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Protocol for Ground-based Monitoring of Vegetation in the Southwest Alaska Network

Natural Resource Report NPS/SWAN/NRR—2010/205

ON THE COVER
Mid-elevation low shrub (*Betula glandulosa*) tundra, Lake Clark National Park & Preserve.
Photograph by: Amy Miller

Protocol for Ground-based Monitoring of Vegetation in the Southwest Alaska Network

Natural Resource Report NPS/SWAN/NRR—2010/205

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Contents

Figures v
Tables vi
Appendices vii
Acknowledgements viii
1 Background and Objectives 1
1.1 Introduction 1
1.2 Rationale for Monitoring Vegetation in SWAN parks 2
1.2.1. Management Concerns 2
1.2.2. Rationale for Ground-based Monitoring 3
1.3 Measurable Objectives 4
2 Sampling Design 5
2.1 Rationale for Selecting this Sampling Design over Others 5
2.1.1. Accessibility 7
2.1.2. Estimated Sample Size Required to Detect Change across all Vegetation Classes 8
2.1.3. Constraining the Sample to Selected Vegetation Classes 9
2.2 Site Selection 13
2.3 Recommended Sample Size and Sampling Frequency 13
2.4 Targeted Sampling in Sensitive Communities 18
2.5 Change Detection 19
3 Methods 19
3.1 Preparation for field season 20
3.1.1. Recruiting 20
3.1.2. Logisitics, Data Uploads, and Preparation of Working Database 21
3.1.3. Training 21
3.2 Field methods 21
3.2.1. Plot Layout 21
3.2.2. Plot Descriptive Data 22
3.2.3. Plot Photos 22
3.2.4. Species Composition 22
3.2.5. Tree Measurements 22
3.2.6. Coarse Woody Debris, Litter and Duff 24
3.3 End-of-season procedures 25
3.3.1. Processing of Collections 25
3.3.2. Equipment Inventory 25
4 Data Processing, Analysis and Reporting 25
4.1 Project Information Management Overview 25
4.2 Database Design and Data Management 25
4.2.1. Data Backups 27
4.2.2. Data Verification 27
4.2.3. Geospatial Data 27
4.2.4. Metadata 27
4.3 Data Reduction and Analysis 27
4.3.1. Reporting and Product Development 28
4.3.2. Records Management 28

5 Operational Requirements 28
5.1 Personnel Requirements and Qualifications 28
5.2 Annual Workload and Field Schedule 28
5.3 Facility and Equipment Needs 28
5.4 Startup Costs and Budget Considerations 29
6 Literature Cited 30

Figures

Figure 1. Parks of the Southwest Alaska Network 1

Figure 2. Proposed plot locations in LACL 15

Figure 3. Proposed plot locations in KATM 16

Figure 4. Proposed plot locations in KEFJ 17

Figure 5. SWAN plot layout 23

Figure 6. Plot monument stamped with the plot id number 24

Figure 7. Layout of nested quadrats. 24

Figure 8. Summary of CAKN database structure as model for SWAN. 26

Tables

Table 1. Hierarchy of vegetation monitoring projects in the SWAN..... 3

Table 2. Cover changes, cover types of interest, and separability of cover types..... 4

Table 3. Characteristic vegetation classes targeted for monitoring in the SWAN..... 10

Table 4. Percent cover of landcover classes in the three largest parks of the SWAN ....**Error! Bookmark not defined.**

Table 5. Interannual variability and rates of change in species attributes reported for high elevation and high latitude ecosystems..... 14

Table 6. Panel design for monitoring vegetation in the SWAN..... 18

Table 7. Simulation results: ability to detect different levels of total decline for a true average total decline of 50% over 31 years..... 18

Table 8. Annual work cycle for ground-based vegetation monitoring 20

Table 9. Staffing needs for SWAN ground-based vegetation monitoring 29

Appendices

Appendix A: Standard Operating Procedures..... 37

Appendix B: Field Data Forms..... 126

Appendix C: Using S-DRAW to Generate GRTS Samples..... 150

Appendix D: Simulation results for evaluating minimum number of points and grids of points required to detect change in two landcover classes, Lake Clark National Park & Preserve 172

Appendix E: Simulation results for evaluating minimum sample size and sample frequency required for detecting a specified total change in vegetation plots within SWAN parks..... 179

