INVENTORY AND MONITORING PROJECT

VEGETATION PROTOCOL

DENALI NATIONAL PARK AND PRESERVE

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INTRODUCTION

The location of the zone of transition between boreal forest and tundra, often referred to as treeline, has shifted in the past in response to climate change (Hopkins 1972). Anthropogenic influence in climate pattern is predicted to have a major effect on this ecotone within several decades, when the boreal forest is likely to expand into areas that are now upland tundra (Chapin et al. 1992). A recent study has detected a shift in the growth patterns of conifers at many boreal forest locations (Briffa et al. in press). The vegetation changes at the northern treeline, in turn, are expected to have feedback effects on global climate through changes in carbon budgets and albedo (Starfield and Chapin 1996). Accompanying changes in the rate and frequency of natural disturbances, including fire and insect outbreaks, will both cause and be caused by vegetation shifts.

The vegetation in Alaska's largest national parks and preserves, including Denali, Wrangell St. Elias, Gates of the Arctic, Katmai, and Noatak, is dominated by a mix of boreal forest and upland tundra. The predicted expansion of the boreal forest into the upland tundra would have major effects on distribution and population size of the plant and animal species. Monitoring vegetation parameters that will predict and document this shift as it occurs will be a useful adjunct to monitoring of other park resources.

The vegetation monitoring portion of the initial phase of the Denali inventory and monitoring study was designed to focus on parameters of the boreal forest/upland tundra ecotone which may help detect a response to climate change against the background of natural variation. This study appeared likely to provide the most useful information from the landscape unit selected for this study, a small watershed which crosses treeline. The treeline species in this watershed, white spruce (*Picea glauca*) is also the major treeline species in other Alaskan parks and throughout western North America, both currently and historically (Hopkins 1972). The treeline ecotone in this watershed is particularly suitable for monitoring because the density of white spruce trees in upland areas across the elevational gradient is not limited by topography or influenced by major differences in substrate.

The vegetation monitoring program for climate change which has been tested in this Denali watershed can be expanded to other areas of similar landscape scale, but does not represent a comprehensive vegetation inventory and monitoring scheme for Denali or other national parks. This is intended to be integrated into vegetation program which currently includes parkwide plant species inventory, wildfire monitoring, and vegetation mapping, as well as programs which focus on human impact on small landscape units, such as exotic species management, monitoring impacts of roads and trails, and restoring disturbed sites.

The vegetation monitoring in the riparian zone of this watershed has a slightly different focus. Just at the current treeline, the stream enters a narrow canyon that does not support riparian vegetation. Therefore, monitoring of any expansion of treeline is limited to the upland areas. Furthermore, the Rock Creek valley below the canyon is narrow and steep, with little room for stream movement and the development of stable terraces that would support riparian succession as described for interior Alaska (Viereck 1970, Walker et al., 1986). Most of the riparian vegetation in this watershed is frequently disturbed by flooding that both erodes new channels and deposits large amounts of rock and gravel. This maintains early successional vegetation dominated by willows (primarily *Salix alaxensis*) and alder. This type of stream is common in Denali and in other Alaskan national parks. This protocol is an attempt to monitor vegetation dynamics in this type of unstable environment.

The vegetation study of the Denali National Park Long Term Inventory and Monitoring project was initiated in the Rock Creek drainage during the 1992-1995 growing seasons. The specific objectives are as follows:

- Monitor composition and structure of major plant communities in the watershed, including monitoring natural change (wildfire, flooding, climatic variation).

- Monitor growth rate and reproduction of the dominant treeline species, *Picea glauca*.

- Collect data compatible with other long-term monitoring data sets for (1) similar plant communities and (2) white spruce growth rates and reproduction.

- Compare data with other sites to amplify monitoring power.

The project protocol is based on, and data-compatible with, the well-established National Science Foundation Long Term Ecological Research (LTER) study at the Bonanza Creek Experimental Forest near Fairbanks, Alaska. The vegetation measurements are based on standard procedures (Bonham 1989, Husch et al. 1982).

METHODS-VEGETATION ANALYSIS

Permanent vegetation plots were established in 1992 in the following vegetation types: forest (*Picea glauca/Populus tremuloides/Betula papyrifera*), open woodland at the treeline (*Picea glauca/Betula glandulosa*), alpine tundra with a variety of forbs and prostrate woody plants, and riparian tall shrub (*Salix alaxensis/ Alnus crispa*). Plots were randomly located with the restriction that the area within the plot was topographically homogeneous. Three replicate plots are established in forest, riparian, treeline, and tundra.

The watershed had a small area on the north-facing slope of open woodland (*Picea mariana*) underlain by continuous permafrost. This area was of interest to the soil scientists and a meteorological monitoring station was established at this site, but was rejected for vegetation plots because it was too small. However, at the request of the soil scientists, two replicate plots were established in the area in 1995.

Plot design, including the nested plot design, the subplot sizes for trees, shrubs, and herbs, the cover classes, and the monitoring methods are based on and compatible with the Bonanza Creek LTER site near Fairbanks. Similar methods have been used for the last 30 years to establish vegetation plots throughout Alaska (Viereck et al. 1992). These methods are based on classic techniques for vegetation analysis (Oosting 1956). To accommodate plant communities with low cover, such as pioneer and alpine plant communities, the cover classes differ in number and magnitude from the classic methods.

Establishing Vegetation Plot Boundaries and Markings

The basic plot design has an inner plot nested within an outer plot. The area between the inner and the outer plot boundaries has been designated as the "buffer" region. This buffer area is used for instrumentation, "destructive sampling" (i.e. small soil samples and vegetation species verifications), and berry counts.

Each replicate plot is oriented approximately N-S. The outer plot boundary is marked with rebar w/yellow caps. White PVC stakes (0.5 m) w/orange painted tops were slid over the rebar to make the outer boundary more visible. The inner plot boundary is marked with Rebar w/yellow caps and white PVC (0.5 m) over the rebar.

The corners of the outer and inner replicate plots are labeled with 2"x 4" aluminum tags using a heavy gauge wire. Labels indicate the name of the site, replicate #, and the orientation of the corner from the center (NW,SW,NE,SE).

The SW corner of each block has been assigned as the coordinate origin (0,0) for the vegetation mapping of the inner block . From this point, tapes are laid out to form the "X" and "Y" axis. (see below).

<u>The inner replicate plot area must not be walked in except for one yearly tree</u>

measurement and 10-yr vegetation measurements. Trampling may alter ground vegetation, seedling establishment, and the soil thermal regime, which would compromise the value of long-term measurements. Trampling should be kept to a minimum in the buffer zone. Avoid trail formation around the inner plot boundary. In addition, two "Research Area" signs are posted around the block area of Forest Replicate 3 during the field season. The well defined moose trail, which runs through the middle of this replicate plot, had also become a researcher passage during the '92 season.

Forest and treeline replicate plots

For the forest and treeline plots, the outer replicate plot boundary is 50 x 50 m (2500 m^2, 0.25 ha). The inner replicate plot boundary is 25 x 25 m (625 m^2, 0.06 ha) and is centered within the outer plot. Within the inner plots, 12 study subplots have been set up for measurements of vegetative cover. The cover subplots consist of a 2 x 2 m (4 m^2) plot for measuring shrub cover, with a nested 1 x 1 m (1 m^2) plot for measuring herbaceous cover. The S.E. corners of the cover plots are oriented at the cross points formed from transects at X=7,13,19 and Y=4,9,14,19.

Tundra plots

For the tundra plots, the outer replicate plot boundary is 20 x 20 m (400 m^2, 0.04 ha) and the inner plot is 10 x 10 m (100 m^2, 0.01 ha). The 12 herbaceous cover 1 x 1 m (1 m^2) subplots are set up at the cross points formed by transects at X=3,6,9 and Y=2,4,6,8. There are no shrub cover plots in the tundra replicates.

Riparian Replicate Plots

The boundary for each outer riparian replicate plot is 10 x 10 m (10 m^2, 0.01 ha). The inner plot boundary is 5 x 10 m with the 5 m side adjacent to the creek, creating a buffer zone of 2.5 m on the N and S sides (Fig. 1). The plots must have no buffer zone on the stream side because the interaction of stream dynamics and vegetation should be monitored to the stream edge. The rebar stakes marking the inner plot are set back from the stream edge so they won't be washed away. The design for the inner block is a 5 m x 10 m area. The S.W. corner of the inner block is the designated coordinate origin (0,0).

Within the inner plot, there is a 2 x 8 m plot for mapping tree sapling/seedlings. Within this plot, there are three plots for measurement of vegetative cover. The cover subplots consist of a 2 x 2 m (4 m^2) plot for measuring shrub cover, with a nested 1 x 1 m (1 m^2) plot for measuring herbaceous cover. The S.E. corners of the cover plots oriented at the points formed from transects at X=4.75,9.25 and Y=0.5.

