DRAFT

Evaluation of Existing Vegetation Protocols for Denali Long Term Ecological Monitoring

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Executive Summary

Vegetation has been sampled as part of the Denali Long Term Ecological Monitoring (LTEM) program from 1992 until 1998. Protocols and some objectives for the work from 1992 to 1998 are documented in Densmore et al (1998a). Broader objectives are in the Strategic Plan (Denali National Park and Preserve and USGS Biological Resources Division 1997). This report evaluates the existing vegetation protocols with respect to the objectives in Densmore (1998a) and the Strategic Plan (Denali National Park and Preserve and USGS Biological Resources Division 1997).

The objectives in Densmore et al (1998a) included: (1) monitoring composition and structure of major plant communities in the watershed, including monitoring natural change (wildfire, flooding, climatic variation); (2) monitoring growth rate and reproduction of the dominant treeline species, *Picea glauca*; (3) collecting data compatible with other long-term monitoring data sets for (a) similar plant communities and (b) white spruce growth rates and reproduction; and (4) comparing data with other sites to amplify monitoring power. It was not intended to be a complete vegetation monitoring program but was supposed to be integrated with other on-going monitoring in the park. These objectives were limited by what was possible in the Rock Creek watershed.

According to the Strategic Plan, priority monitoring topics that are most directly related to vegetation include (1) detecting significant changes in the structure, composition and distribution of major vegetation communities due to regional and park development, and global influences, (2) monitoring fire regimes to evaluate effects of fire management on plant succession and habitat quality, and (3) discerning changes in biodiversity, including introduction or loss of species, due to habitat fragmentation/loss, park and visitor activities, and regional development. (Denali National Park and Preserve and USGS Biological Resources Division 1997)

Initial vegetation data collected included ocular estimates of vegetation cover by plant species in the first year only and mapping of trees and logs in the stands which is used to generate size structure data. These data may be suitable for identifying plant species present, but wildlife habitat would need more detailed vegetation information and repeatable characterization by height class. Ocular estimates by species may have substantial observer error and do not allow the data to be recombined later into life form categories such as low shrub, which may be more critical for wildlife than the individual species. Other monitoring programs such as EMAP and USFS should be examined for both parameters and techniques they use. Vegetation characterization suitable for documentation of existing plant communities, wildlife habitat characteristics, and forest health have been used on large inventories in Alaska for about two decades. Some of these were inventories while some were baseline data for monitoring. We should learn from their experiences where appropriate.

Monitoring data include data for white spruce growth and reproduction (dendrobands, cone counts, seed traps). Cones are counted on the north side of selected trees using binoculars. This method probably has large observation errors but is probably adequate for identifying good years as opposed to average or poor years for cone production. Seed trap data may be useful for monitoring seed deposition in an area for treeline advance but also suffered from small sample sizes. These data will be useful to tie into other units, such as the Bonanza Creek Long-Term Ecological Research site (LTER), that are monitoring white spruce in conjunction with global change.

Berry crops are being monitored in conjunction with bear studies by counting berries in plots selected for their high productivity. These are undersampled. It may be that a more categorical observation could be useful for good year/bad year type data. Potential changes in productivity or usage by bears on a decades-time scale should be considered in the design. For instance, areas without berry plants now may eventually have berry plants as a result of succession or mildew may cause bears to avoid plants in some years. Long term dynamics

would best be monitored by incorporating berry sampling in all plots. It would not require any additional work where they do not exist yet but would provide background data as vegetation changes.

The phenology data are extremely cumbersome, and their objective not well documented. Phenology can probably be simplified substantially and needs to be tied directly to objectives. Objectives could include documenting changes in greenup each year in response to yearly variation in weather patterns, documenting start of food availability for moose in spring or bears during fruit ripening. If general patterns are all that is desired, then this may be done more efficiently and effectively using AVHRR data with just enough field work to make sure these linkages are valid. Because the sites need repeated monitoring within a year, they would need to be relatively accessible and would be more suitable in intensive monitoring sites than in the extensive sites. Phenological state of selected species should be recorded in all plots.This would be too late for greenup phenology but could be very useful for berry availability.

Although some of the data are reasonably adequately sampled within Rock Creek, we do not have a handle as to variability across the park using these techniques. As changes take place over decades, some vegetation types may change. They may change uniformly as a polygon or patch or more likely, the changes will occur in patches different from the original patches (e.g. in response to fire) or as a gradient (e.g. changing treeline if tree seeds have not arrived). For instance, as treeline advances into the shrub communities along the road system, only part of the 'low shrub' community progresses from low shrub to woodland or open forest each year, thus causing a change in plant community 'boundaries.'

The systematic grid design suggested by statisticians has some limitations, but it frees us from vegetation type boundaries and may enable us to generate contour maps of tree densities or sizes that would be readily updated each year using ArcView. The wave of trees moving into the shrub communities could be readily documented, although it might be on a scale of 5 to 10 years. This approach might also be suitable for berries. Landscape scale analysis, such as wildlife corridors, may be easier to do with a grid design. However, one of the characteristics recorded at each grid point or cell would be the vegetation type present. This grid would be overlaid on vegetation types.

In short, the present protocols do some things adequately, but need to focus more on larger sample sizes, upscaling, integration, and management applications.

Some existing plots in the park should provide invaluable data for understanding ecosystem processes and changes. Some date back over 40 yr, although some are much newer. These plots are usually tied to succession or wildlife studies so would be tremendous source of knowledge for these models.

Numerous remote sensing techniques are potentially available for vegetation studies using either optical or radar sensors. At any given time, some satellites may be inoperational. Because of the variety of bandwidths, resolutions, and frequency of return, a 'final' decision on imagery will need to depend on objectives to be investigated. It is anticipated that multiple types may be used, each for a particular purpose, and this may change over time as new technologies become available and management issues change. Careful documentation of the decision process is needed for future users and provide a flowchart for future decisions.

Frame-based models for interactions of vegetation with other components will be developed. Overall ecosystem models may be too complex, but frame-based models may be easier for managers and users to understand and to maintain.

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1 Introduction

The National Park Service recognized the need to detect and document resource changes and established a prototype Long-term Ecological Monitoring Program in 1991 at the national level (Denali National Park and Preserve and USGS Biological Resources Division 1997). Denali National Park and Preserve (DENA) was chosen for the pilot program for subarctic ecosystems, and vegetation sampling was initiated in 1992 and has continued through 1998. Changes were made to some of the protocols as experience with the techniques was gained (Densmore et al. 1998a).

The original vegetation protocols for the Denali Long Term Ecological Monitoring (LTEM) program included descriptions of methods for cover and tree/log mapping, white spruce growth and reproduction, berry crop measurements, and phenology observations as well as photographic documentation and data management and analysis. Several of these are oriented toward global change. To put those original protocols into perspective a brief quotation from their Introduction summarizes some of the why's of that design:

> 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, as small watershed which crosses treeline. ...
>
> 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. {p. 3 in Densmore et al. (1998a)}

The specific objectives were to:

> 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. {p. 4 in Densmore et al. (1998a)}

Implementation of some of the designs were probably limited by the size and vegetation types within Rock Creek.

However, the “Final Draft” of the Strategic Plan for the program was produced in October 1997. Among the priority monitoring topics most directly related to vegetation were the ability to detect significant changes in the structure, composition and distribution of major vegetation communities due to regional and park development, and global influences. It should also be related to fire monitoring with respect to succession, and discern changes in biodiversity . . . due to habitat fragmentation/loss, park and visitor activities, and regional development. {paraphrased from Strategic Plan (Denali National Park and Preserve and USGS Biological Resources Division 1997)}

This report will focus on evaluation of the protocols for their original objectives but will also take into account the objectives outlined in the Strategic Plan. Suggestions for upscaling and integrating will be included. In particular, the protocols should be expanded to accommodate larger spatial scales and address additional management issues, such as air quality - vegetation interactions. The development of new protocols for these expanded objectives will be developed in a later report, but 'hooks' will be provided now to indicate where the present protocols may be adequate or inadequate, as the case may be.

2 Analysis of Existing Protocols

2.1 Site Selection

Permanent vegetation plots were established in four vegetation communities (forest, treeline, tundra, riparian) in 1992. “Plots were randomly located with the restriction that the area within the plot was topographically homogenous.” {p. 5 in Densmore et al Densmore et al (1998b)}. However, no method was given for “random” selection. The precise method of selecting plots needs to be documented. Was the vegetation type located, then a grid of points overlaid on it and random points selected? Usually the selection of random points is painful enough, that the process is carefully documented.