Appendix F: SAS Code for Summary Statistics..... 196

Appendix G: Using BugsXLA and WinBUGS to Estimate Trends from Vegetation Plot Data 210

Appendix H: Guidelines for Voucher Collections 231

Appendix I: Plant Association Descriptions..... 234

Appendix J: Proposed Database Structure……..……..242

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Roland C, Oakley K, Debevec EM, Loomis P. 2004. Monitoring vegetation structure and composition at multiple spatial scales in the Central Alaska Network. U.S. Dept. Interior, National Park Service, Fairbanks, AK. (http://science.nature.nps.gov/im/monitor/protocols/CAKN_Vegetation.zip)

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1 Background and Objectives

1.1 Introduction

This protocol outlines methods for ground-based monitoring of vegetation in the Southwest Alaska Network (SWAN) following a sampling design developed by the North Coast and Cascades Network (NCCN; Woodward et al. 2009). Vital signs addressed by this protocol are ***vegetation composition and structure*** and ***sensitive plant communities***. Standard Operating Procedures (Appendix A) and field data forms (Appendix B) outline sampling procedures.

Vegetation is integral to ecosystem function, energy transfer, and element cycling, and serves as a sensitive indicator of environmental conditions. Coastal Aleutian, low Arctic, interior-boreal, and Pacific coastal floras converge in southwest Alaska, resulting in a floristically rich area that supports approximately 60% of the state's vascular taxa (University of Alaska Fairbanks Museum Herbarium, ARCTOS, 2004). In the Southwest Alaska Network (SWAN; Fig. 1), the ***structure and composition*** of vegetation are expected to respond to increasing variability in climate and the occurrence of pathogens and pests; increasing occurrence of exotic species; and increasing pollutant loads.

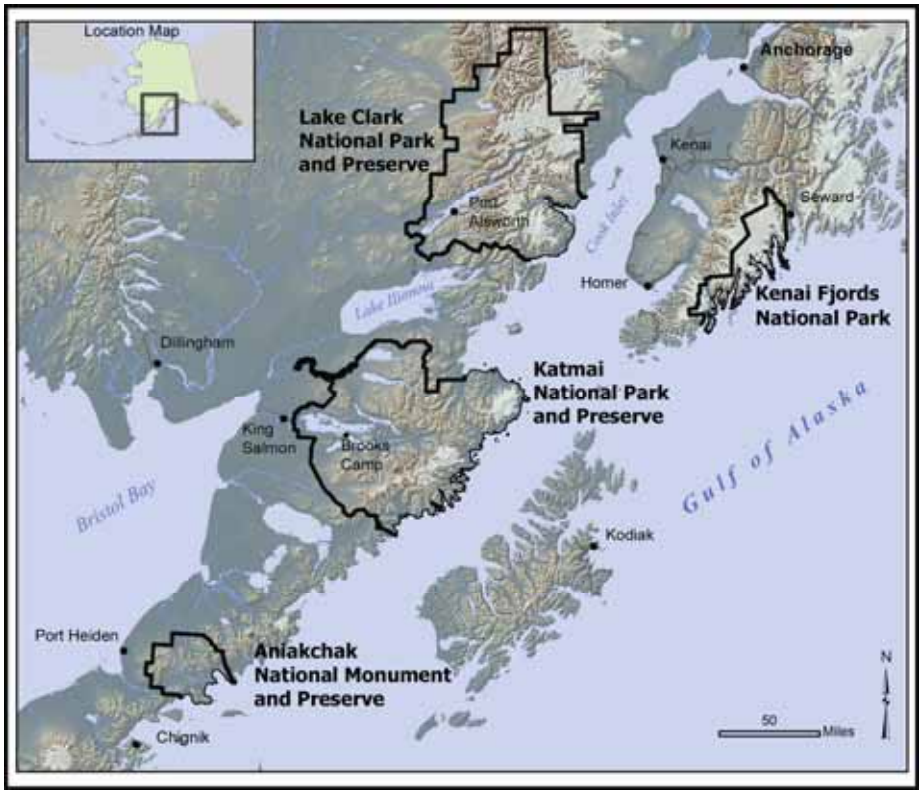

Figure 1. Parks of the Southwest Alaska Network (from Bennett et al. 2006). Park area is expressed in millions of hectares (M ha): Aniakchak National Monument & Preserve (ANIA; 0.2 M ha); Lake Clark National Park & Preserve (LACL; 1.6 M ha); Katmai National Park & Preserve (KATM; 1.7 M ha) and Alagnak Wild River (ALAG; 0.01 M ha); and Kenai Fjords National Park (KEFJ; 0.3 M ha). Ground-based monitoring is planned for the three largest parks (LACL, KATM, KEFJ), which total more than 3.6 million hectares.