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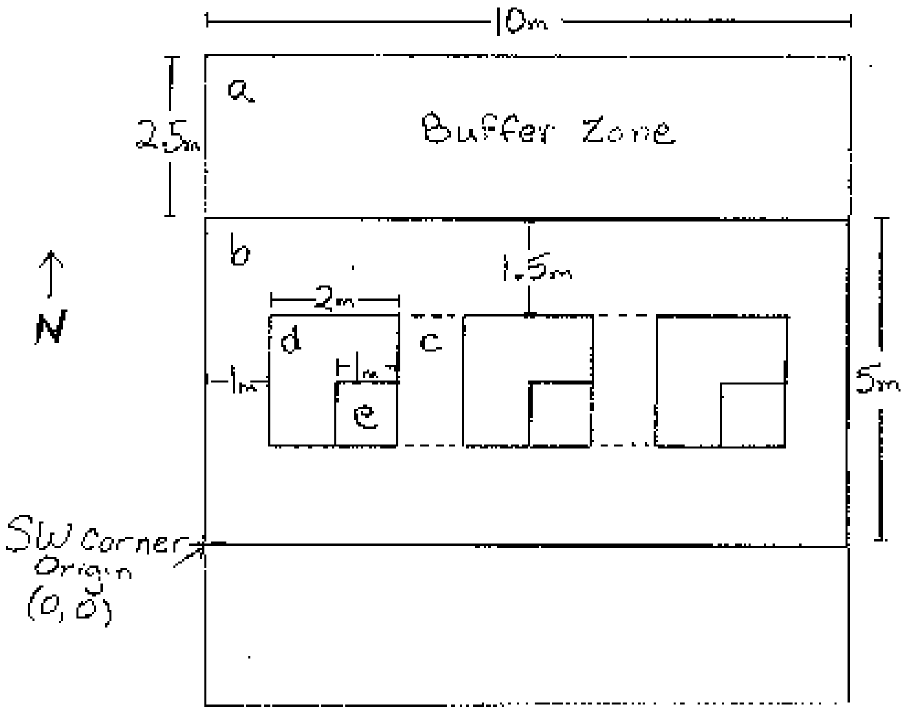
Fig. 1. Plot design for riparian plots; (a) 10 x 10 m outer plot, (b) 5 x 10 inner plot, (c) 2 x 8 m subplot for measuring tree sapling/seedlings, (d) 2 x 2 m plot for shrub cover, and (e) 1 x 1 m plot for low shrubs, forbs, mosses, and lichens.



Species List

All vascular plant, moss, and lichen species present within the inner plots of all the replicate plots are identified and listed. Voucher specimens are collected of species which are not readily identified in the field and/or are not well-represented in the Denali National Park and Preserve herbarium. Voucher specimens are never collected from the inner plot, but from the buffer zone or outside the buffer zone if necessary. Nomenclature follows Hulten (1968) for herbs, and Viereck and Little (1972) for trees and shrubs.

Vegetative Cover Measurements

Cover for shrubs whose mature height is over 0.5 m, such as willows and alders, is measured in the 12 - 4 m^2 subplots within the inner forest and treeline replicate plots, and in the 2 - 4 m^2 subplots in the inner riparian replicate plots. Low shrubs are sampled with other low-growing plants in smaller subplots (see below).

Low shrub, herb, lichen, moss, and other ground surfaces (litter, bare soil, rock) is measured by species in the 1 m^2 subplots nested within the 4 m^2 shrub subplots within the inner plot.

Cover percentage estimates are as follows: <1% = 1%; 1-10% estimate at 1% intervals; 11-90% estimate at 5% intervals; 91-100% estimate at 1% intervals (Appendix A, Cover data sheet).

Schedule for Long-Term Monitoring

Measurements of vegetation cover and plot surveys for the species lists are to be repeated every 10 years unless catastrophic environmental change such as fire, landslides, or severe flooding occurs. Measurements should be repeated as soon as possible after catastrophic change. The 10-year interval in the absence of catastrophic was selected for three reasons: (1) most subarctic plants are long-lived perennials with slow growth rates, and vegetational response to environmental change is likely to be slow; (2) observer bias will obscure small changes; and (3) for many reasons, it will be surprising if the plots are monitored even every 10 years.

Mapping and Measuring Trees, Saplings/Seedlings, and Logs in Forest and Treeline Plots

Trees

A tree is defined as having a diameter at breast height of greater than 2.5 cm, and includes large willows and alders. By convention, tree diameter is measured at "breast height", which is standardized at 1.3 m, and is referred to as "diameter at breast height" or "DBH" (Husch et al. 1982). Where a tree bole forks below 1.3 m, each fork with a diameter of greater than 2.5 cm is considered an individual and given an I.D. number. This includes trees with multiple trunks from ground level, such as paper birch, willow, and alder.

Each tree is assigned a number and tagged with aluminum tags (stamped with an I.D. #). The I.D. tags are nailed into the trees at height at which tree diameter is measured and to aid with future DBH measurements. The aluminum nails used are less damaging to the tree than the standard nails. The nails are only partially nailed in and should be pulled out as the tree diameter enlarges. DBH is read just above the nail following these guidelines:

1. DBH measured on the trunk at 1.3 m above ground level.

2. On inclined trees, measure the DBH at 1.3 m from the ground level on the side opposite the direction of inclination of the tree.

3. Where a tree is on a slope, measure 1.3 m above the ground on the uphill side of the tree.

4. If the tree is on a slope and is inclined uphill at an angle of >45 degrees, the DBH is taken from the opposite side of the inclination of the tree.

5. These guidelines also apply to decumbent trunks of alders and willows, which are measured along the length of the trunk from the base to 1.3 m.

6. Where a tree bole (trunk) is forked at breast height, measure DBH below the point where the tree forks.

7. Where a tree bole forks below 1.3 m, measure the DBH of each fork. Each fork is considered an individual and given an I.D. number.

8. If a root covers the entire ground area on the uphill side of the tree, the 1.3 m distance for the DBH is measured from on top of the root at the point where the root and the vertical part of the tree meet.

9. If the root is smaller and only covers a portion of the ground area on the uphill side of the tree, the 1.3 m distance for the DBH is measured from the ground level on side of the root.

The height of tall trees is measured using a clinometer. The height of small trees and sapling/seedlings can often be measured with a meter stick or a longer measuring stick, such as a level rod. The height of leaning or decumbent trunks and stems is measured as the vertical distance from the ground straight up to the highest point of the trunk or stem (alders often have leaning or decumbent stems).

The coordinates of all trees (dead and live) in the block areas are recorded (Appendix B, mapping data sheet). As stated above, the SW corner of each block has been assigned as the coordinate origin (0,0) for the vegetation mapping of the inner block (25 m sq.). From this point, tapes are laid out to form the "X" and "Y" axis. The coordinates for each tree and sapling/seedling are used to generate maps of tree and sapling/seedling locations for each plot (Fig. 2). Sapling/seedlings are mapped separately to make the maps easier to read.

The condition of the tree is described using the condition codes (Table 1). An individual tree may have several applicable condition codes. These condition codes are based on the Bonanza Creek LTER protocol so that data can be compared between the two sites. Therefore, the codes should not be altered without coordinating changes with that program.

Seedlings and Saplings

The coordinates of all tree seedlings and saplings are recorded. In the forest and treeline plots, this category includes white and black spruce, paper birch, aspen, and balsam poplar plants with a DBH < 2.5 cm which have at least one additional branch off of the main leader. These sapling/seedlings are mapped to predict changes in stand density across the spruce treeline ecotone.

Seedlings under 0.5 m are labeled with aluminum tags at their base using a loosely tied electrical wire. (Durable and less damaging than bare wire, the electrical wire, tied loosely, will allow for 5 years of growth.) Seedlings that are > 0.5 m are labeled with the thicker adult tree tags that have been cut down in size. These seedlings are tagged with loosely affixed electrical wire at one or two whorls from the top of the main leader. In these stands, the alder and willow plants are all mature or decadent with sprouts at the base. Sprouts are not included as sapling/seedlings. If disturbance creates suitable seedbeds and sunlight, willow and alder seedlings may establish. These would be measured as described for the riparian plots (below).

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Fig. 2. Sapling/seedling location map for a permanent plot.