2.2 Vegetation Community Analysis

2.2.1 Cover

Permanent vegetation plots had been established in 1992 in forest, treeline, alpine tundra, and riparian tall shrub types. A potential permafrost site was rejected because it was 'too small' for vegetation plots but two replicates were later added in 1995 (Densmore 1998). Using the existing protocols and objectives, the size may have been an appropriate concern. However, this may be a reason to reconsider these protocols if areas as large as the permafrost site were going to be eliminated from potential study. It may be that this design is appropriate for research objectives of long-term ecological research, but not large-scale characterization of the vegetation communities in the park. Subplots were located systematically within each replicate so that the sample unit for statistical analysis is the entire plot.

Cover was ocularly estimated in 5% classes with the upper and lower 10% categories (1-10%, 91-100%) being estimated in 1% intervals to avoid over- or under-estimating. However, it was never defined what cover actually is - are the small holes in shrub canopies considered as part of the canopy or are they considered to be whatever is underneath. This could be critical where shrub health may be declining. Other than using 0.5 m as the breakoff for shrub height, heights are not considered for cover in the present protocols, yet this may be important for availability of moose browse, height structure for bird usage, and hiding cover.

The LTEM vegetation data were difficult to analyze to determine sampling adequacy because of the limited design. With randomly selected data in a hierarchical (nested) design, frequently an analysis of variance is performed to determine the variance at the different levels. The lowest level mean square (variance) is used to calculate the number of sampling units needed within a plot, the next level up is used to calculate the number of plots needed (between variance; replicates in Rock Creek terms), and the next level (possibly highest level) is used to calculate the number of sites needed in a region, for example. Rock Creek only had one site per vegetation type, so there is no estimate of variability at that level. Many of the observations were systematic within the plot that resulted in no 'within' variability. Hence, the only thing that could be calculated was then number of plots. Table 1 demonstrates the number of plots needed to sample cover in the forest, treeeline, and tundra sites based on the one set of observations.

Table 1a. Mean cover (%), standard error, and estimated sample size to adequately sample cover of species with at least 10% cover in forest, treeline, and tundra sites, Rock Creek, 1992. (n=3)

	Forest			Treeline			Tundra		
	Mean	SE	n̂	Mean	SE	n̂	Mean	SE	n̂
Empetrum nigrum	10	4	27						
Vaccinium uliginosum	18	2	2	21	5	13			
Betula nana				33	3	2			
Ledum palustre				11	3	24			
Astragalus umbellatus							11	10	182
Dryas octopetala							36	14	32
Salix reticulata							21	14	96

n̂ = sample size needed to adequately sample the parameter within 20% of the mean with 68% confidence (2/3 of the time the measurements will lie in the interval $\bar{x}$ ± SE (standard error).

I used the formula $\hat{n} = \left[\frac{st}{.2\bar{x}}\right]^2$ with s = standard deviation and t with approximately 30 degrees of freedom for 68% confidence. This is done since calculating sample sizes is, in reality, an iterative process. Initial samples are collected, sampling adequacy is calculated, additional samples are taken, adequacy is recalculated, and so on. On an inventory of this scale, usually 20 to 30 samples are considered a minimum to have a realistic estimate of values. Also, for 68% confidence, t is approximately 1 while for 95% confidence, it is approximately 2. Hence, the intervals correspond to the box and whiskers on graphs I present later.

Because the estimates are made by species and species may overlap, there is no way of recovering cover by life form from the existing data. For instance, blueberry may have 40% cover, Labrador tea have 15% cover, and resin birch have 40% cover, but total cover by low shrubs may only be 75% because the shrubs overlap. It may be that life form categories (or something like willows suitable for moose browse) are more important than actual species. Cover for the different categories can be estimated in the field, but chances are some other category will be needed later. However, the individual species are needed for community description and species distribution documentation.

If ocular estimates are used as in the present protocols, there should be some training or quality control to minimize variation among observers. It would also be helpful to resample areas to see if the results are reproducible and how much noise may be present in the data. Without this type baseline data, it is difficult to determine whether later 'differences' in community composition are true 'differences' or noise resulting from observers and techniques. Also, square plots are less efficient than rectangular plots but have less boundary error associated with them.

A number of extensive vegetation surveys have been done in Alaska, and some measure the parameters needed to describe the height structure of the vegetation as needed for wildlife habitat {e.g (USDA Forest Service 1998)}. The Cooperative River Basin study has some points in Denali initially measured in the early 1980s. The proposed national Forest Health Monitoring program may also have valuable methods but may need to be adapted to Alaska (Mangold 1998). Useful parameters and methods from these other studies should be considered after a "shopping list" of objectives and parameters is developed.

2.2.2 Tree / Log Mapping and Densities

All trees (dead or alive) and saplings/seedlings are mapped by x, y coordinates within each replicate, numbered, and height and dbh measured (Densmore et al. 1998b). This allows summaries of densities by size structure, which is useful for wildlife habitat. However, this does not give any idea as to how much of the plot is covered by the various species or life forms. Tree condition was to be monitored annually but seedlings/saplings were to be monitored only every 10 yr. Locations of logs at least 10 cm diameter were also recorded but were not labeled in the field. These were classified into decay classes.

Table 1b demonstrates the number of trees needed for adequate sampling of density and basal area.

Table 1b. Basal area (m^2/ha) and density (stems/ha) of white spruce >1.3 m in forest and treeline sites, Rock Creek, 1992.

	Forest				Treeline			
	Mean	SD	nhat1	nhat2	Mean	SD	nhat1	nhat2
Density	560	304	29	7	208	131	40	10
Basal Area	21.13	5.18	6	2	1.01	1.01	100	25

nhat1 = number of samples needed based on 95% confidence; nhat2 = number of samples needed based on 68% confidence. (I don't have the actual sample size collected.)

2.3 White Spruce Growth and Reproduction

2.3.1 Growth

Because changes in treeline and white spruce growth and reproduction were concerns associated with climate change, these were monitored in the plots. Growth was monitored with dendrology bands to measure the increase in diameter. The five individuals were selected to represent the average dbh within a replicate plot, so are not random. Measurements are increases in dbh and not actual dbh, but dbh could be calculated (Table 2).

Table 2. Diameter growth increase (in) per year and estimated sample sizes.

Site	Year	n	Mean Growth (in / yr)	20% of Mean	Variance	nhat1	nhat2
Forest							
	1993	13	0.294	0.003	0.309	358	90
	1994	15	0.080	0.000	0.006	93	23
	1995	14	0.128	0.001	0.008	51	13
	1996	15	0.129	0.001	0.006	39	10
	1997	15	0.164	0.001	0.004	17	4
	1998	15	0.113	0.001	0.004	32	8
Treeline							
	1993	8	0.098	0.000	0.007	73	18
	1994	8	0.083	0.000	0.008	123	31
	1995	8	0.150	0.001	0.023	104	26
	1996	8	0.043	0.000	0.024	1316	329
	1997	8	0.192	0.001	0.021	57.2	14.3
	1998	8	0.061	0.000	0.065	1720.8	430.2

Although the plots in Figure 1 do not appear too wild, the estimated number of samples needed (Table 2) are generally much greater than the numbers actually collected. Although these numbers have only been calculated within these two sites, the number of samples could be increased both by increasing the number at a site and increasing the number of sites. We have no estimate on the variability between sites within with the same vegetation type classification since only one of each site existed in the Rock Creek analysis.