Shifts in the structure and composition of *sensitive plant communities*, in particular, are expected to serve as early indicators of ecosystem change, as these communities often occur at the edge of their environmental tolerance (Spicer and Chapman 1990, Lesica and McCune 2004, Epstein et al. 2004).

1.2 Rationale for Monitoring Vegetation in SWAN parks

1.2.1. Management Concerns

Enabling legislation for the SWAN parks (ANILCA 1980; §101(b) and §201(7)) establishes as broad purposes the need ... *to preserve in their natural state extensive unaltered arctic tundra, boreal forest, alpine meadows, and coastal rain forest ecosystems.* These ecosystems provide forage and habitat for Dall sheep, caribou, and brown bears; subsistence resources to humans; and scenic qualities that enrich visitor experience. All are protected under ANILCA (§201(1), §201(7), and §202(2)).

These focal ecosystems that are valuable to wildlife and humans – low arctic tundra, boreal forest, alpine, and coastal forest – are expected to be sensitive to a number of drivers, including climate (e.g., temperature; Spicer and Chapman 1990, Epstein et al. 2004), pollutant loads, and physical disturbance (e.g., Auerbach et al. 1997). Increased drought stress (Barber et al. 2000) and insect disturbance (Logan et al. 2003); increasing fuel loads and changes in fire frequency and severity (Flannigan and Van Wagner 1991; Stocks et al. 1998); and increased occurrence of exotic species (Dukes and Mooney 1999) are potential management concerns associated with regional warming. In the SWAN, regional-scale spruce bark beetle (*Dendroctonus rufipennis*) and localized noctuid moth (*Sunira verberata*) outbreaks have altered stand structure in recent years, and the resultant dieback will likely result in short- or long-term changes in species composition. Fuel loads are expected to increase with increasing forest mortality, likewise increasing fire risk in some areas.

Increasing temperatures may also result in changes in species composition across ecosystem types. Warming experiments in the arctic have shown an increase in shrub cover (Walker et al. 2006), consistent with the rise of alder and willow in the paleoecological record (Hu et al. 2002, Brubaker et al. 2001) and the broad-scale expansion of shrubs in recent decades (Suarez et al. 1999, Sturm et al. 2001, Silapaswan et al. 2001, Klein et al. 2005). Experimental warming has also resulted in a loss of lichen cover (Cornelissen et al. 2001), concomitant with an increase in herbaceous species and shrubs (Klein et al. 1987). Lichens are a major component of the winter diet for caribou and an important source of nutrients during the calving season (Klein 1982, Barten et al. 2001), and thus reductions in lichen cover associated with other ecosystem changes could have measureable effects on caribou populations over the long-term.

Additional effects of warming may include broader shifts in species' ranges, including the southward migration of Sitka spruce (Capps 1937), the regional expansion of alder in southwest Alaska (Heusser 1983, Nelson 2004), and the displacement of obligate alpine species to higher elevations by more competitive mid-elevation species (Lesica and McCune 2004). Paradoxically, increased warming could also lead to greater frost damage in some species, which in turn could affect ecosystem productivity at decadal scales or longer (Gu et al. 2008; Bokhorst et al. 2008).

Comprehensive reviews of the potential effects of climate, pollutants, fire and other disturbances on vegetation are provided by Roland et al. (2004) and Woodward et al. (2009).

1.2.2. Rationale for Ground-based Monitoring

Vegetation composition and structure can be described at a range of spatial and temporal scales that meet different monitoring objectives (Table 1). The wall-to-wall coverage and long time scales that characterize remotely-sensed imagery make it an appropriate tool for park-wide inferences of vegetation change. Remote sensing data are valuable in detecting landscape-scale changes in dominant vegetation types, such as large-scale shrub expansion (Sturm et al. 2001, Silapaswan et al. 2001) and changes in productivity (Myneni et al. 1997, Verbyla 2008) and surface hydrology (Klein et al. 2005, Riordan et al. 2006). In the SWAN, Landsat TM/ETM+ (Kennedy et al. 2006, 2009), MODIS (Reed et al. 2009), orthorectified aerial photos, and high-resolution IKONOS data (e.g., Jorgenson 2007) are being used to document park-wide changes in the distribution and abundance of major cover types (e.g., ice/snow, rock, coniferous forest, tall shrubs, surface water); landscape-level disturbances or transitions (e.g., forest mortality, channel migration, pond drying or infilling); changes in altitudinal and latitudinal tree- and shrub-line; and interannual variation in productivity and growing season length.