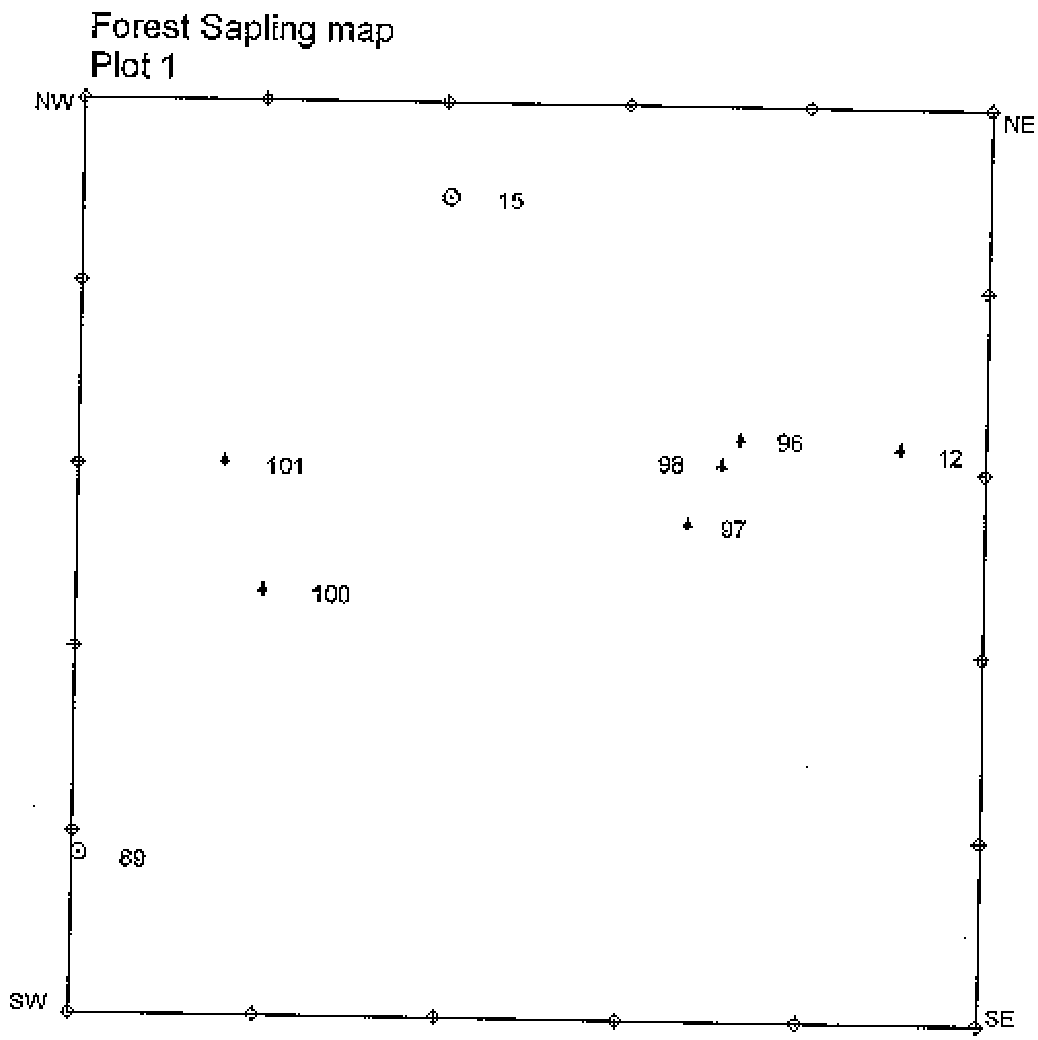

Table 1. Condition codes for trees.

A	=	alive
BL	=	bleeding
BN	=	banded
BU	=	burned
BW	=	bowed (curved over its entire length)
BR#	=	broken but still attached at # m above the ground
CV#	=	curved at # m above the ground
CO	=	contorted (abnormally or violently twisted)
CR	=	cracked (open or closed over)
D	=	dead
DT#	=	dead top at # m
F	=	fork
F#	=	# forks beginning at # m above the ground
HR	=	horizontal but alive
LN	=	leaning at x angle
MB#	=	missing bark at # m above the ground
OK	=	fine and dandy
SK	=	sick
SP#	=	split with #(s) tree (growing from the same base)
T#	=	topped at # m above the ground
TW	=	twisted
WD	=	wounded
WB#	=	witches broom at # m above the ground

Logs

A log is defined as a "dead and down stem" with a minimum diameter of 10.0 cm at one end. The coordinates of the larger and the smaller end of each log were recorded as well as the diameter at each. Logs were also classified into decay classes in the 1992 field season, but this part of the protocol was dropped. The logs are not labeled in the field and should be located from coordinates or a field map at the 10-year measurement interval. The guidelines for measuring log diameters are as follows:

1. If a log is decaying into the ground, the DBH is measured on the top surface and extrapolated below.

2. On logs that are split only measure the largest branch for diameter.

3. If logs lie partly outside the inner plot boundary, measure diameter where it enters the inner plot.

Mapping and Measuring Trees, Sapling/Seedlings, and Logs in Riparian Plots

The protocol is slightly different for the riparian plots. These plots are dominated by stands of alder and willow (primarily *Salix alaxensis*). Plants in these plots have multiple stems that are replaced by resprouting when they die from old age or being knocked down by flooding. There are also many seedlings on areas where vegetation has been eroded away and new soil has been exposed or deposited. The riparian plots are intended to monitor this stem turnover and seedling establishment.

In the riparian plots, the coordinates of all trees in the 5 x 10 m inner plot which have a DBH ≥ 1.0 cm (live and dead) are recorded. Each tree trunk/stem with a DBH ≥ 1.0 cm is assigned an ID number. If the tree trunk/stem DBH is ≥ 5.0 cm, it is labeled with a heavy gauge aluminum tag which is nailed to the trunk/stem at 1.3 m from its base. If the DBH is < 5.0 cm, it is labeled with an aluminum tag loosely tied with electrical wire. The height and condition code of each labeled trunk/stem are recorded as described for forest and treeline plots.

Sapling/seedling size trees with a maximum DBH < 1.0 cm are mapped and measured in a subplot within the inner plot because seedling density is so high that using the whole plot is too time-consuming. The subplot is 2 m x 8 m, centered within the mapping block (Fig. 1). It is measured 1 m in from the north and south sides and 1.5 m in from the west and east sides. The coordinates of all sapling/seedlings are recorded and each is assigned an ID number. Sapling/seedlings are labeled in the same way as those in the forest and treeline plots. The basal diameter of the sapling/seedlings < 1.3 m was measured.

All logs ≥ 3.0 cm (vs. ≥ 10.0 cm for forest and treeline plots) at the large end are labeled and measured following the methods described for forest and treeline plots.

Maps and Annual Tree Condition Monitoring

Each year, the condition of the trees in the forest, treeline, and riparian plots is monitored. Take a copy of the plot maps and a copy of the tree condition descriptions into the field. Record conspicuous changes by tree number. For example, in the last four years some trees have fallen over and other trees have had the tops broken off. Easily noticed dead or broken sapling/seedlings should be recorded, but comprehensive monitoring of sapling/seedling health and seedling recruitment is conducted only at the 10-year assessment to reduce trampling which might damage seedlings.

METHODS-WHITE SPRUCE GROWTH

Measurements of the annual growth in the diameter of individual tree trunks are a are important for measuring and modeling forest dynamics because this measurement can be used to calculate annual biomass accumulation (Shugart and Prentice 1992). Tree cores are often used to provide data on past diameter growth, but repeated coring would be too destructive on long-term plots. Dendrology banding, in contrast, is a non-invasive but accurate method for following the changes in tree bole diameter (Husch et al 1982).

Dendrology bands were installed in the Rock Creek vegetation plots in August 1992. Five trees were banded per block in the forest plots. At treeline there were not enough trees to band five trees/block. The trees selected for the installation of the dendrology bands are representative of the average DBH sizes in the vegetation block. (In the statistical design of this study, the replicate block is randomly selected, and any plot value (i.e. the mean diameter growth of the five trees), but measurements of individuals within the plot are not random).

Tree band construction and installation

The following materials and methods used for band making and installation are based on those used in the LTER study. The band material was ordered from:

Royce Aerospace Materials Corp.
7200 New Horizons Blvd.
N. Amityville, NY 11701

Specifications:

Alloy Stripping, Invar 36, Rustproof
Coefficient of expansion: 0.655 in/in F x 10^{-5},
Size: 0.003" x 7/8"
Chemical analysis:

C	MN	S	NI	FE	C_6
0.0026	0.11	0.002	35.96	balance	0.028

The only available crimping tool is in inches. Therefore, the scale on the crimpers and the dendrology bands is in inches and the data must eventually be converted to metric. However, these instructions for constructing, installing, and reading the bands need to be in inches.

The set of banding crimpers used in the '92 season where a loan to us from the USFS Institute of Northern Forestry and were used on the LTER study. At that time this was the only set of crimpers that existed in Alaska. The crimpers are specifically manufactured (not inexpensively) for the crimping of a vernier scale onto banding material. If we intend on continuing with this study in other watersheds or other vegetation plots, the Park Service should consider having some crimpers manufactured for our own study.

1. Cut length of band (circumference at DBH + 23.5 cm). Measure the circumference at DBH from left end of the band and mark the band at this distance.

2. On left end of band, crimp with small crimper 1.5 <u>inches</u> from end (crimp with ridges on top) (Fig. 3a).

3. Cut band down to top of mark and round off end (don't shorten too much). Punch hole near end (Fig. 3b).

4. Mark right end of band with pencil 1.5 <u>inches</u> right of the circumference mark (Fig. 3c).

5. Line large crimper up with pencil mark, and crimp marks to the right of the pencil mark.

6. Punch hole 0.5 inches left of marks. Punch three more holes each 1.5 inches further along band.

7. Fold right end under. Cut 3 inch scrap and fold over in thirds. Slip over end of band.

8. Put band around tree. Feed through loop and attach with spring. The zero line mark for the lower, overlapping scale should be in line with or to the right of the zero line mark for the upper scale (scale closest to the tree trunk or the scale is difficult to read (see Fig. 4 for how it looks).

