoldia hypocrita – McCune 27582, plot Q3-S4.
Farnoldia jurana – McCune 27565, plot Q3-L5.

Fuscopannaria praetermissa – Occasional.

Hypogymnia bitteri – Common in forested areas.
Hypogymnia physodes – Common in forested areas.
Hypogymnia subobscura – Common in tundra.

Lecanora dispersa – Wiese K-05-02a.
Lecanora epibryon – Fairly common in tundra.
Lecanora fuscescens – Ahti 63922,plot Q3-L2.
Lecanora luteovernalis – Rosentreter 15888, Camp Copter, mixed with Pertusaria; ?Wiese K-03-05, Wiese K-06-04
Lecanora symmicta s.l. (or a *Pyrrhospora* species) – McCune 27560, Rosentreter 15854 plot Q3-L5.

Lecidea albohyalina – McCune 27532, plot Q3-A5.
Lecidea diapensiae – Restricted to dead parts of *Diapensia lapponica*.
Lecidea lactea – Wiese AT-1.
Lecidea plana – McCune 27512b, plot Q3-H3.
Lecidea ramulosa – Rosentreter 15890, Camp Copter.

Lecidella euphorea – McCune 27534, plot Q3-A5.
Lecidella wulfenii – McCune 27546b, plot Q3-L2.

Leciophysma finmarkicum – Frequent on rock.

Lempholemma sp. – Ahti 63817d, plot Q3-A5.
Leproloma diffusum – Rosentreter 15867, Camp Copter.

Leptogium arcticum – Holt 23328b, plot NE-5b.
Leptogium lichenoides
Leptogium saturninum – Common on shrub bark.
Leptogium schraderi? – Wiese AK-1-09

Leucocarpia biatorella (Vezda 1969) – Rosentreter 15835b, plot Q3-L5; new to the American Arctic; only recently reported from North America (Buck and Harris 2001, from New Mexico). Otherwise known from high elevations in Europe and from Fennoscandia.

Lobaria kurokawae – Locally common but sporadic in tundra.
Lobaria linita – Fairly common
Lobaria pseudopulmonaria – Uncommon; Holt 22191, plot 04-H3; Holt 23139, plot NW-1b; Holt 23292, plot NE-5b
Lobaria pulmonaria –Holt 23565, plot SW-1b.
Lobaria scrobiculata – Occasional.

Lopadium coralloideum – Rosentreter 15792, plot Q1-L2
Lopadium pezizoideum – Common.

Masonhalea richardsonii – Fairly common.

Massalongia carnosa

Megaspora verrucosa

Melanelia agnata – McCune 27617, Camp Copter; TLC: alectoronic acid.
Melanelia disjuncta – Ahti 63483, Low Rock Ridge.
Melanelia panniformis – Fairly common.
Melanelia septentrionalis – Occasional.
Melanelia sorediata – Occasional.
Melanelia stygia – Common.
Melanelia tominii – Neitlich 2723, plot Q3-H3.
Melanelia trabeculata – Uncommon, herb-rich tundra.

Micarea sp. – Ahti 63481, Low Rock Ridge; McCune 27479, plot Q3-D2.
Micarea crassipes – Wiese K-01-08.
Micarea incrassata – Wiese K-02-03.
Micarea ternaria – McCune 27553, plot Q3-L5; Wiese KAL-01

Multiclavula vernalis – Common.

Mycobilimbia sp. – McCune 27585, outcrops near plot Q3-S4; dark brown convex apothecia.
Mycobilimbia berengeriana – Rosentreter 15736, plot Q3-D2.
Mycobilimbia carneoalbida – Ahti 63817a,plot Q3-A5.
Mycobilimbia hypnorum – Common.
Mycobilimbia obscurata? – McCune 27525, plot Q3-A5.

Mycoblastus alpinus? – Ahti 63817e, plot Q3-A5.

Naetrocymbe punctiformis – McCune 27535, plot Q3-A5 (nonlichenized).

Nephroma arcticum – Locally common but infrequent in Noatak.
Nephroma bellum – Common.
Nephroma expallidum– Common.
Nephroma helveticum – Infrequent on woody plants.
Nephroma parile – Common.

Ochrolechia androgyna – Ahti 63971, plot Q3-L5.
Ochrolechia frigida – Ahti 63338, plot Q3-D2; sorediate f. *lapuensis* (Vainio) Tønsberg; otherwise the typical form is common.
Ochrolechia gyalectoides – Ahti 63531, outcrops near plot Q3-S4.
Ochrolechia inaequatula – Ahti 63967, plot Q3-L5.
Ochrolechia upsaliensis – Rosentreter 15728, plot Q3-D2; Wiese NM-1-10.