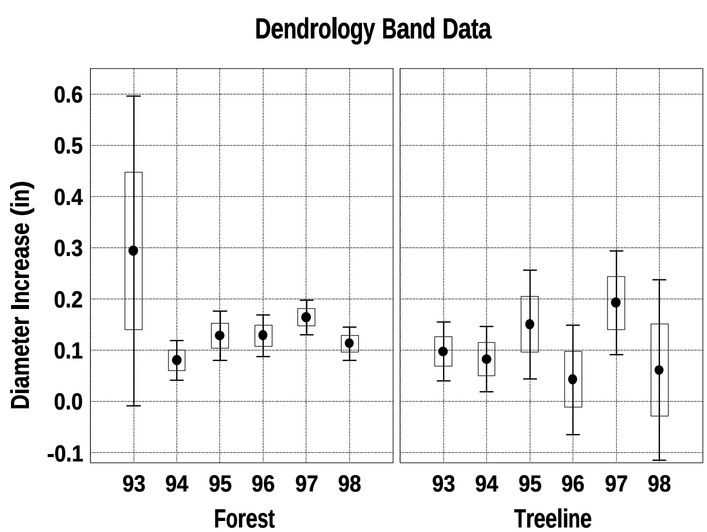

Figure 1. Variation in diameter increase in selected trees in Forest and Treeline sites, Rock Creek, 1993-1998.

2.3.2 Cones

Cones have been counted during the last week of July and the first week of August (Densmore et al. 1998b). From outside the block, the number of cones visible on the north side of selected trees are counted using binoculars. These are the same trees that have bands in the growth study.

As a general observation, this seems to have the potential for a lot of user inaccuracies – depending on the size of tree, and how clear a view one has of the canopy top. However, it is probably suitable for gross levels of cone production, as long as one does not place too much emphasis on the actual numbers, e.g. that tree had 'exactly' 42 cones this year.

This is where the objectives may need to be more clearly spelled out. Is the number of cones per tree critical? Or are we looking for peak cone years, such as 1998? Or are we looking for wildlife food? If we are looking for relatively specific numbers, then I suspect closer observations may be needed, and a lot of them. However, if we are looking for general patterns in cone productivity, then a more categorical approach may be more appropriate. It could still be a count, but recognize that an observation of 52 cones per tree should be considered the same as an observation of 63 cones per tree. How reproducible are these results among users?

An analysis of the distribution of cone data to date in Rock Creek suggests that the data are not normally distributed and are probably closer to something like a lognormal distribution (Fig. 2). From existing data, it appears that there will always be more trees with few cones, resulting in a skewed distribution. These distribution plots were based on individual trees as if they were selected randomly. However, these are the same trees that were banded and were selected for 'average' size. Also, there were five trees per plot, which were averaged to form one mean. Although 15 trees went into the value for a site (forest, treeline), n=3 within a site.

The frequency distribution for forest plot consists of all observations except the 1995 data which may have some erroneous entries. However, I thought the 1998 data and other very large values may have skewed the data, so I eliminated the higher values, which only accounted for 10% of the numbers. The second forest graph and the treeline graph focused on the more common numbers, and they were still skewed.

If one were to calculate the mean number of cones produced per tree and the variabilities according to the sampling design setup, it would look something like this for the forest and treeline plots, the only ones where cone data were collected (Fig. 3). The box represents one standard error above or below the mean while the whiskers represent two standard errors. These correspond to the 68% and 95% confidence intervals. What that means is that if a person were to resample the same population, then 68% of the time, he/she would have a result within the box, and 95% of the time, he/she would have a result within the whiskers. If one ignores the 1998 data for the moment, one can see that although the variability among the earlier years is probably year-to-year variation.

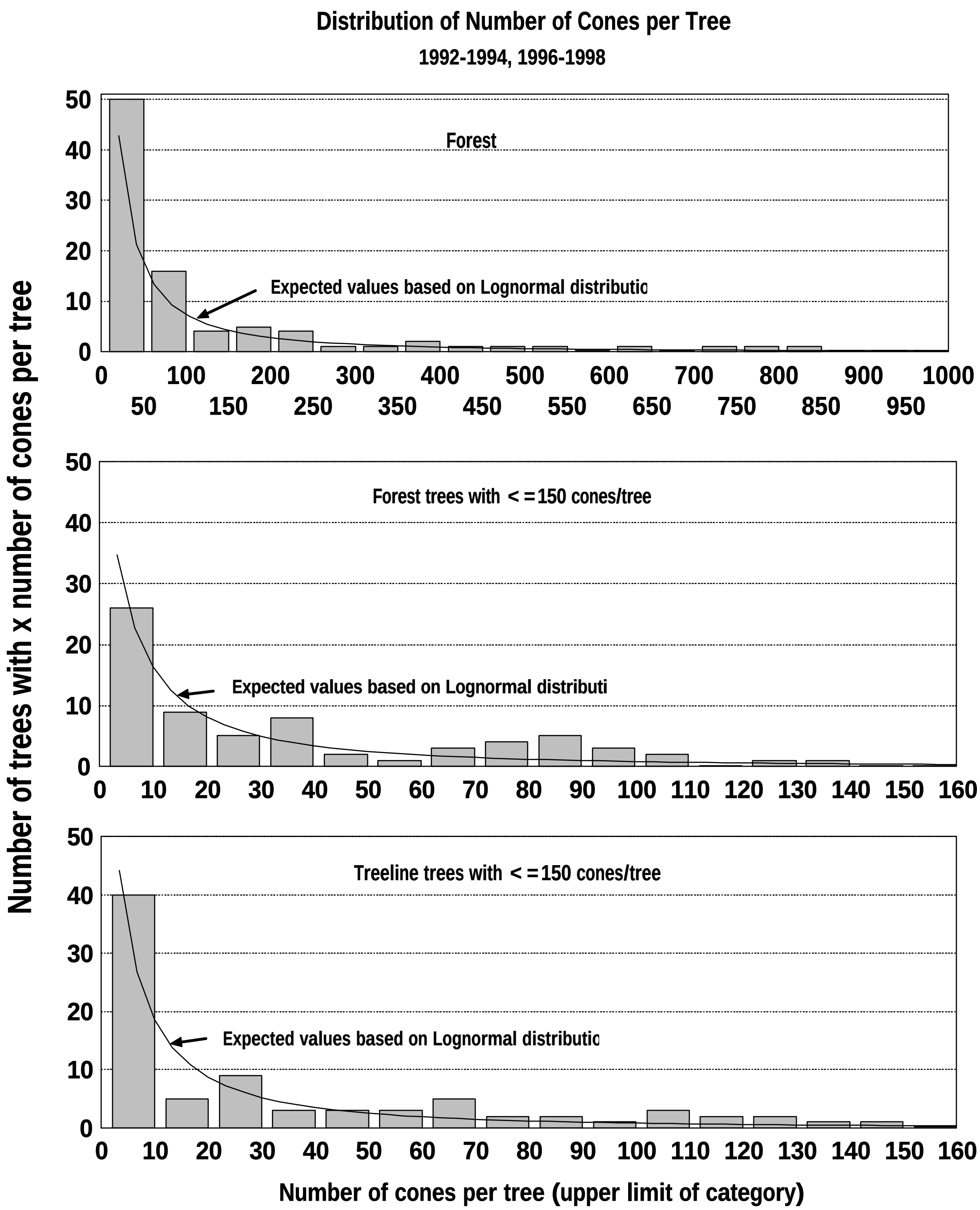

Figure 2 Distribution of cones per white spruce (*Picea glauca*) tree from 1992-1998, excluding 1995, for Forest and Treeline plots in Rock Creek watershed.

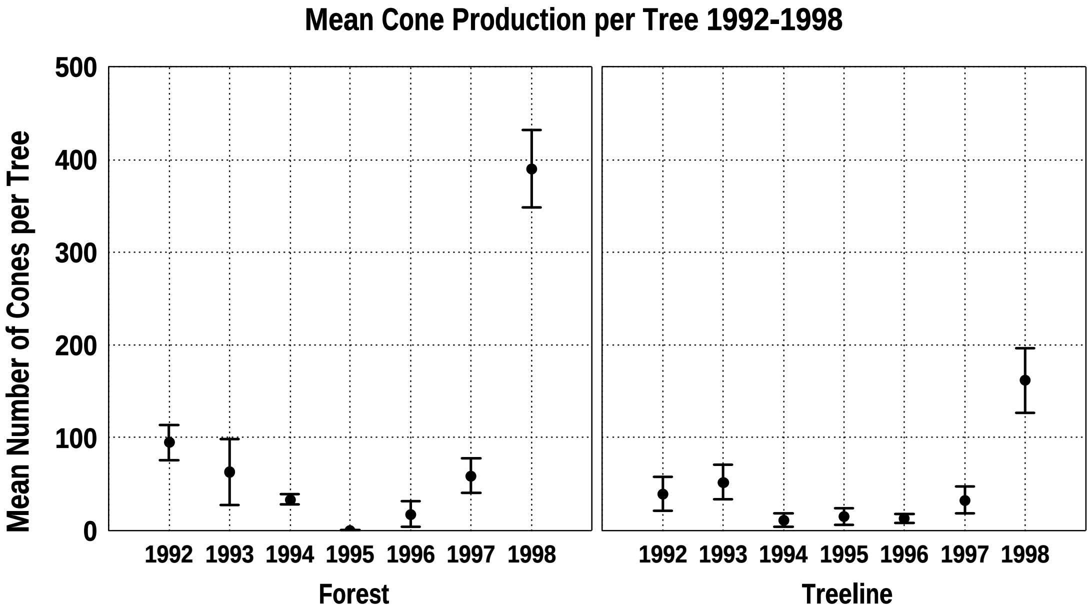

Figure 3 Mean number of cones per tree by year in Forest and Treeline plots, Rock Creek watershed.