9. Record date, DBH, and band reading.

Reading tree bands

The dendrology bands must be allowed to settle for one year before a baseline measurement can be taken. Therefore, the Rock Creek bands were installed in 1992 and the baseline measurement was taken in 1993. The bands are read in late August or early September after the trees have stopped growing. Dates for reading bands have been as follows:

1993	Forest 1-2 8/20-31	Forest 3 9/7-8 Treeline
1994	Forest 8/22	Treeline 8/24
1995	Forest 9/12	Treeline 9/13
1996	Forest 7/31	Treeline 8/2

Instructions for reading the dendroband are given in Fig. 5. Bring the plot maps (to locate banded trees) and the previous dendrology readings (to check whether you are reading bands correctly) into the field for reference when the year to year readings are carried out. Record the band readings on the table of previous dendrometer readings that you have brought into the field (Tables 2 and 3).

The table of band readings to date (Table 2 and 3) shows some of the problems with the bands now installed in Rock Creek. First, one band in the forest plots and four bands in the treeline stands were originally installed with the zero mark on the upper scale not aligned with the zero mark on the vernier scale, but with a mark to the right of the zero on the vernier scale. Therefore, these trees had to be read as negative numbers, which is confusing. However, by 1996 only two bands were still reading negative numbers. In the future, bands should never be installed with negative readings. Second, two of the treeline bands have come off and had to be reinstalled, which causes lost of data unless it is caught early in the season. Lost of bands at treeline is most likely due to small trees bending in the wind.

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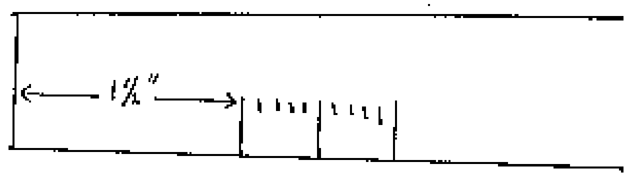
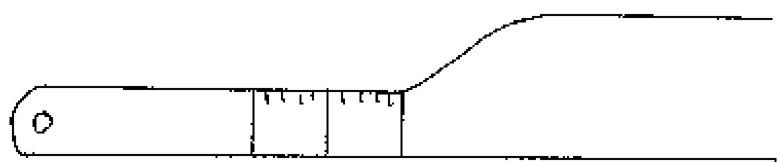
Fig. 3. Construction and installation of dendrometer bands.

(a)



(b)



(c)

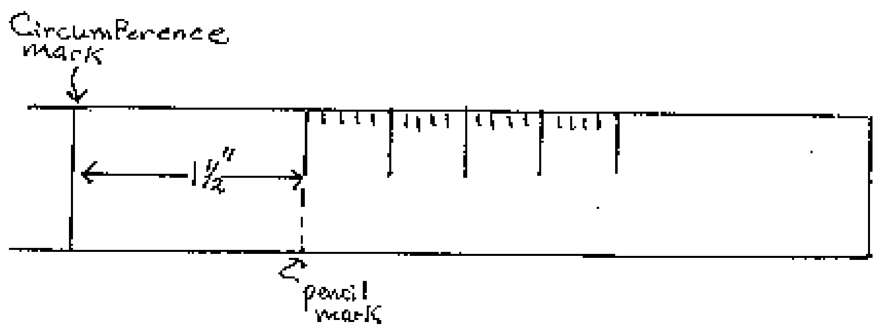


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Figure 4. Reading a dendroband. Each line mark on the top scale equals 0.1 inch. Count the lines from zero until reaching the line just to the left of the zero line on the lower, overlapping scale. The lower, overlapping scale is the vernier scale. Each line mark on this scale equals 0.01 inch. To read this scale, count the lines from zero until reaching the line that lines up most closely with a line on the upper scale. The example reads 0.62.

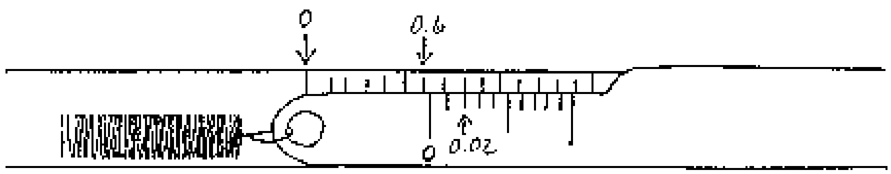

Table 2. Dendrometer band measurements and annual tree diameter growth (in) for the forest plots in the Denali Rock Creek Watershed.

Site	Plot	Tree	1993 Measure	1994 Measure	1994 Growth	1995 Measure	1995 Growth	1996 Measure	1996 Growth
Forest	1	18	0.13	0.20	0.07	0.40	0.20	0.51	0.11
Forest	1	20	0.04	0.20	0.16	0.44	0.24	0.65	0.21
Forest	1	27	0.07	0.10	0.03	0.18	0.08	0.24	0.06
Forest	1	30	1.48	1.50	0.02	1.60	0.10	1.65	0.05
Forest	1	36	0.01	0.09	0.08	0.26	0.17	0.40	0.14
mean±SE				0.07±0.02		0.16±0.06		0.11±0.03	
Forest	2	2	0.09	0.09	0.00	0.25	0.16	0.40	0.15
Forest	2	9	0.04	0.08	0.04	0.15	0.07	0.20	0.05
Forest	2	16	0.09	0.20	0.11	0.38	0.18	0.58	0.20
Forest	2	28	-0.09	-0.01	0.08	-0.04	0.00	-0.01	0.03
	Band 28 installed in 1992 so that mark is one notch over on the vernier scale.								
Forest	2	135	0.11	0.31	0.20	0.37	0.06	0.48	0.11
mean±SE[a]				0.09±0.03		0.09±0.03		0.11±0.03	
Forest	3	11	0.19	0.35	0.16	0.61	0.26	0.78	0.17
Forest	3	12	-[b]	0.20	-	0.41	0.21	0.59	0.18
Forest	3	31	-	0.10	-	0.10	0.00	0.13	0.03
Forest	3	47	1.60	1.60	0.00	1.81	0.21	1.97	0.16
Forest	3	61	0.00	0.00	0.00	0.10	0.10	0.12	0.02
mean±SE				0.05±0.04		0.16±0.09		0.11±0.03	
overall mean±SE[c]				0.07±0.01		0.14±0.02		0.11±0.00	

[a]Plot means calculate negative growth values as 0.00.
[b]No data.
[c]Overall mean is mean of plot means, n=3.

Table 3. Dendrometer band measurements and annual tree diameter growth (in) for the treeline plots in the Denali Rock Creek Watershed.

Site	Plot	Tree	1993 Measure	1994 Measure	1994 Growth	1995 Measure	1995 Growth	1996 Measure	1996 Growth
Treeline	1	1	0.25	0.22	-0.03	0.28	0.06	0.32	0.04
Treeline	1	5	0.15	0.30	0.15	0.59	0.29	0.82	0.23
Treeline	1	7	0.15	0.14	-0.01	0.21	0.05[a]	0.26	0.05
	Band 7 was adjusted to a new baseline of 0.17 in June,1995.								
Mean±SE[b]					0.05±0.04		0.13± 0.16		0.11±0.05
Treeline	2	5	0.11	0.14	0.03	0.26	0.12	0.38	0.12
Treeline	2	8	-0.05	-0.01	0.04	0.02	0.03	0.11	0.09
	Band 8 installed in 1992 so that zero mark on the upper scale was aligned with 0.01 (one notch right of zero) on the vernier scale.								
Treeline	2	13	-0.07	0.09	0.16	0.29	0.24	0.45	0.16
	Band 13 installed in 1992 the same as Band 8.								
Treeline	2	18	-0.27	-0.27	0.00	-0.27	0.00	-0.27	0.00
	Band 18 installed in 1992 so that zero mark on the upper scale was aligned with 0.03 (three notches right of zero) on the vernier scale.								
Mean±SE					0.06±0.03		0.11±0.03		0.09±0.03
Treeline	3	19	-0.41	-0.28	0.13	0.07*	-[c]	0.44	-[d]
	Band 19 installed in 1992 so that zero mark on the upper scale was aligned with 0.05 (five notches right of zero) on the vernier scale.								
	**Band fell off summer 1995, replaced with new baseline of 0.07.*								
Overall mean±SE[e]					0.06±0.0	0.12±0.01		0.10±0.01	

[a]Value includes an estimated measure of growth in the 1995 growing season before the band was readjusted.
[b]Plot means calculate negative growth values as 0.00.
[c]No data.
[d]Band settling during first year. 0.44 should be baseline.
[e]Overall mean is mean of plot 1 and 2 means, n=2.

METHODS-WHITE SPRUCE SEED PRODUCTION

Production of viable seeds is a major bottleneck in the establishment of white spruce, and is therefore a major factor in the location and composition of boreal forests (Walker et al. 1986, Zasada 1990, Zasada et al. 1978, Zasada et al. 1992). Good cone crops are sporadic throughout the range of white spruce. In addition, the production of mature seeds requires an adequate length of time with warm temperatures. At treeline, seeds may be so immature that cones do not open and are held on the tree. A treeline tree may produce only one or two good seed crops in a lifetime. The lack of mature seeds at treeline can affect the location of treeline as much as conditions for vegetative growth.