Omphalina umbellifera – Rosentreter 15778, plot Q3-H3.

Ophioparma ventosa

Orphniospora moriopsis – Ahti 63932, plot Q3-L2; McCune 27607, Low Rock Ridge.

Pannaria conoplea – Infrequent. Holt 23172, 23185, plot NW-1e; Holt 23552, plot SW-1b; Rosentreter 15779, plot Q3-H3.

Parmelia omphalodes – Common. Specimens similar in morphology to *Parmelia skultii* Hale were analyzed by TLC; none contained norstictic acid, and all had at least a few laminal pseudocyphellae. Although *P. skultii* is expected in Noatak, we have no collections of it.
Parmelia saxatilis
Parmelia squarrosa – Holt 22437a, plot 04-F2.
Parmelia sulcata – Common.

Parmeliopsis ambigua
Parmeliopsis hyperopta

Peltigera aphthosa – Very common.
Peltigera canina – Common.
Peltigera collina – Holt 21842, plot Q3-A5.
Peltigera didactyla – Common.
Peltigera extenuata– Common.
Peltigera horizontalis– Infrequent
Peltigera kristinssonii – Fairly common.
Peltigera lepidophora – Fairly common.
Peltigera malacea – Common.
Peltigera membranacea – Common.
Peltigera neckeri – Holt 23214, plot NW-1c.
Peltigera neopolydactyla – Common.
Peltigera occidentalis – Ahti 63310, plot Q3-D2, conf. O. Vitikainen; ?Ahti 63815, plot Q3-A5; McCune 27483, plot Q3-D2, det. Miadlikowska.
Peltigera polydactylon – Common.
Peltigera ponojensis – Common.
Peltigera praetextata – Holt 22344, plot 04-W4; Holt 22372, plot 04-D1.
Peltigera rufescens– Very common.
Peltigera scabrosa – Very common.
Peltigera venosa – Occasional.

Pertusaria alaskensis – McCune 27502, plot Q3-H3.
Pertusaria bryontha – Ahti 63797, plot Q3-H3; Ahti 63945, McCune 27556, plot Q3-L5.
Pertusaria dactylina – Apparently common.
Pertusaria geminipara – Apparently common.
Pertusaria oculata – Ahti 63308x, Camp Copter.
Pertusaria panyrga – Apparently common.
Pertusaria sommerfeltii – Ahti 63579, Camp Copter.
Pertusaria subdactylina – Rosentreter 15834, plot Q3-L5; Wiese K-01-02.

Phaeophyscia constipata – Holt 23484, plot NE-5c.
Phaeophyscia kairamoi – McCune 27594a, outcrops near plot Q3-S4, det. T. Esslinger.
Phaeophyscia orbicularis? – Wiese AT-1-13f.
Phaeophyscia sciastra – McCune 27594b, outcrops near plot Q3-S4, det. T. Esslinger.

Phaeorrhiza? – Ahti 63952, plot Q3-L5.

Physcia aipolia – Infrequent on woody plants.

Physcia caesia – Fairly common.
Physcia dubia – McCune 27593, outcrops near plot Q3-S4.
Physcia phaea – Holt 23339, plot SE-5a, det. T. Esslinger.

Physconia muscigena – Fairly common.

Pilophorus cereolus – Holt 22262, plot 04-H2; Holt 22297, plot 04-L2.
Pilophorus robustus – Holt 22872, plot NE-3c; Holt 23351, plot SE-2a.
Pilophorus vegae – Ahti 63798, plot Q3-H3.

Placidium norvegicum – Rosentreter 15884, Camp Copter.

Placopsis cribellans – Rosentreter 15785, plot Q3-H3
Placopsis gelida –Rosentreter 15775, 15780, plot Q3-H3.
Placopsis lambii – Ahti 63805, McCune 27503, plot Q3-H3.

Placynthiella icmalea – Fairly common.
Placynthiella oligotropha – Rosentreter 15917, Low Rock Ridge.
Placynthiella uliginosa – Fairly common.

Placynthium asperellum – McCune 27492b, plot Q3-H3.
Placynthium nigrum – Common in calcareous areas.

Pleopsidium sp. – Ahti 63607x, Camp Copter.

Polyblastia terrestris – McCune 27564, plot Q3-L5; Wiese 01-09a.

Polychidium muscicola – Apparently common.