If one wanted to determine how many plots would be needed to adequately sample the cones within a site within a year to within 20% of the mean with various degrees of precision, it would take the number of plots indicated in Table 3.

Note that even at the 75% level of confidence, the treeline sites were never 'adequately sampled' (estimated sampled size <3) although they were closest in 1998 with a larger cone crop. In the forest site, they were adequately sampled or almost adequately sampled in only 3 of the 6 years. I did not count 1995 as there appears to something strange with that data (Roland 1999).

If these 15 non-random trees are representative of what might have occurred with 15 random trees per site, then the numbers might be as in Table 4. However, since these were stratified by plot, this last number may be a high estimate but since trees were not randomly selected it may be a low estimate. Since the sample size is small, and probably not representative of the rest of the park, any of these results must be taken with a grain or two of salt. In this case, there are only two years when the cones are adequately sampled based on these criteria. Rock Creek variability is only a subset of the white spruce cone crop in Denali National Park and Preserve (DENA). Hence, it is anticipated that a lot more sampling would be needed for long term monitoring, unless categorical data were suitable for objectives.

Counting cones on mature white spruce trees is obviously a difficult task. Whether the existing protocols are adequate or not depends on exactly how the results will be used. If it is desired to relate the seedling densities in an advancing treeline to a mean number of seeds per tree or per area (seeds per trees times trees per area with variances multiplied), it may not be adequate. However, to do this on a large scale would be rather expensive. If the objective is to identify peak years, it could be analyzed categorically and these data are probably adequate.

Table 3. Number of samples needed to adequately sample number of cones/tree based on the Rock Creek LTEM design where the 5 trees per replicate count as one observation. (N=3 replicates/Site)

Site	Year	Mean number of cones per tree	Variance	20% of Mean	Number of Plots to Sample within 20% of Mean with these Confidence Levels (%) Sample Size Formula (z)				Sample Formula (t)	
					95%	90%	80%	75%	95%	68%
Forest										
	1992	95	1053	19	11	8	5	4	12	3
	1993	63	3797	13	92	65	39	32	6	24
	1994	34	85	7	7	5	3	2	7	2
	1995	0.1	0	0	1	1	1	1	500	125
	1996	18	575	4	170	120	73	59	177	44
	1997	59	1050	12	29	20	12	10	30	8
	1998	390	5184	78	3	2	1	1	3	1
Treeline										
	1992	40	1024	8	61	43	26	21	64	16
	1993	52	1049	10	37	26	16	13	39	10
	1994	11	158	2	126	88	54	43	131	33
	1995	15	228	3	97	69	42	34	101	25
	1996	13	76	3	43	30	18	15	45	11
	1997	33	621	7	55	39	23	19	57	14
	1998	162	3627	32	13	9	6	5	14	3

Keep in mind for the sample numbers, an individual plot does not have to be sampled adequately by itself, but rather all the plots of that type in the park or a region or some other strata are pooled to obtain an estimate. Usually an analysis of variance is used, and the lowest level mean square corresponds to the variance for the number of sampling units per plot, the next level up is used for number of plots per site, and the next one for number of sites.

Given the coarseness of the existing measurements, the increased work level needed to adequate sampling, and the lack of correlation with the viable seed crop (Densmore 1998), the cone crop data may not be that useful. Potential uses would be for assessing reproductive health of tree (although viable seeds for that tree might be more useful), source of food for squirrels (filled seed probably more useful), and source of seed for treeline advance (viable seed needed). Seedtrap data (next section) is more useful than cone counts for relations to treeline advance and probably also for wildlife food, but it cannot be tied directly to the health of a specific tree, if that were desired.

Since spruce seeds generally do not disperse much farther than about 100 m (Zasada and Lovig 1983) , seed fall data are probably adequate to assess seed availability and viability for succession / treeline advance and wildlife food. However, if cone data (such as categorical data) could be easily obtained, it might provide some backup data for seed fall data. I believe that Rupp is not using cone count??

Table 4. Number of trees to adequately sample the number of cones per tree for Forest and Treeline sites, Rock Creek watershed. These calculations assume the existing sampling of n=15 trees were randomly selected, which they were not.

Site	Year	Mean number of cones per tree	Variance	20% of Mean	Number of Plots to Sample within 20% of Mean with these Confidence Levels (%)					
					Small Sample Size Formula (z)				Large Sample Size Formula (t)	
					95%	90%	80%	75%	95%	68%
Forest										
	1992	95	2849	19	30	21	13	10	32	8
	1993	63	12223	13	296	208	126	102	308	77
	1994	34	829	7	69	49	29	24	72	18
	1995	0	0	0	26	18	11	9	2700	675
	1996	18	925	4	274	193	117	94	285	71
	1997	59	7899	12	218	154	93	75	227	57
	1998	390	69319	78	44	31	19	15	46	11
Treeline										
	1992	40	2000	8	120	85	51	41	125	31
	1993	52	3541	10	126	89	54	43	131	33
	1994	11	325	2	258	182	110	89	269	67
	1995	15	1214	3	518	365	221	178	540	135
	1996	13	522	3	297	209	127	102	309	77
	1997	33	1949	7	172	121	73	59	179	45
	1998	162	14945	32	55	39	23	19	57	14

2.3.3 Seed Fall Data

Seed traps are set out around August 15 - six traps in buffer zone in each replicate of forest and treeline plot resulting in up to 18 traps per site (Densmore 1998). They are collected again between May 15 and June 1. Seeds receive 90 days of cold treatment in a refrigerator. Viable seeds are counted after cold treatment. Monitoring should be done on a yearly basis because some years are peak years.

Seed fall data should be related to potential for white spruce recruitment, but recruitment requires that the seed germinate and grow, which may also require a suitable safe site. Given the relatively short distance that white spruce seed disperses (100m) (Zasada and Lovig 1983) compared to other species such as poplar (*Populus balsamifera*) and aspen (*P. tremuloides*), it would be expected that the seeds collected in the traps came predominantly from the local trees within the site and hence may also be an indicator of wildlife food and reproductive health of the trees. Table 5 suggests that these data are also underestimated.

Table 5. Mean number of seeds per trap, and number of plots with seed traps needed within a site for adequate sampling at Forest and Treeline sites, Rock Creek. (n=6)

	Forest			Treeline		
	Mean	SE	$\hat{n}$	Mean	SE	$\hat{n}$
1993	4	1	11	0	0	56
1994	51	12	12	3	1	23
1995	2	0	7	0	0	56
1996	21	12	70	0	0	23

2.4 Berries

Berries were being monitored throughout the park as part of grizzly bear studies (Densmore et al. 1998b), but berries may also be relevant for voles and some birds. The most important species were blueberry, crowberry, and soapberry, which is not common in Rock Creek watershed. Other species include lowbush cranberry (*Vaccinium vitis-idaea*), red bearberry (*Arctostaphylos rubra*), bunchberry (*Cornus canadensis*), and geocaulon (*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).” {p. 27 in Densmore et al. Densmore et al (1998b). Therefore, berry plots are located where at least one of the important berry species is productive. Results are in number of berries per 0.75m^2.

However, bears have been observed to avoid buffaloberry affected by mildew (J. Kaye? Or F. Dean, pers. comm.). Successional variability may cause this to change also.

Figure 4 shows the distribution of berries among plots and years. The variability for tundra plots in 1997 is particularly notable. Table 6 has the estimated sample sizes.