Counting cones provides a rough estimate of the potential number of seeds. Seed traps measure the number of seeds which fall out of the cones, and germination tests estimate the number of viable seeds produced. A continuing increase in the proportion of viable seeds indicates a shift in weather patterns and a potential for an expansion of treeline.

Cone Count

The white spruce cone crop is counted every year during the during the last week of July and the first week of August, after cones should have attained maximum size and before squirrels have harvested large numbers of cones. From outside the block, one simply counts the number of cones that are visible on the North side of the selected trees using a pair of binoculars (method after Zasada et al. 1978). The five banded trees in each plot are counted in each of the replicate blocks at the forest site. At the treeline site, 5 trees/block are designated for the cone count since there are not 5 banded trees in each of these replicate blocks. The block map and the tree I.D. numbers are used to locate the trees to be counted (Appendix C, cone count data sheet).

Measuring Seed Rain

<u>Construction of Seed Traps</u>

The seed traps are 0.54 m x 0.54 m wooden frames with a seed collection area of 0.25 m^2. The bottom side of the frame has been fitted with a piece of wire hardware cloth with 0.56 cm^2 (0.25 in^2) openings. An 0.8 m x 0.8 m piece of unbleached muslin cloth (available at most fabric shops) is stapled into the trap tautly to prevent the wind from blowing up the muslin and knocking the seeds out (Fig. 6). A Leatherman or some similar tool may be needed to fix staple jams and to pull out old staples. No gaps between the muslin and frame should be left to catch seeds. Another piece of wire hardware cloth with 0.56 cm^2 holes (large enough to allow seeds to pass through but small enough to block out small mammals) is stapled over the top.

The seed traps are set out every year around August 15. Six seed trap frames are placed in the buffer zone of each 50 m x 50 m forest and treeline plot in Rock Creek. Traps should be placed in an open area on a flat surface. The exact location of the seed traps intentionally remains unmarked to encourage rotation of trap location from season to season allowing the vegetation to

recover. At this time, there are two traps in the parts of the buffer zone on the north and south side of the inner 25 x 25 m plot and one trap in the parts of the buffer zone on the west and east sides. At the treeline site, avoid placing the traps in microsites exposed to wind. In most microsites at this treeline site, the shrubs protect the traps from wind during the growing season and trap snow for protection during the winter.
Equipment needed: 80 cm x 80 cm square of muslin cloth, staple gun and extra staples, and Leatherman.

Seed Trap Collection

Collect the seed traps between May 15-June 1. Remove all staples holding the wire hardware cloth cover to the seed trap frame. Carefully remove all staples which hold the muslin into the seed trap frame without spilling its contents. Write the site and date on a piece of write-in-the-rain paper and place the label in the middle of the trap and tightly roll up the muslin and its contents and place it in a ziplock bag. Labels should include any comments in reference to the condition the trap was found in; e.g. stepped on by moose. A trap with a loose cover or no cover at all is susceptible to vole and squirrel visits and needs to be documented.

Place the empty seed trap frame and hardware cloth upright against a tree so that the vegetation can re-grow where the trap had been sitting all fall and winter.

Bring seed traps indoors and remove the muslin traps from the ziplock and allow the traps and their contents to dry thoroughly (1 or 2 days depending on how wet they were when collected). After they are dry, place them back into the ziplock bag and seal the bag so the seeds won't completely dehydrate and die. Place all traps in a freezer until you are ready to process them. These steps prevent the seeds from rotting and losing their viability.

Equipment needed: Pliers, 3 large ziplock bags, labels (All-weather cotton paper marked with site name, replicate number, trap number, date and comments).

Seed Processing

Lay out a large piece of paper on a well lit desk. Carefully dump all the contents of the muslin seed trap onto the paper. Roll the muslin back up and place aside for inspection later. Pile the contents of the trap in the middle of the paper and begin by spreading about a teaspoon of the trap litter across the paper in front of you. Look carefully at each particle of litter and separate out the spruce seeds using the forceps and hand lens if needed (Fig. 6). When the litter has been sorted, carefully examine the empty seed trap for seeds that may be stuck to the fabric.

Record data on seed trap data sheets (Appendix D). All seeds from each seed trap should be placed in a small envelope labeled according to the label found in the seed trap and sealed. All processed seed envelopes should be placed in a ziplock bag and put back in the freezer until you are ready to germinate them.
Equipment needed: Small forceps, hand lens, 1 large piece of white paper, several small

envelopes (small envelopes may be made by folding scraps of paper), seed trap data sheets.

Seed Germination

Take several Kimwipes or other tissue (as many as the thickness of 1/2 cm) out of the box and cut into squares about 6 cm x 6 cm (the size of a square which fits exactly into a petri dish). Place the Kimwipe squares into the petri dishes and wet each one using the distilled water. Pour off the excess water until no more water will drip off the Kimwipe square. Smooth out the surface of the square and begin to place the seeds in rows. Every row placed should contain the same number of seeds in order to make counting easier later. Each seed trap should have its own petri dish. Two dishes may be used if necessary for one trap.

Label each dish with the information found on its labeled seed envelope. The seeds in the petri dishes should be carefully placed into a ziplock bag and put in the refrigerator. Leave the seeds in the refrigerator for 60-90 days.
Equipment needed: Petri dishes, Kimwipes, distilled water, forceps, grease pencil or sharpie, scissors, large ziplock bags.

After refrigerating for 90 days, move the dishes to room temperature (20-22^{o} C, 68-72^{o} F) in a spot where they will receive some light. Remove seedlings as they germinate and record on seed trap data sheets. After 30 days, determine the viability of any ungerminated seeds with a cutting test. Cut the seeds in half with a single-edge razor blade or a scalpel. Viable seeds will be white and crisp, and the embryo and endosperm will fill at least three-fourths of the seed. Non-viable seeds will have yellow squishy material, dried material, or nothing in the seed. Seeds will often have a fungus growing on and around them. This fungus is usually most abundant on rotten seeds, but it is not the cause of death. Viable seeds seem to be unaffected by the fungus. Record the number of viable ungerminated seeds (usually very few). The number of germinated seeds plus the number of ungerminated viable seeds is the number of viable seeds in the sample.
Equipment needed: Hand lens, seed trap data sheets

Long-Term Monitoring

It is important that the monitoring of seed production be continued on a yearly basis. The results to date are presented in Table 4, including comparison to seedfall in three stands at the LTER site near Fairbanks. Seed crops are poor at both sites from 1993-1995, but do not vary from year to year in a synchronous fashion, even within the LTER site. The most important future data will determine if good crops are synchronous and what climatic factors are associated with good crops at both sites.

25

Fig. 5. Design of seed traps.

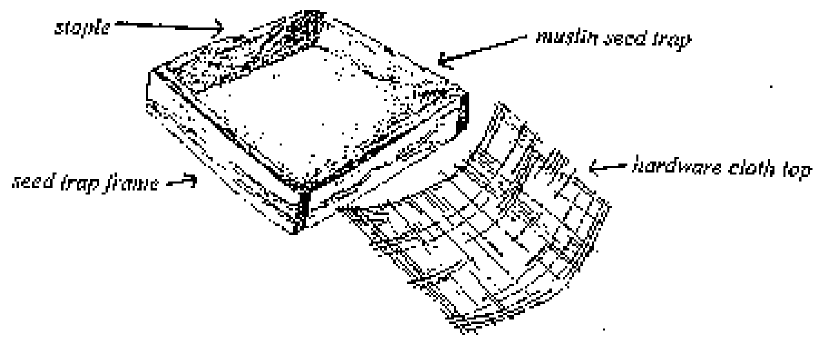

Fig. 6. White spruce seeds; (a) magnified and (b) actual size.

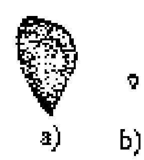

Table 4. Annual cone production, total seedfall, and viable seedfall of white spruce in Rock Creek watershed and at the LTER site near Fairbanks. Values for Rock Creek are the mean ± S.E. of the measurements taken in three permanent plots, and LTER measurements are based on one permanent plot.

	1993	1994	1995
Forest site			
Total seeds/m^2	16.2 ± 7.1	264.2 ± 38.8	9.5 ± 1.9
Viable seeds/m^2	1.3 ± 0.3	16.2 ± 2.7	0.0 ± 0.0
Cones/tree	126 ± 58	67 ± 9	0 ± 0
Treeline site			
Total seeds/m^2	1.7 ± 0.5	13.3 ± 6.0	1.7 ± 0.5
Viable seeds/m^2	0.0 ± 0.0	1.0 ± 0.8	0.0 ± 0.0
Cones/tree	104 ± 42	21 ± 12	31 ± 14
LTER site, Fairbanks[a]			
Upland site 3A			
Total seeds/m^2	0	7	1
Viable seeds/m^2	-[b]	-	-
Floodplain site 3A			
Total seeds/m^2	162	40	110
Viable seeds/m^2	70	0	3
Floodplain site 4A			
Total seeds/m^2	103	25	3
Viable seeds/m^2	4	2	1

[a]Cones not counted on LTER site.
[b]Seeds not tested for viability in 1993.