Table 1. Hierarchy of vegetation monitoring projects in the SWAN.

Protocol	Spatial Extent & Scale	Parks	Frequency	Monitoring Objectives
Remote sensing	• Wall-to-wall coverage • Coarse to moderate scale • Platforms: Landsat, IKONOS, air photos	• ALAG • ANIA • KATM • KEFJ • LACL	Decadal to Multi-decadal	• Describe distribution of dominant vegetation • Document landscape-level disturbance • Surface hydrology and glacier extent • Encroachment of woody vegetation • Phenology
Ground-based monitoring	• Accessible areas • Probabilistic design • Fine scale	• KATM • KEFJ • LACL	Decadal	• Describe representative vegetation classes • Document changes in structure, composition of canopy and understory • Measure environmental variables
Ground-based monitoring	• Targeted environments • Fine scale	• KATM • KEFJ • LACL	Decadal	• Describe sensitive vegetation types • Document changes in structure, composition of canopy and understory

Remote sensing techniques provide a powerful tool for detecting change on the landscape but have several limitations, particularly at finer spatial scales. First, subtle spectral changes, many of which are of interest to the SWAN (e.g., low shrub encroachment into tundra) are difficult to detect and must be assigned a low level of confidence (Kennedy et al. 2006, 2009; Table 2). Second, the change of interest must be of a large enough geographic extent to cover several pixels (e.g., ≥0.25 ha for Landsat TM/ETM+; ≥25 m^2 for IKONOS), whereas many changes of interest in the SWAN are finer-scale and/or discontinuous in extent (e.g., changes in lichen cover). Because changes detected by remote sensing must be relatively extensive, longer time frames (e.g., decades to centuries) are also required to detect change. Lastly, frequent cloud cover and a short growing season limit the number of usable images available to the SWAN.

Ground-based vegetation monitoring is intended to target changes in vegetation structure, species composition, and selected environmental variables that are too subtle spectrally or occur at too fine a scale to monitor through remote sensing techniques alone. Estimates of species richness and diversity, for example, or species turnover, can be acquired only through ground-based measurements at the community scale. Effects of overstory change (e.g., shrub encroachment; treeline migration) on understory composition (e.g., lichen cover) are likewise detected only through ground-based measurements.

Table 2. Cover changes, cover types of interest, and separability of cover types (Kennedy et al. 2006).

Cover change	***Beginning type***	***Ending type***	***Spectral separability (good, marginal, poor)***
Avalanche/landslide	Conifer trees	Soil, herbaceous	Good
	Broadleaf trees/shrubs	Soil	Good
		Herbaceous	Marginal
Insect/disease-related mortality/defoliation	Conifer trees	Dead trees at approximately > 75% mortality*	Good
		Dead trees at 25%-75% mortality*	Marginal
		Dead trees at < 25% mortality*	Poor
	Alder shrubs/tree	Defoliation at unknown (high) rate, captured in year of mortality	Good
		Defoliation at unknown (high) rate, captured in years after mortality	Likely poor
Volcanic eruptions/ash deposits	All vegetation	Volcanic ash	Likely good
	Volcanic ash	Herbaceous vegetation	Marginal/poor
	Volcanic ash	Alder/other shrub	Good
Change in snow/ice cover or extent	Glacier	Exposed rock	Good
	Glacier	Alder/other shrub	Good
Encroachment of vegetation into glacial forefront	Exposed rock/soil	Alder/other shrub	Good
Encroachment of shrubs into subalpine or alpine	Exposed rock/soil	Alder/other shrub/herbaceous	Marginal/good (SE aspects) Poor (NW aspects)
	Herbaceous	Alder/other shrub	Marginal (SE aspects) Poor (NW aspects)
Overtopping of lichen by shrub	Lichen	Low shrubs	Marginal/poor
	Lichen	Alder/tall shrub	Marginal/good
Infilling of ponds with vegetation	Water	Herbaceous vegetation	Good
Changes in river course	Water	Soil/rock	Good
		Vegetation	Good
	Vegetation	Water	Good
		Soil/rock	Good
Change in tidal wetland conditions	Vegetation	Soil/mud	Good
	Vegetation (flooded)	Vegetation (dry)	Poor
*Mortality percentages are based on ocular estimates of areal cover, and are approximate.			