Porpidia sp. – Ahti 63954, plot Q3-L5.
Porpidia crustulata? – Ahti 63795, plot Q3-H3.
Porpidia flavocaerulescens – Ahti 63605, Camp Copter; Wiese NM-1-17
Porpidia grisea – McCune 27609a, Low Rock Ridge.
Porpidia speirea – McCune 27536, plot Q3-L2.
Porpidia superba – McCune 27537, plot Q3-L2; McCune 27539b, plot Q3-L2.
Porpidia thomsonii – McCune 27538, plot Q3-L2; McCune 27563, plot Q3-L5.
Porpidia tuberculosa – Wiese NM-1-07

Protoblastenia rupestris – Rosentreter 15889, Camp Copter.
Protoparmelia badia – Ahti 63843a, plot Q3-A5.
Pseudephebe pubescens – Common.

Pseudocyphellaria crocata – Holt 23179, plot NW-1e.

Psora cerebriformis – Ahti 63553, outcrops near Q3-S4.
Psora decipiens – Rosentreter 15873, Camp Copter; Wiese K-05-03.
Psora himalayana – Rosentreter 15886, Camp Copter; Rosentreter 15893b, 15894b, outcrops near Q3-S4.
Psora rubiformis – Rosentreter 15892, outcrops near Q3-S4.

Psoroma hypnorum – Common.

Pyrenopsis grumulifera – McCune 27539c, plot Q3-L2; McCune 27541, plot Q3-L2.

Ramalina almquistii – Holt 21991, plot 04-B3; Holt 22909, plot SE-6b; Wiese AT-1-06
Ramalina pollinaria – Holt 22992, plot NE-5a.
Ramalina roesleri – Fairly common in forested areas.
Ramalina sinensis – Infrequent; Holt 22010, plot 04-B5; Holt 23551a, plot SW-1b; Holt 23586b, plot SW-1c.
Ramalina thrausta – Holt 22446, plot 04-F2; Holt 23586a, plot SW-1c.

Rhizocarpon chioneum – Wiese K-03-06
Rhizocarpon cinereovirens – McCune 27539a, plot Q3-L2.
Rhizocarpon cumulatum – Wiese K-01-07. This is apparently the first location beyond the type locality (Thomson 1997). East side of Kavachurak Creek , ca. 13 km miles from mouth of creek on gravelly herbaceous knoll with lichen, sedges, and *Dryas* (67.80491^{o}N 156.7081^{o}W, 568 m) The type locality is on the Pitmeaga River on the north slope of Alaska. According to Feuerer (1991) this may be a *Buellia*.
Rhizocarpon eupetraeoides – McCune 27606, Low Rock Ridge.
Rhizocarpon eupetraeum – McCune 27609b, Low Rock Ridge.
Rhizocarpon expallescens? – McCune 27562, plot Q3-L5.
Rhizocarpon geographicum
Rhizocarpon rubescens – Wiese NM-1-04b.

Rimularia limborina – McCune 27501, plot Q3-H3.

Rinodina bischoffii – Wiese K-05
Rinodina mniaraea – McCune 27531, plot Q3-A5; McCune 27610b, Low Rock Ridge; Rosentreter 15700, plot Q3-D2.
Rinodina olivaceobrunnea – McCune 27510, plot Q3-H3.
Rinodina roscida – McCune 27580, plot Q3-S4; McCune 27610a, Low Rock Ridge.
Rinodina septentrionalis – Wiese AK-1-03b
Rinodina turfacea – Ahti 63794f, plot Q3-H3; McCune 27592, outcrops near Q3-S4.

Ropalospora lugubris – Wiese AT-1

Sarcogyne? – Ahti 63843c, plot Q3-A5.

Sarcosagium campestre – Rosentreter 15835, plot Q3-L5, on organic matter.

Siphula ceratites – Rosentreter 15883, Camp Copter.

Solorina bispora – Common.
Solorina saccata? – Ahti 63943, plot Q3-L5.
Solorina spongiosa – Holt 22855, plot NE-2c; Holt 22867, plot SE-5b.

Sphaerophorus fragilis – Ahti 63477, Rosentreter 15906, Low Rock Ridge; Rosentreter 15897b Camp Copter.
Sphaerophorus globosus – Apparently uncommon; Holt 23080, plot SW-6c; McCune 27504, plot Q3-H3; McCune 27574, plot Q1-L2.

Stereocaulon alpestre? – Ahti 63308a, Camp Copter.