METHODS-BERRY CROP MEASUREMENTS

Berry crops are critical factors in the distribution and population dynamics of many park mammals, particularly bears and voles. Berry crops are monitored throughout the park as part of a study of grizzly bear population dynamics. Berry plots were added to the Rock Creek study because the intensive meteorological data could be used to relate weather patterns to berry crops.

The primary berry food sources in the park are blueberry (*Vaccinium uliginosum*), crowberry (*Empetrum nigrum*), and soapberry (*Shepherdia canadensis*). Of these three, blueberry and crowberry are abundant in the Rock Creek watershed. The berries on all the berry-producing species present in a plot are counted because large less-common species may be important when the common species have a poor crop, and the information is easy to obtain. Less-common berry-producing species include lowbush cranberry (*Vaccinium vitis-idaea*), red-fruit bearberry (*Arctostaphylos rubra*), bunchberry (*Cornus canadensis*), and *Geocaulon lividum*.

Observations of blueberry, crowberry, and cranberry crops have shown that there are consistently productive patches within a matrix of consistently unproductive plants (Densmore unpublished data). Bears (and probably other mammals and birds) concentrate on the productive patches for foraging efficiency (Welch et al. 1997). Monitoring unproductive plants provides little information on berry crop variations important to animals. Therefore, all the berry plots in the park, including those in the Rock Creek watershed, are placed in microsites or clones where one or more of three most common berry species are productive.

The berry crop plots are set up in the buffer region between the inner block and the outer replicate boundaries. Each forest and treeline replicate plot has two berry plots. Tundra replicate plot 2 has two berry plots, and the other two tundra plots do not have berry plots because they have few or no berry-producing species. The riparian site does not have berry plots installed since it also does not have the berry-producing species.

The monitored areas are 0.5 m x 1.5 m and are set within a larger 1.0 m x 2.5 m plot which is marked on the SW and NE corners using rebar w/yellow caps.
The berry count should occur during the first week of August. The area to be counted is 0.5 m in from the boundaries delineated by the corner stakes. A 0.5 m x 1.5 m study area is formed. (Pin flags are useful for this.) All of the fruit producing species within that area are recorded and the number of berries/species are counted (including the ones that may have fallen and are hidden in the moss layer). The observer should not eat the fruits from within the buffer area! (Appendix E Berry Crop Study data sheet). Results for the most common species are shown in Table 5.

Table 5. Berry production in Rock Creek Watershed. Values are the number of berries per 0.75 m^2. Values are the mean of two subplots within the buffer zone of each vegetation plot.

Species	Plot	1994	1995	1996
Forest Site				
Vaccinium uliginosum	1	7	13	24
	2	2	8	3
	3	3	9	3
V. vitis-idaea	1	0	0	0
	2	2	0	1
	3	4	18	32
Empetrum nigrum	1	0	2	3
	2	2	8	24
	3	0	2	28
Treeline Site				
Vaccinium uliginosum	1	10	24	2
	2	25	36	20
	3	38	60	14
V. vitis-idaea	1	0	0	0
	2	0	0	0
	3	0	0	1
Empetrum nigrum	1	0	0	1
	2	0	10	2
	3	7	4	4
Tundra Site[c]				
Vaccinium uliginosum	2	0	24	0
V. vitis-idaea	2	0	36	0
Empetrum nigrum	2	93	71	75

[a]Some berry species did not occur in all three plots.

METHODS-PHENOLOGY

Phenology readings are conducted in the forest, riparian, treeline and tundra sites once a week beginning May 15 or earlier. A period no longer than 5 days should separate readings on each plot. If possible, plots should be read within a day of each other. Data collected at the forest and riparian sites can be completed in about 4 hours. The treeline and tundra sites can be completed the next day in approximately 8 hours.

Never walk within the inner plots. Use binoculars to look at stages of spruce, shrubs and other vegetation easily seen within the plot. Use ‘buffer zone’ vegetation to record all other phenology. Care should be taken not to create trails around the plots.

Phenology sheets are labeled according to site name (Appendix F, phenology data sheets). Use one phenology sheet for each replicate plot. The numbers in parentheses below each species name on the phenology sheets represent the replicates in which the species may be found. A space is provided after each phenology term for a number, 1-5. This number represents the species phenological stage in percentages. A key to these percentage categories is located at the top of each phenology sheet for reference. Definitions of terms used are shown in Table 6, and phenological stages for selected species are shown in Fig. 7.

Phenology is read by estimating a population's progression in a phenological stage. For example in the "Repro" (reproductive structures) category, *Mertensia* may have as many flower buds as it does full flowers. This relationship can be represented as 50% budding and 50% flowering, equaling 100%. The ‘Leaves’ category should also equal 100%. For example, 75% of the leaves may be expanded while 25% are still in the process of expanding. An example data sheet entry is shown below.

Mertensia paniculata Leaves: expanding_2_ expanded__4_color change___
(1,2,3) Repro: budding_3_flowering_3_ post flower/ seeds maturing__releasing seeds___
seeds released___

This study focuses on the stages of vegetation not productivity, therefore the percent of plants not showing any activity should be dismissed. For example, if a population of 100% *Vaccinium*, has half of its population flowering at peak and half is not flowering at all this year, the phenology data should read 100% (5) flowering in the "repro" category.

It should also be noted that the majority of leaves on trees and shrubs expand early in the season while the tips and shoots extend throughout the rest of the season. Leaves should be considered expanding 100% (5) until ALL growth has stopped.

Development of Phenology Protocol and Current Specific Problems

Establishing an efficient and effective phenology monitoring protocol was difficult, and changes in monitoring frequency and methods are apparent in the data sheets from 1992 to 1995. Monitoring was conducted once a month from 1992-1994, but preliminary analyses indicated that more frequent monitoring was needed to produce useful data (Table 7). In 1995, plots were monitored weekly throughout the growing season.

The number of species monitored started with almost all vascular plants in the plot in 1992, but locating and identifying this many species was difficult and ineffective. By 1995, the list of species being monitored had been reduced to those meeting one or more of the following criteria:

- Easy to locate without trampling plot.

- Easy to identify in the field.

- Phenology of species from the forest, treeline, and riparian sites is being monitored in the Bonanza Creek LTER site.

- Phenology of species from the tundra site is being monitored in the circumpolar ITEX protocol (International Tundra Experiment 1993).

The categories used to describe phenological stages for individual species were also developed and modified over the first four years of monitoring, as can be seen by looking at old data files. The data sets were calibrated and standardized to the 1996 data format before the phenology data base files were created.

There are still several problems in the current methods and techniques of data collection. Some problems were able to be corrected in the phenology database and also on original data sheets using red pen. The original data sheets are filed in the fireproof file in Research and Resource Preservation. The rest of the problems are described below and should be taken under consideration when analyzing the phenology data.

Blank spaces were left on data sheets by observers to denote several things. Some blanks left early on in the season meant that the leaf or flower buds were not developing yet or were not developed enough to be identified by the observer. These blanks should have been filled in with zeros and were corrected and entered as such on the database. Other blanks were left because the species did not exist or were too few in number to follow on that particular replicate. These entries were left blank and not entered unless comments were made about that particular species.

Spaces were left on such categories as "leaves expanded" or "fruits ripe" by mistake or because the observer took for granted that "leaves expanded 5" on the last entry implied that it would be "5" on the next entry as well. Where obvious, the missing data were corrected and filled in. Where it was not obvious what the observer intended, the space was left blank.

Blank spaces at the end of the season may denote the loss of a species at a particular phenological stage. For example, on the tundra site, many flowers and seed capsules are eaten by ground squirrels and data are no longer able to be collected. These were left blank and not entered on the database unless a comment was written on why data collection may have stopped.

The "no cone" column should be eliminated. The same ideas can be represented using other means. If there are no cones on the trees, because they never budded in the first place, then a zero should be used in the "opening/maturing" category. If there are no cones because they finished pollinating or dispersing seeds and fell off, then a five should be used in the "released pollen" or "dispersed seed" space. This was also corrected for in the original data by crossing out the number in the “no cone” category and changing the "dispersed" or "opening/maturing" categories accordingly.

Spruce tree cones and especially paper birch catkins are sometimes difficult to see due to their height. If it is too bright, colors may be washed out or the top of the tree may be just a silhouette. The point at which male cones begin and end releasing pollen is difficult to determine unless the cones are low and accessible. Data collected for male spruce cone pollination may therefore be inaccurate.

The male and female catkins for paper birch are up high and hidden. They are very difficult to see even with binoculars. Data taken on this species may be patchy and incomplete. Data taken in 1996 was complete due to a fallen, but not broken, birch found in the perimeter of the plot.