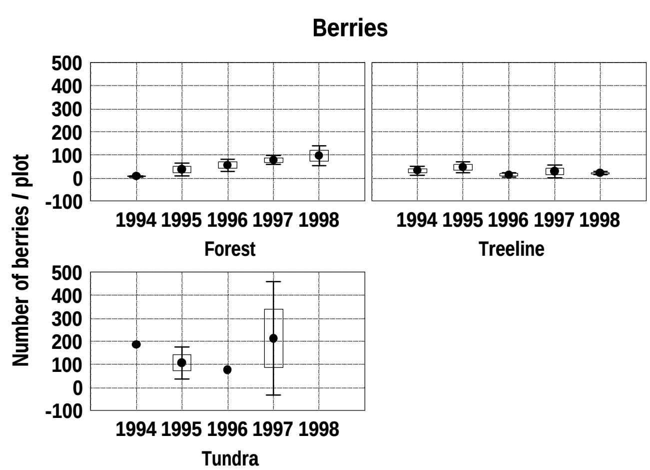

Figure 4. Mean number of berries per plot in Forest, Treeline, and Tundra plots, Rock Creek.

Table 6. Number of plots needed to adequately sample number of berries by species, year, and site, Rock Creek. (Emni= *Empetrum nigrum*, crowberry; Vaul=*Vaccinium uliginosum*, bog blueberry; Vavi=*V. vitis-idaea*)

Site	Year	Species	Mean number of berries per plot	S^2	20% of Mean	Number of Plots to Sample within 20% of Mean with these Confidence Levels (%)			
						95%	90%	80%	75%
Forest									
	1994	Emni	1	1	0	134	95	57	46
	1994	Vaul	4	27	1	164	116	70	57
	1994	Vavi	2	6	0	144	101	61	50
	1995	Emni	4	41	1	247	174	105	85
	1995	Vaul	8	107	2	160	113	68	55
	1995	Vavi	7	82	1	160	113	68	55
	1996	Emni	18	334	4	99	70	42	34
	1996	Vaul	17	306	3	108	76	46	37
	1996	Vavi	11	276	2	219	154	93	75
	1997	Emni	30	876	6	93	66	40	32
	1997	Vaul	19	711	4	189	133	81	65
	1997	Vavi	9	173	2	205	144	87	70
	1998	Emni	32	1003	6	94	66	40	32
	1998	Vaul	11	171	2	136	96	58	47
	1998	Vavi	41	2522	8	144	101	61	50
Treeline									
	1994	Emni	2	33	0	785	553	335	270
	1994	Vaul	24	423	5	71	50	30	24
	1994	Vavi	0	0	0	0	0	0	0
	1995	Emni	4	45	1	270	190	115	93
	1995	Vaul	40	714	8	43	30	18	15
	1995	Vavi	0	0	0	0	0	0	0
	1996	Emni	2	4	0	96	68	41	33
	1996	Vaul	12	143	2	96	67	41	33
	1996	Vavi	1	0	0	19	14	8	7
	1997	Emni	9	n/a	n/a	n/a	n/a	n/a	n/a
	1997	Vaul	13	161	3	92	65	39	32
	1997	Vavi	0	0	0	0	0	0	0
	1998	Emni	13	114	3	65	46	28	22
	1998	Vaul	10	117	2	112	79	48	39
	1998	Vavi	2	33	0	785	553	335	270

2.5 Phenology

Phenology data is cumbersome and probably requires more detail than needed, depending on the objectives which were not clearly stated. No more than 5 days should separate readings on each plot (Densmore et al. 1998b). Originally all species were being monitored, but this was reduced to those that could be observed without trampling plots and were easy to identify in the field and species that were being monitored on the BNZ LTER and ITEX (International Tundra Experiment 1993).

Is phenology being monitored for changes in weather patterns because of global change or changes in food availability for moose, bears, and other wildlife. Specific objectives would allow it to focus either on general remote sensing techniques or development of specific species.

The present phenology protocols have a number of challenges with them. As stated in Densmore (Densmore 1998), the observations were made only once month, thus limiting their usefulness. Of the data I had available, that left only 1995 and 1996 to work with. By simplifying the data to focus on the earliest observation for each category, a plot could be made of when the various stages were reached. However, it's not clear if that's what's wanted or not.

The protocol requires extensive detailed observations, but binoculars were used for 'easily seen' plants so as to reduce trampling in the plots. Yet, some of the observations may not be easily evaluated even when close. In addition to focusing on certain species, only certain phenological stages may be important and they should be focused on. Are these observations intended to 'predict' within a year when forage becomes available based on some earlier signal? Are they to observe differences in greenup time with respect to global change? Can it be tied to remote sensing data - like AVHRR - only thing that is frequent enough, but scale is coarse? Some phenological field work is still needed in case the linkages between remote sensing and field break down.

2.6 Photographic Documentation

Some protocol needs to be established for photographs. Which side of plot? This may vary from plot to plot, perhaps different angles for alpine and forested sites.

2.7 Gaps

Good vegetation descriptions are needed to document the communities and their wildlife habitat values. Change can be documented only when you know what you are starting with. Cover was only documented once, and as far as I can tell, there was no attempt to standardize observations among users or determine if the values were repeatable. With only one set of measurements, we do not know what the year-to-year variability or noise might be. The plots are fixed locations so there would be less noise than using random locations each year, but herbaceous plants, such as tall fireweed (*Epilobium angustifolium*), may have variable cover each year. Although tree mapping provides height and density data, it gives no idea how much foliage might be present at a given height. This is related to thermal cover and sometimes to hiding cover for wildlife. Certain height plants may be buried by snow while others may be out of reach of wildlife. What about food for birds, small mammals, caribou, wolves, and sheep?

Phenology deals with a lot of species but it may be overlooking some species. In particular, overwintered berries may need to be assessed as these are reported to be early season food in both Denali (paper by Fred Dean and others) and the Susitna basin (Helm and Mayer 1985). Other species used by bears early in the year include Hedysarum (dig roots), berries, and horsetail (Helm and Mayer 1985) (and paper by Fred Dean and others). Although current year berries may be important while preparing for winter, overwintered berries may be important early in the year.

Some yearly production data might be useful to tie in with global networks, but this is expensive and highly variable. Unless someone is doing a food availability study or knows how much food the various species require for a carrying capacity model or estimates, this may not be desirable.

Seedling documentation is good for succession information.

Habitat patchiness and corridors may be beneficial knowledge but probably needs to be analyzed at a scale much larger than Rock Creek. This is probably a GIS application with suitable design and sampling to provide the information.

No fuel loading data were collected with the assumption that this was being done by FirePro. However, FirePro has not been very active the past couple years. I suspect the work that they were doing, or at least some of it, could or should be incorporated into the LTEM design. I did not see any attempt to integrate these. If one study is using plots and the other transects, then the designs may not mesh well. (I'm not sure how FirePro collected their data.) Log mapping may be partially useful for FirePro but LTEM only used logs >10cm diameter, and fuel loading probably needs additional information.

No air quality issues were addressed in the protocols although Gough and Crock (1990) evaluated element content of some plant species and surface soils in conjunction with the power plant at Healy. This study should be built on in the future.

3 Previously Studied Vegetation Plots

Denali National Park and Preserve has had a number of vegetation studies, some of which could provide valuable background information for the LTEM program. Some have been performed by the National Park Service and others been done performed by outside organizations / researchers. Along these lines, Joe Van Horn provided me with a list of prior studies. I also visited with Fred Dean, Joan Foote, and Les Viereck concerning their studies. In terms of developing a successional model in the Park, we would either need to capitalize on past chronosequence studies, develop new chronosequence studies, track plots over time, or remeasure existing plots. Chronosequence studies are a starting point, but we do not always know conditions that accompanied changes. LTEM will track plots over time but that data would not provide actual successional data to a model for a number of years, probably decades. However, remeasuring selected plots from prior studies may provide valuable input to understanding ecosystem dynamics.

Dr. Fred Dean (University of Alaska Fairbanks, Emeritus) has worked in Denali National Park for over 40 years. Although much of this dealt with grizzly bears, vegetation observations with respect to grizzly bears and caribou have been made in various reports. Most notably, 642 ground plots and 600 low-level photo points were obtained to characterize caribou habitat beginning in 1976 (Dean and Heebner 1982). These data were provided to the DENA and to the regional NPS, and he has copies as well. At least some of these should be relocatable and resampled. Results should be meshed with both the vegetation story and the caribou story.