Stereocaulon alpinum – Common.
Stereocaulon apocalypticum – Occasional.
Stereocaulon arcticum – Holt 22726 plot SV2.
Stereocaulon arenarium –Holt 22717, 22723, plot SV2; McCune 27505, plot Q3-H3. TLC: porphyrilic acid.
Stereocaulon botryosum – Fairly common. TLC: porphyrilic acid.
Stereocaulon glareosum – Holt 21855, plot Q3-L2; Holt 23382, plot SE-3b. TLC: lobaric acid.
Stereocaulon groenlandicum – Occasional. Five specimens with TLC containing miriquidic acid.
Stereocaulon intermedium – Holt 22242a, plot 04-H2. TLC: lobaric acid.
Stereocaulon paschale – Common. TLC: lobaric acid.
Stereocaulon rivulorum – McCune 27489, plot Q3-H3. TLC: lobaric acid.
Stereocaulon spathuliferum – Holt 23604, plot SV2, TLC: stictic acid complex.
Stereocaulon subcoralloides – Fairly common. TLC: lobaric acid.
Stereocaulon symphycheilum – Occasional. TLC: lobaric acid.
Stereocaulon tomentosum – Fairly common. TLC: stictic acid complex.
Stereocaulon vesuvianum – Infrequent. TLC: stictic acid complex.

Sticta arctica – Infrequent. Ahti 63343a, plot Q3-D2; Holt 23121, plot SW-4b; Holt 23444, plot SE-4a; McCune 27517, Neitlich 2758, cyanolichen-rich tundra near plot Q3-H3.

Syzygospora bachmannii (nonlichenized, lichenicolous fungus) – Ahti 63309a, plot Q3-D2, on *Cladonia gracilis* ssp. *elongata*; Ahti 63314, plot Q3-D2, on *Cladonia crispata* var. *crispata*; Ahti 63347e, plot Q3-D2, on *Cladonia gracilis* cf. ssp. *elongata*.

Thamnolia subuliformis – Abundant. Multiple collections were made at each plot and checked with UV light. *Thamnolia vermicularis* is more common in Bering Land Bridge Preserve (BELA) than in Noatak, while the reverse is true of Noatak. This accords with the observation that *T. vermicularis* is a more coastal species than *T. subuliformis* in the southern portion of its range in North America (McCune and Geiser 1997). *Thamnolia subuliformis* also appeared to be more associated with calcareous substrates, while *T. vermicularis* was more associated with acidic, wet lowland habitats dominated by low shrubs.

Thamnolia vermicularis – Common.

Thrombium epigaeum – Rosentreter 15717, plot Q3-D2.

Toninia aromatica – Rosentreter 15875, Camp Copter.

Trapeliopsis granulosa – Apparently fairly common.

Tremolecia atrata – Ahti 63591, Camp Copter.

Umbilicaria arctica – McCune 27495, plot Q3-H3.
Umbilicaria caroliniana – Holt 22784, plot SW-5b; Neitlich 2653, Low Rock Ridge.
Umbilicaria cylindrica – Holt 22276, plot 04-H2; Holt 23275, plot NE-5b.
Umbilicaria deusta – Holt 22263, plot 04-H2.
Umbilicaria hyperborea – Wiese NM-1-16a; Holt 23401, plot NE-7a.
Umbilicaria hyperborea var. radicicula – Apparently fairly common.
Umbilicaria phaea – Ahti 63934, plot Q3-L2.

Umbilicaria polyphylla – Holt 22694a, plot NW-5a.
Umbilicaria proboscidea – Common.
Umbilicaria torrefacta – Common.

Varicellaria rhodocarpa – Apparently common.

Verrucaria sp. – Ahti 63800, plot Q3-H3; Wiese K-01.

Vestergrenopsis elaeina – McCune 27491, 27492a, plot Q3-H3.

Xanthomendoza borealis – McCune 27514, Neitlich 2781, bird perches on knob of volcanic rock above plot Q3-H3.

Xanthoparmelia coloradoensis – Neitlich 2774, 2775, plot Q3-H3.

Xanthoria elegans – Wiese K-04-01; Wiese K-04-03.
Xanthoria polycarpa – Holt 22009, plot 04-B5.
Xanthoria sorediata – Rosentreter 15914, Low Rock Ridge.

ACKNOWLEDGEMENTS

We thank Sarah Nunn and Amanda Hardman for assistance with field work; Othmar Breuss, Ted Esslinger, Doug Glavich, Jolanta Miadlikowska, Arne Thell, and Orvo Vitikainen for checking selected specimens; and Corinne Duncan, Myrica McCune, and Courtney Miller for TLC and lab work. Tracy Wiese and Bruce Carter made numerous lichen collections along the Noatak River that were included in this study. Funding was provided by the National Park Service, cooperative agreement number CA9088A0008.

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