Another problem arose with assigning a value to leaf/shoot growth. If a branch has ANY growing leaves or shoots on it, it is defined as 100% expanding. In previous years - for example 1995 - shoots and leaves still growing on a branch were described as a percentage of that entire branch’s growth. This was not corrected when the data was entered due to the fact that it can no longer be identified at which point leaves/shoots actually did start maturing and stop growing. It is very important that this be taken into consideration when analyzing the data.

Data collected on emerging willow catkins may be inaccurate due to the fact that early male and female catkins cannot easily be told apart. This is apparent in the “Female catkin maturing” and “Male catkin maturing” categories. Early in the season some data show only one sex maturing. I feel this is due to the possibility that the observer was unsure which catkins were male and which were female at the time. Possibly in the future a general "catkin emerging" category can precede the separate male and female catkin maturing categories. No corrections were made.

The same may be applied to the leaf and reproductive bud categories. Before buds open into leaves or flowers, it is sometimes difficult to tell if the bud is a leaf bud or a flower bud. As above, it may be helpful to have a general "budding" category preceding the "leaf" and "repro budding" categories.

Some of these problems and suggested data collection techniques for specific species are also listed in the section on phenology definitions (see above). Some problems, including standardizing the data base, have already been dealt with by park personnel implementing the program.

Table 6. Definition of Terms for Rock Creek Phenology Sheets

Leaves:	
Budding **-**	The appearance of undeveloped, unexpanded leaves (Fig. 8).
Bud opening **-**	Apparent definition of individual leaves.
Candling **-**	The whitish, furled, undeveloped leaves of *Ledum palustre* (Fig. 8).
Expanding -	Leaves separating from each other and growing to their full size (Fig. 8).
Expanded **-**	Leaves have reached full maturity.
Color Change **-**	Leaves begin to loose their green color and change to red, orange or brown.
Dropping -	Leaves die and fall off of the plant.
Shoots:	
Bud Swelling **-**	The protective winter bud cap enlarges with newly expanding shoots inside (Fig. 8).
Bud Break **-**	The point at which the bud cap separates revealing the new shoot underneath (Fig. 8).
Shoots Extending **-**	New shoots elongating.
Shoots Extended **-**	Shoots have elongated to their full extent.
Repro:	
Picea glauca	
Male Cone Bud Opening **-**	The appearance and expansion of upright, rosy colored cones approximately 1.5-2.0 cm in length (Fig. 8).
Pollen Dispersing **-**	Cones will yield yellow pollen when shaken.
Pollen Dispersed **-**	Cones will no longer yield pollen and are drying out, turning yellow/brown.
Female Cones Maturing **-**	The appearance and growth of small, green to wine colored, fleshy cones usually found at the top of trees (Fig. 8).
Seeds Dispersing **-**	The point at which cones open and seeds fall out.
Problems **-**	It is difficult, even with binoculars, to see the cone phenology on tall spruce trees. If it is too bright, colors may be washed out or the top of the tree may be just a silhouette. The point at which male cones begin and end releasing pollen is difficult to determine unless the cones are low and accessible.

Alnus crispa

Male Catkin Bud Opening -	The appearance and expansion of yellow/brown cones hanging from the ends of branches and elongating before dispersing pollen.
Female Cones Maturing -	The appearance of small, upright, brown/green cone-like fruit approximately, 5-1.0 cm in length.
Problems -	Note should be taken - the majority of alder leaves expand early in the season while the tips and shoots extend for the rest of the season. Alder leaves should be considered expanding 100% (5) until ALL growth has stopped.

Betula papyrifera

Male Catkin Bud Opening -	The appearance and expansion of yellow/brown catkin hanging from the ends of branches and elongating before dispersing pollen.
Female Cones Maturing -	The appearance and expansion of brown/green, hanging cone-like fruits with developing seeds.
Seeds Dispersing -	The point at which the seeds dry and fall from the tree.
Problems -	The male and female catkins for birch are up high and hidden/camouflaged and are difficult to see even with binoculars.

Betula nana/glandulosa

Male Catkin Bud Opening -	The appearance and expansion of yellow/brown catkins hanging from the ends of branches and elongating before dispersing pollen.
Female Cones Maturing -	The appearance of small upright brown/green cone-like fruits.
Problems -	Note should be taken - the majority of dwarf birch leaves expand early in the season while the tips and shoots extend for the rest of the season. Birch leaves should be considered expanding 100% (5) until all growth has stopped.

Salix species

Male Catkin

Maturing - The appearance and growth of a woolly, staminate catkin. Anthers first appearing as closed pollen sacs before pollination.

Releasing Pollen - Pollen sac opens releasing yellow pollen.

Released Pollen - Pollen not longer present and anthers are turning brown.

Female Catkin

Maturing - The appearance and growth of a woolly pistilate catkin

Seeds Formed - Distinct seed containing capsules form.

Releasing Seeds - Capsules break open and release wind borne, hairy seeds.

Released Seeds - No seeds remain on the capsule.

Problems - Note should be taken - the majority of Salix leaves expand early in the season while the tips and shoots extend for the rest of the season. Salix leaves should be considered expanding 100% (5) until all growth has stopped.

It is also difficult to tell the difference between female and male catkins while they are still emerging.

Dryas octopetala

Budding - Single yellow bud on a leafless hairy stalk.

Flowering - Single white flower.

Post Flower/
Seeds Maturing - Petals fall off while seed head spirals and matures.

Releasing Seeds - White hairy seeds become air borne.

Problems - *Dryas* leaves begin to expand later in the season and continue through to the end of the season. New growth can only be seen by pushing back the adult leaves revealing the small light green young leaves at the base.

Vaccinium uliginosum

Budding - Small pink buds drooping beneath the leaves.

Flowering - A nodding, white/pink, open bell.

Post Flower/
Fruit Maturing - Flower is drying and brown or has fallen off leaving a small green/blue swollen ovary with pistol still attached.

Fruits Ripe - Mature, blue berry.

Problems - Flowers and berries are more easily seen by lifting and looking underneath the branches of the blueberry bushes.

Vaccinium vitis-idaea

Budding -	The appearance of several dark pink buds on one stalk at the top of the plant (Fig. 8).
Flowering -	Several pink/white, open bell flowers.
Post Flower/ Fruit Maturing -	Flower is drying and brown or has fallen off leaving a small green/red swollen ovary.
Fruits ripe -	Deep red/maroon cranberries.
Problems -	It is difficult to tell the difference between early leaf and flower buds.

Ledum palustre

Budding -	A group of small white buds on brown stalks at the top of the plant.
Flowering -	Several small white flowers.
Post Flower/ Seeds Maturing -	A group of swollen green ovaries on long brown stalks.
Releasing Seeds -	Brown capsules open
Problems -	Open seed pods persisting from the previous growing season can easily be confused with new pods. It is difficult to tell the difference between early leaf and flower buds.

Rosa acicularis

Budding -	A green/pink, raindrop shaped flower bud on top of a conspicuous green ovary (Fig. 8).
Flowering -	A single bright pink flower.
Post Flower/ Fruit Maturing-	Petals fall off leaving sepal and the maturing ovary or 'hip'.
Fruit Ripe -	Deep red rose hip with persistent sepals.

Cornus canadensis

Budding -	Several small white buds in the center of four white petal-like bracts.
Flowering -	Small purple/white flowers.
Post Flower/ Fruit Maturing -	Ovaries begin to swell and white bracts begin to fall off.
Fruits Ripe -	Several bright red/orange berries at top of plant.
Problems -	White bracts may be mistaken for petals. Emerging *Cornus* leaves are difficult to see.

Lupinus arcticus

Budding - Several purple buds on a leafless stalk.
Flowering - Several purple/white flowers.
Post Flower/
Seeds Maturing - Green hairy pods.
Seeds Released - Pods open

Problems - Young lupine plants are difficult to find, however, they are easily seen when in flower. The plants are difficult to follow post flowering. The seed pods are.difficult to spot and seem to have a low survival rate.

Mertensia paniculata

Budding - Several blue/purple buds on a leafy stalk.
Flowering - Nodding blue/purple bell flowers.
Post Flower/
Seeds Maturing - Petals fall off leaving a four lobed, green ovary and pistil.
Releasing Seeds - Lobes fall off individually.

Epilobium latifolium

Budding - Deep pink buds at top of plant.
Flowering - Deep pink flowers.
Post Flower/
Seeds Maturing - Long thin seed capsules.
Releasing Seeds - Seed capsules break open to release hairy, air-borne seeds.

Aconitum delphinifolium

Budding - Blue/purple buds on along stalk.
Flowering - Blue/purple flowers
Post Flower/
Seeds Maturing - Green capsules
Releasing Seeds - Open capsules

Problems - Young monkshood are difficult to find, however, they are easily seen when in flower. The plants are difficult to follow post flowering. The seed pods are difficult to spot and seem to be eaten by ground squirrels at tundra site.

Dodecatheon frigidum

Budding - 1-3 purple buds on a stalk
Flowering - Nodding purple flowers
Post Flower/
Seeds Maturing - Upright cylindrical seed capsules.
Releasing Seeds - Capsules open

Problems - The plants are difficult to follow post flowering. The seed pods are difficult to spot and seem to be eaten by ground squirrels at tundra site.