A classic study of succession after glacier retreat was documented by Les Viereck beginning in 1955? (Viereck 1962; Viereck 1966). These plots were marked. They were reread by Roseann Densmore's husband in about 1975?. The NPS asked that the plot markers be less visible, and now all the plots cannot be found. However, Les is looking for his notes to try to relocate as many plots as he can, and is very interested in doing this.

Moose habitat had been characterized by Joan Foote in conjunction with Vic VanBallenberghe but no official report was produced by this. However, the data and photos are supposed to be on file in DENA. These plots were relocated and GPS locations obtained in 1997 or 1998. She would be interested in reevaluating the plots.

The USFS / NRCS have about a half dozen plots in Denali (south side?) That were installed in early 1980s as part of the Susitna portion of the Cooperative River Basin studies. These plots could be invaluable as they were based on large scale sampling protocols.

FirePro put out plots in the early 1990s although I have not had a chance to track down their details (Friesen and Johnson 1992; Ledwith and Forbes 1993; Ledwith and VanderMeer 1995).

There are a number of other studies present in the Park, but I do not know if there are permanent plots that could be resampled. These studies are discussed under the Model section, as they should have data / observations for modelling.

4 Remote Sensing Imagery Options

Portions of the long term monitoring should be done by remote sensing. Exact imagery selected will depend on the objectives because of the options as far as wavelengths and resolution are concerned. Availability and frequency of return are two other critical considerations.

There are three main wavelength sets: optical (red, green, blue), infrared, and radar (Table 7). Although infrared is not visible, platforms that support optical sensors usually support infrared. For the purposes of this discussion, infrared will be lumped with the optical techniques. Both can be space-borne or air-borne. Since platforms change over time, it is suggested that protocols be developed in terms of bandwidths, resolutions, and return cycles. The decision should be documented and perhaps a flowchart developed to help guide future changes.

Optical techniques are passive and rely on reflected light. The fact that they are passive means that they use less power and may be functional for longer periods. This means they cannot 'see' through cloud cover or darkness. Hence, availability of good images may be limited in cloudy areas, like Denali during July and August. If passes are frequent enough, as with AVHRR, mosaics of cloud-free areas can be constructed to create a useful scene. This has been done to view phenological development in Denali on a coarse scale (pixel size in AVHRR is about 1 km). The visible wavelengths are just that, scenes appear in true color. However, a useful image is also 'false color' or 'color IR'. This shifts the spectrum so that green vegetation (in most cases) appears red. However, conifers and species such as resin birch (*Betula glandulosa*) and dwarf arctic birch (*B. nana*) show up dark. Platforms supporting optical sensors and their characteristics are indicated in Table 8.

Radar is less intuitive than the optical techniques. It is an active sensor – a beam of a certain wavelength is emitted, reflects (backscatters) off an object on earth, and is received by the sensor, which is now in a different place. Because these devices provide their own beam, they can provide useful information at night and in cloudy weather, although I believe some rain may provide an additional signature. Since they must transmit a beam, they require more power and may not last as long as the passive active devices. There are four main bands for radar – C, L, P, X – with the longer bands penetrating more (Table 8).

Table 7. Summary of electromagnetic energy spectrum.

Category	Band (μm unless indicated otherwise)
Optical	
Photography	0.3 -1.3 approx
UV	<0.4
Visible	0.4- 0.7
Blue	.45-.52
Green	.52-.60
Red	.63-.69
Near Infrared	.76-.90
SWIR	1.55-1.75
SWIR	2.08-2.35
Thermal	3.0-20. (general) ; or 10.4-12.4 (Landsat?)
Multispectral encompasses all the above	.3 to 20
Radar bands	Wavelength (other)
K-band	.6mm
X-band	
C-band	5.65cm
L-band	23 cm
P-band	

Summarized from Kaupp and Guritz (1998) and other sources.

Backscatter is the radar equivalent of reflectance and depends on the wavelength, polarization, incidence angle, and look direction (with respect to platform velocity direction) of the beam and the roughness, shape/orientation, and dielectric constant of the surface (Kaupp and Guritz 1998). Keys to interpretation include shape, shadow, size, pattern, tone, and texture. The longer wavelengths may penetrate some types of vegetation. Table 9 summarizes the most common SAR (Synthetic Aperture Radar) platforms and their characteristics although there are others. Table 10 has the more detailed characteristics for RadarSAT.

Because radar is relatively new compared with the optical images, interpretations for vegetation applications are still being developed. Radar scientists have developed models that suggest certain things should provide distinct signatures (such as many-branched trees vs dead snags after a fire) (citation?), but vegetation people have not been able to confirm these interpretations (C. Williams, pers. comm.). It can sense freezeup quite abruptly as the dielectric constant of water changes dramatically at that time (citation?). Also, depending on the type of image ordered, it may be raw data or a level 1 archive (Kaupp and Guritz 1998). Raw data needs much processing to be useful while the level 1 archive does not require as much processing but does require some. Terrain and radial corrections must be provided. The Alaska SAR Facility (ASF) has developed a number of tools and made them available on their web site. However, they are mostly available for UNIX systems at this time.

Table 8. Platforms supporting optical sensors and their characteristics. (Data from assorted web pages, brochures)

Name	Landsat	AVHRR (NOAA)	DMSV (airborne)	CAR-TERRA	LISS (Linear Imaging Self Scanning Sensor)	LISS	WiFS
Platform	Landsat	Weather satellite	Airborne	Satellite (IRS?)	IRS-1A&B	IRS-1C 1995	
Ground resolution	30m	1 km	1m to 6 m	180m	72.5m, 36.25	5.8 m, 23.5m,	188 m
Repeat cycle	16 days at equator	couple days	selected		22 days at equator	24 days at equator	5 days at equator
Time between adjacent swaths (revisit)			-			5 days	
Size scene (swath)	185 km	2400km	-	810 km	148 km, 146 km	70 km, 142 km	774 km (810 km)
Bands (wave-length)							
	Blue (.45-.52)	Blue	Blue		Blue (.45-.52)		
	Green (.52-.60)	Green	Green		Green (.52-.59)	Green (.52-.59)	
	Red (.63-.69)	Red	Red	Red (.62-.68)	Red (.62-.68)	Red (.62-.68)	Red (.62-.68)
	Near IR (.76-.90)	IR	IR	Near IR (.77-.86)	Near IR (.77-.86)	Near IR (.77-.86)	Near IR (.77-.86)
	SWIR (1.55-1.75)	temper-ature				SW Infrared (1.5-1.70)	
	SWIR (2.08-2.35)					Panchromatic (0.5-0.75)	
	Thermal (10.4-12.4)						
Availability (potentially)	"always" if satellite is functioning		scheduled	routinely available for select areas or requested by customer			
Source	EROS?, GI?	GI?	Private contractors	Space-Imaging			
Launched		1st in 1978	scheduled			Dec 28, 1995	
Country	USA			India			

Table 9. Characteristics of radar platforms.

Characteristic		ERS-1/2	JERS-1	RadarSat	AirSAR
SAR					
	Frequency	C-band 5.65 cm	L-band 23 cm	C-band	
	Polarization	VV	HH	HH	
	Swath	100 km	75 km	50 to 500km	
	Resolution/looks	30 m /4	30 m /4	30m/4 - 100m/8	
	Incidence angle	23 deg	35 deg	20-50+ deg	
	Orientation	Right	Right	Right	
	Onboard storage	None	10 min	15 min	
Orbit					
	Inclination	97.5 deg	98.5 deg	98.6 deg	Airborne
	Altitude	785 km	568 km	768 km	
	Repeat cycle	35 days	41 days	24 days	
	Time between adjacent swaths	3 days			
	Type	Sun-synchronous	Sun-synchronous	Sun-synchronous	
Mission					
	Launch	Jul 1991, Apr 1995	Feb 1992	Nov 1995	scheduled
	Design lifetime	3 yrs +	2 yrs +	5 yrs +	
	Status	Both active	Died Oct 1998	Active	
Other instruments		Radar altimeter Wind/wave scatterometer Along track scanning radiometer	Optical sensor	None	
Other Comments			Longer wavelength than ERS1,2; therefore better penetration; steeper angle means less distortion		

Adapted from Kaupp and Guritz (1998).

Table 10. Characteristics of RadarSAT that make it more flexible than other radar platforms. (Kaupp and Guritz 1998)

Operational Beam Mode	Beam Position	Incidence Angle	Nominal Resolution (m)	Nominal Area (km)	Number of Processing Looks
Fine			10	50 x 50	1 x 1
	F1	37-40			
	F2	39-42			
	F3	41-44			
	F4	43-46			
	F5	45-48			
Standard			30	100 x 100	1 x 4
	S1	20-27			
	S2	24-31			
	S3	30-37			
	S4	34-40			
	S5	36-42			
	S6	41-46			
	S7	45-49			
Wide			30		1 x 4
	W1	20-31		165 x 165	
	W2	31-39		150 x 150	
	W3	39-45		130 x 130	
ScanSAR Narrow			50	300 x 300	2 x 2
	SN1	20-40			
	SN2	31-46			
ScanSAR Wide			100	300 x 300	2 x 2
	SW1	20-49			
Extended Position			25	75 x 75	1 x 4
	H1	49-52			
	H2	50-53			
	H3	52-55			
	H4	54-57			
	H5	56-58			
	H6	57-59			
Extended Low			35	170 x 170	1 x 4
	L1	10-23			

Another issue with radar satellites is that most only return over an approximate location about every 24 to 35 days, making it difficult to use for phenology. However, SCANSAR does return every 3 to 4 days. Some satellites may not cover Alaska at all; others may cover it but not be within reach of their tracking station. If they have a tape recorder on board, they can save the data and transmit it when in reach of a station. Otherwise, no data are available. Most radar satellites at this time only provide one bandwidth (in contrast to the usual four with optical systems) and one polarization. It is anticipated that most interpretations will require at least two radar bands or use radar in conjunction with optical. This means registration of multiple images, which adds a complexity compared to optical. Important characteristics of radar platforms are summarized in Table 9 with more detailed characteristics of RadarSAT in Table 10.

At this point, I think radar may have its best applications for phenology on a small scale since images should be obtainable regardless of weather and some of these images can have resolutions of 30 m or smaller. NASA is subsidizing the availability of images to the federal government (if I understand the process correctly) , otherwise I suspect the cost of radar would be much greater than AVHRR, which also has a temperature sensor. Radar would also be useful for monitoring wetlands, especially where there is floating vegetation. Shorter wavelengths would be reflected from the vegetation while longer wavelengths would penetrate the vegetation and 'see' the water. This could be particularly beneficial in the western portion of the park.

People that have compared optical and radar seem to be finding optical provides about the first 80% of recognition with radar improving recognition (in some cases) up to 95% (hearsay). However, on northslope tundra sites, radar provided no improvement over AVHRR at the scale being used (Dave Douglas). Tundra does not have the structure that forests do so that result was not too surprising.

Canada's RadarSAT is probably the most complex radar satellite in orbit (Table 10). It can provide multiple beamwidths and incidences angles. Because of its complexity, it is heavier than the other satellites and hence is affected more by gravity so is not as stable a platform as the other radar satellites (R. Guritz, pers. comm. In class).

Most radar applications to date have been for sea ice, water, glacier, and volcano applications. For instance, on glaciers, it can 'see' through dry snow, and allow the investigator to see the actual glacier, something that is not possible with optical techniques.

5 Integration with Other Components

Vegetation data will be useful to a number of other disciplines and needs input from other disciplines as well.

5.1 Meteorology

Vegetation growth patterns both between years (normal changes as well as global change) and within years (phenology) should be related to meteorological data such as temperatures and precipitation. Relations to soil moisture may also be useful. Soil temperatures will be needed to recognize when permafrost has thawed, and thermokarsting may occur, which would likely cause changes in vegetation.

5.2 Air Quality

The effects of air quality on vegetation need to be documented. A literature review on that is still underway, but I am looking for responses to NOx and SOx as well as the metals and ozone. Although we have listed arctic haze separately in the past, as far as I can tell, it is just industrial pollution that's gone awry and spread globally. In other words, the things that we might monitor for local industrial pollution would be the same things monitored for arctic haze. The primary difference between the two would be reflected in the sampling design and sample allocation, rather than the parameters. It is anticipated that we will look at vegetation structure, including mosses and lichens, nutrient content of selected species, and possibly mushrooms as these have been implicated in pollution studies in Europe.

5.3 Small Mammals

Production and timing of plant growth may be of importance to the small mammals. Small mammal workers were not sure if delays in the spring were a direct result of low temperatures or if it was a response to delayed greenup in the plants (E. Rexstad, pers. comm.). In other words, phenology should be measured for small mammals.

Small mammals overwinter in the duff so duff depth would be a potential parameter to measure for them (E. Rexstad, pers. comm.). Past observations indicated that aufeis killed some plants so observations on this type of disturbance would be beneficial. Evidence of deeper snow areas would also provide evidence of potentially good overwintering areas. The presence of standing water would also be desirable, and this is easily recorded.

Some small mammals were frugivores and so the berry plot data, especially crowberry, would be of use to them. Others feed on grasses and sedges. Although production may be the most useful data for this, cover (already planned) may be almost as useful and is not nearly as expensive to collect.

5.4 Birds

Bird people (Anne Marie) would like habitat data in vicinity of nests - shrub height, canopy height, plant species, berries. Bird count data are taken June 10-25 which may be too early for vegetation characteristics.

Ptarmigan are dependent on willow buds, possibly feltleaf willow (F. Dean, pers. comm.).

5.5 Large Mammals

For large mammals, see the conceptual model section for parameters.

Right out of den bears tend to eat meat (F. Dean, pers. comm.). After thaw, they eat Hedysarum roots as soon as shoots appear and old crowberry berries. They will eat young Calamagrostis but prefer Arctagrostis. They also eat Boykinia leaves and flowers as well as horestail. As berries ripen (about third week of July), they eat Shepherdia berries that may still be green. They'll eat blueberries with some leaves. Crowberry has low protein. In the fall, they eat Hedysarum roots. They'll eat meat most anytime they can get it. They'll also eat ground squirrels to obtain protein to go along with the berries.

5.6 Fire

Interactions with fire people and succession will likely include duff and moisture. I need to find out more about the FirePro work to integrate that material.

5.7 Aquatic Habitat

Aquatic habitat may require evidence of overhanging trees that create shade. I have not had a chance to talk with those people yet. I am assuming they will take care of the aquatic vegetation in streams and lakes.

5.8 Fungi

Certain fungi are critical for plant growth and survival as well as for wildlife food. They may also be indicators of pollution concerns. These need to be discussed with the fungi folks.

5.9 People and Other Disturbance Evidence

Records will be made of evidence of human disturbance, such as trampling, as well as wildlife use, fire, flooding, or any other disturbance..

6 Preliminary Conceptual Model

At this point a conceptual vegetation model is best dealt with in several pieces, like the frame-based models of Starfield (Starfield 1997). There will be several successional models: glacier (north and south sides), flood, mining, revegetation, thermokarst, fire, trampling, overuse by animals (probably very coarse scale at this point), and air pollution. It is anticipated that the fire model may be the most detailed (hopefully) and most useful. Hopefully, it will include not just plant community succession, but also fuel loading information, so that fire managers will have a model to work with. Or if there is already a fire model (in either Denali work or Joan Foote's work), perhaps the vegetation data may provide more details for the model. Flood and mining would probably be similar unless metals affected colonization on mining sites. In order to keep the models simple, we will use categorical data where appropriate. Chances are we do not know the signficance of interactions at a finer scale.

Glacier succession model on north side will be based on Viereck (1966). South side glaciers may have a different sequence in some cases. Flooding and mining may follow a similar sequence and may be depend on elevation, geology, soils, slope and aspect. Some of this material may be available in the literature, but additional observations and probably data may be needed. Revegetation model would be based on documented revegetation in the Park (Densmore 1994; Karle and Densmore 1994).