Silene acaulis

Budding - Pink flower buds
Flowering - Pink flowers
Post Flower/
Seeds Maturing - Small brown/purple capsules below the flower
Releasing Seeds - Open brown capsules

Problems - Difficult to tell when, exactly, the seeds are being dispersed. However, it is obvious when the seeds have already dispersed.

Astragalus umbellatus

Budding - Several yellow buds
Flowering - Yellow tube-like flowers
Post Flower/
Seeds Maturing - Green, hairy pod
Releasing Seeds - Open pod

Problems - The ground squirrels at tundra site feed on the flowers and the seed pods of *Astragalus* making it difficult to follow the phenology.

Arnica lessingii

Budding - Brown/yellow, nodding bud on a long leafless stalk
Flowering - Yellow, dandelion-like, nodding flowers.
Post Flower/
Seeds Maturing - Flower head loses ray flowers or "petals"
Releasing Seeds - Hairy achenes become air borne

Pedicularis langsdorfii

Budding - Several purple buds.
Flowering - Several purple flowers.
Post Flower/
Seeds Maturing - Balloon-like seed capsules
Releasing Seeds - Capsules open

Sedum rosea

Budding - Cluster of red buds.
Flowering - Red flowers with yellow stamens
Post Flower/
Seeds Maturing - Spike-like, red seed capsules.
Releasing Seeds - Capsules open

Along with this protocol, use the book Wild Flowers of Denali National Park (Pratt and Pratt 1995), as a reference for plant and plant stage identification

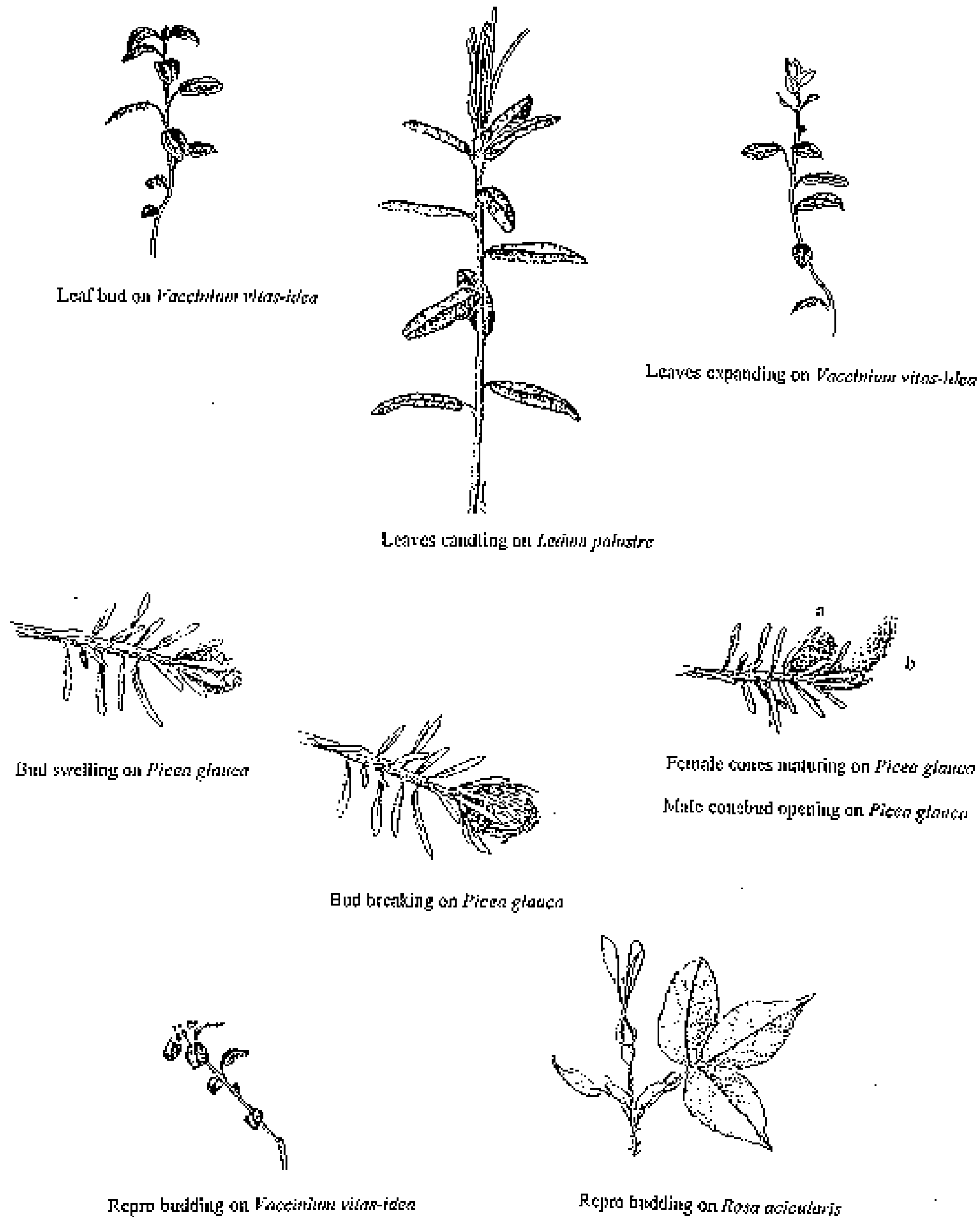

Figure 7. Phenological stages of plants monitored in the Rock Creek watershed.

Table 7. Phenology observation dates, 1992-1995, by site.

	1992	1993	1994	1995
Forest				5/17
				5/24
				5/30
	6/6	6/7		6/6
				6/14
				6/19
			6/24	6/28
				7/4
		7/8-9	7/9	7/10
	7/15			7/18
				7/27
				8/2
		8/4-6	8/9	8/7
	8/17			8/21
				9/1
Treeline				5/16
				5/25
				5/31
	6/7	6/8-10		6/7
				6/13
			6/23	6/20
				6/29
	7/6	7/9	7/8	7/5
	7/14			7/13
				7/19
				7/26
		8/11	8/9	8/8
	8/17			8/22
				9/5

Table 4, continued. Phenology observation dates, 1992-1995, by site.

	1992	1993	1994	1995
Tundra			5/29	
				6/7
	6/16	6/8-11	6/13	
				6/20
			6/26	6/29
		7/5	7/8	7/5
	7/14			7/13
				7/19
				7/26
		8/11	8/9	8/8
	8/17			8/22
				9/5
Riparian				5/17
				5/24
				5/30
		6/9-10	6/6	
	6/15			6/14
				6/19
				6/28
		7/9	7/9	7/4
	7/15			7/10
				7/18
				7/27
				8/2
		8/9	8/9	8/7
	8/17			8/21
				9/1

METHODS-PHOTOGRAPHIC DOCUMENTATION

Aerial photos were taken of the tundra, treeline, and riparian sites in Rock Creek during the 1993 field season. Cover plots were also photographed. The photos filed in a photo case in the Denali Research and Resource Protection office. This file also includes photos from the tour of the Bonanza Creek LTER site (8/92) and photos from the 1992 field season (corner photos of the Rock Creek forest replicates).

The cover plots are photographed at 10-year intervals when the cover data is read. It is difficult to frame the whole cover plot from standing height and maintaining a consistent angle over the plot, and it may be necessary to use a small stepladder for future photos.

METHODS-DATA MANAGEMENT AND ANALYSIS

Vegetation data is entered into DBASE for Windows or ACCESS, a format which is compatible with that used by the Bonanza Creek LTER Study. Maps were generated for each plot graphing the locations of trees and sapling/seedlings.
Data forms are also in computer files for all measurements (Appendices A-F). Data collected from 1992-1996 is entered. All original data sheets and computerized data files are at the Denali Research and Resource Preservation office.

The experimental design for the permanent plots contains several key elements for statistical analysis of data. First, the sample unit is the entire plot. Therefore, the value used in statistical comparisons is the mean of the plot values for that parameter. For example, the value for cone counts and dendrometer band measurements is the mean of the values for the five trees which are measured in the plot, while the value for the number of viable seeds dispersed per unit area is the mean of the values measured for the six traps placed in the buffer zone of the plot. For purposes of analysis, the study site is divided into forest, treeline, tundra, and riparian (The permafrost plots have a limited data set to date and only two replicates, but can be integrated into study in the future). This design has been used in other studies in Denali and has survived peer review (Densmore 1994, in press) and will provide biologically meaningful results, but might be susceptible to criticism as pseudo-replication by a stringent statistician.

The data from this protocol are designed to be compared to similar data from the National Science Foundation Bonanza Creek Long-Term Ecological Research site near Fairbanks, Alaska. This will allow comparisons between data from a lowland riparian interior Alaska boreal forest site and the Denali plots at higher elevations. One result should be an improved ability to distinguish between local and regional variation, particularly in white spruce growth and reproduction and in stand dynamics. For example, both the Denali and the Bonanza Creek sites documented fallen and broken trees following heavy, early snowfall in the fall of 1992.

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Appendix A

Appendix B

Appendix C

Appendix D

Appendix E

Appendix F