For interactions with animals, ideally the population densities of the respective animal species in region with the food in question and the amount that they eat in a day could be input to a carrying capacity model. Based on the amount of material taken and the amount left, the plant response to browsing/grazing, a carrying capacity model could be developed. However, it is doubtful that we know that much about the animal - plant interactions. Therefore, this will probably be treated on a cursory level, where the input is a usage category (heavy browsing, light browsing), and the output would be a general plant (range) condition response. For instance, moderate browsing of feltleaf willow would likely lead to moderate production (which is browsed each year so no net growth), while heavy browsing for 10 yr may lead to a decline in the plant survival. At least for moose, some of this material could be obtained from re-reading Joan Foote's plots and moose studies performed in the Park (Miquelle et al. 1986; Miquelle and Van Ballenberghe 1986; Miquelle and Van Ballenberghe 1988; Molvar 1992; Molvar et al. 1993). Moose affect vegetation succession, and plant productivity may affect moose populations.

For bears, although they consume plant parts, like berries, it is not anticipated that they affect vegetation, at least not as obviously as moose do. So bear - plant interactions are more likely to be vegetation inputs into a bear model.

Caribou food studies are expected to be found in existing park studies (Boertje 1979c; Boertje 1979a; Boertje 1979b; Boertje 1984; Boertje 1990). There are circumstances under which caribou could affect the plants and vice versa so this would be a plant model with inputs from and outputs to the caribou model.

Data concerning fire succession are expected to be found in existing studies (Buskirk 1976; Viereck and Schandelmeier 1980) and also from additional data collection. It is anticipated that this model, especially, can profit from re-reading plots.

Vegetation responses to air quality changes will require inputs from the air quality component. Accumulations of elements in certain plant species have been documented (Gough and Crock 1990; Crock 1992). Additional literature review needs to be done.

Vegetation changes in response to global change will be modeled based on changes in temperature, moisture, and air quality. Some of this may follow a model developed for interior Alaska (Starfield and Chapin).

7 Recommendations

The methods for describing the existing vegetation need to be reconsidered, especially after firm objectives are determined. Wildlife habitat characteristics need to be considered more.

The issue of monitoring white spruce growth and reproduction may need to be relegated to “intensive” plots if data need to be collected every year. Data that may correlate with this (height, dbh) could be taken on a more extensive scale. The intent of the cone data should be considered since it does not relate closely to viable seed crop in non-peak years. We don't have viability data for 1998 yet, a peak year. A less intensive method of doing this, such as photography and using categorical observations, should be found or drop it. I suspect good cone crops may have a larger percentage of viable seeds (for sure, the number of viable seeds should be greater), and these should be documented as they may be related to certain combinations of weather conditions. Seed fall data should be maintained to relate to seedling colonization since the seed is only part of the story in treeline advance. However, because of the nature of these measurements, they can probably not be done at all white spruce plots. They may be focused along the road corridor where treeline has been observed to be advancing. Take general data throughout the park, and if something looks like it needs more intensive monitoring, then use 'adaptive management' and evaluate whether more intensive monitoring needs to be done. A flow chart might be desirable to document decision process for determining triggers for changes in protocols. This is likely to change over time, but the important thing is to document the process.

Some method of quality control is needed if ocular estimates are to be used.

Berries are probably too expensive and variable to monitor with existing techniques. Qualitative observations (suitably standardized) or image analysis of low-level (hand-held) photographs may provide a method to provide an indicator of good and poor berry years or good and poor patches. If berry analyses are kept, this should be expanded throughout the appropriate portions of the park. Although Densmore et al (1998a) suggests that good berry plants occur within a matrix of non-productive plants, and this is consistent among years, I suspect this changes over a several-decade time frame if not sooner. Other berry studies have found productivity to be variable among years and locations. {can't find citation}

Phenology should be focused on specific objectives and reduced to meaningful observations. The present system is cumbersome, appears to contain a lot of needless observations, but appears to overlook some important items, although these may have been absent in Rock Creek. Because of the repetitive nature of these observations, they would have to be at readily accessible sites. But hopefully, these observations could be tied to remote sensing products, and phenology in remote areas estimated.

For overall monitoring design, it may be useful to consider a grid suggested by the statisticians, rather than the vegetation type design presently used. Firstly, the vegetation types will change over time, and possibly not as a unit. That is, one half the stand may change one way, and the other half not change at all. Secondly, by basing the design on points, extrapolations for management plans are more readily justified. At this point, I would anticipate a grid at a scale where all the points (intersections) would probably only be 'sampled' by remote sensing. Large strata (regions) might be delineated based on topography, like the Alaska Range, since this is expected to last the length of LTEM. Samples would be allocated to each region proportional to the area. This allocation may be modified by the expected variability (more samples needed in more variable areas) and cost (use fewer expensive measurements) (Mendenhall et al. 1971). Plots to be sampled extensively may be allocated systematically (or randomly) among the points (scale to be determined by number of plots capable of being sampled in 5 yr) within a region. Intensive plots would be randomly located in particular vegetation types suitable for that particular project. For instance, white spruce growth and reproduction plots would be put in white spruce stands. A grid-based design would permit contour map generation for various parameters, such as white spruce density, which may be easier to track than vegetation type changes.

8 Caveats

Monitoring will only produce general correlations, not cause and effect. Research manipulations are needed for cause and effect but monitoring can suggest trials.

Terminology needs to be consistent on what a plot or replicate is vs subplot. This was somewhat confusing. A glossary may be extremely beneficial.

My comments in this report were probably shaded by my preliminary concept of what the objectives might be. I have documented those preliminary thoughts about objectives in the appendix.

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11 Appendix - Objectives

Objectives would be organized at three levels: (1) global change and other worldwide impacts would be reflected at Parkwide level, (2) regional effects such as local development would be reflected within regions of the park, and (3) local effects would be at the scale of the vicinity of a campground. These ideas were a distillation of some of the concepts discussed at the October 1998 Modelling Workshop.

1. How might global changes affect the park on a parkwide basis?

Possible causes:

- "global change" (decade-long time frame)
- arctic haze (decade-long time frame)
- nuclear accidents (~ Chernobyl) or bombs
- large volcanic eruptions?
- large fires?
- (These last 3 may have initial short-term impacts followed by longer term effects and succession.)

Possible effects of these events on air quality or soils:

- gas composition - SOx, NOx
- ozone
- deposition of particles
- deposition of chemicals
- temperature
- moisture amount and distribution
- change in fire regime

Possible effects on plants (autecology)

- change in growth or reproduction (esp. rates) of plants (and animals)
- change in rate of soil processes, temperature and impacts on plants
- changes (extinction, introduction, evolution) of species
- expansion / contraction of species' ranges (as species, not the communities)

Possible effects on plant communities (synecology)

- expansion / contraction of plant communities
- mosaic changes - community size, shape, composition
- plant community composition (may not be able to separate from succession, dispersal)

2. How do 'local' external forces (or internal in a region) affect a region of the Park? This might be at a scale of large watershed (half-a-dozen in the park).

Possible external causes:

- Increased development along Parks Hwy ('glitter gulch')
- Increased development in Anchorage and resultant pollution
- Insect outbreak (as result of changed meteorological conditions)
- Power plant near Healy
- Expansion of roads near Park (Stampede Trail, McGrath) (these may be more local effects)

- Local volcanoes
- Regional fires
- Subsistence hunting near Cantwell
- Nenana agricultural development
- Insect outbreak

Possible internal causes - although these may be at next scale down::

- Change in regional wildlife populations
- Road corridor
- Kantishna development
- Revegetation
- Mining (coal, gold)

Possible effects on air quality:

- Automobile fumes, etc.
- Particulate matter

Possible effects on plants (autecology)

- change in growth or reproduction (esp. rates) of plants (and animals)
- changes (extinction, introduction) in species
- metal accumulation
- wildlife changes in abundance may alter plant survival

Possible effects on plant communities (synecology)

- expansion / contraction of plant communities
- mosaic changes - community size, shape, composition
- plant community composition (may not be able to separate from succession, dispersal)
- wildlife changes in abundance may alter plant community structure

3. What are local effects on vegetation?

Possible causes:

- road traffic
- internal park development
- local fires

Possible effects on air quality:

- automobile fumes, etc.
- particulate matter

Possible effects on plants (autecology)

- change in growth or reproduction (esp. rates) of plants (and animals)
- changes (extinction, introduction) in species
- metal accumulation

Possible effects on plant communities (synecology)

- expansion / contraction of plant communities along roads
- plant community composition (may not be able to separate from succession, dispersal)