1.3 Measurable Objectives

Ground-based monitoring objectives for the SWAN are to document trends in the structure, composition, and demography of selected vegetation classes. We are interested in the direct

response of vegetation to environmental change and thus focus on late-successional communities that have not experienced recent stand-level disturbance, and in changes that are not readily documented through other means (e.g., remote sensing techniques).

The specific measurable objective is to estimate long-term trends in community composition and structure (e.g., percent cover of dominant species; percent cover by growth form and height class; frequency of selected dominant, subdominant, and indicator species) of late-successional communities from a random sample of three elevation bands (0-450 m; >450-900 m; >900 m) in the three largest parks (KATM, KEFJ, and LACL).

Structure and composition:

For vascular and common non-vascular species in selected vegetation classes and sensitive communities:

1. Document changes in species occurrence.
2. Document changes in species frequency.
3. Document changes in species cover.
4. Document changes in species height.
5. Document changes in species composition (richness and diversity indices).

Additionally, for trees ≥12.0 cm DBH (cf. Roland et al. 2004):

6. Document changes in indicators of forest health; e.g.,
    a. Number of live and dead trees
    b. Number of insect-damaged trees
    c. Number and decay class of snags
    d. Estimated volume of large woody debris
    e. Mean canopy height

Processes:

1. Document changes in woody species establishment.
2. Document changes in seedling and sapling densities, and stand biomass, if applicable.
3. Document changes in the rate and cause of tree mortality, if applicable.
4. Document changes in active layer depth, if applicable.
5. Document changes in the growth rate of trees at selected sites.

2 Sampling Design

2.1 Rationale for Selecting this Sampling Design over Others

The SWAN uses a sampling frame developed by the NCCN (Woodward et al. 2009) that draws a Generalized Random-Tesselation Stratified (GRTS, Stevens 1997; Stevens and Olsen 2004) sample from fixed elevation bands. The design uses a two-stage sampling scheme, wherein the stage 1 GRTS sample is evaluated in a GIS for safety and accessibility, and the stage 2 sample

that results is evaluated by field reconnaissance for plant communities of interest. The goal of this design is to define the sampled population (vegetation) based on accessibility and fixed features of the landscape; to choose a GRTS sample from all accessible plots within these fixed features; and to then establish permanent plots in a selected number of vegetation classes in each sampled population. Assumptions that underlie the NCCN sampling frame are as follows (Woodward et al. 2009):

- Monitoring will focus on changes in community structure and composition resulting from long-term environmental change, rather than succession following stand-level disturbance. Mid- to late-successional communities will be targeted for monitoring.
- Monitoring must distinguish between interannual variability (e.g., in herbaceous cover) and long-term trends in species composition.
- Monitoring will be based on an inferential statistical design, with sampled populations derived from static characteristics (e.g., elevation) and adequate replication of defined community types to detect changes in the abundance of individual species and growth forms.

Additionally, logistical and cost considerations require the following:

- Accessibility of plots is critical for crew safety and for timely collection of data.
- Sample size must be limited, yet replication must be adequate to detect change.

We use three 450 m-wide elevation bands (0-450 m; >450-900 m; >900 m) that are essentially treated as separate sampling frames within each park. The GRTS sample that is selected is confined to an access layer (GIS) that takes into account topography and barriers to travel, and that includes criteria for safe access to sites (Mortenson and Miller 2008; Woodward et al. 2009). Within the GRTS sample, we document vegetation at all sites but intensively sample specific vegetation communities within each elevation band (cf. Woodward et al. 2009). A GRTS sample has the advantage of spatial dispersion, but without a repeating interval. Unlike a systematic sample, a GRTS sample has an excellent variance estimator, enabling the investigator to exclude sites when they are inaccessible or are not within the population of interest. Likewise, for plots that experience a major disturbance, we can substitute new plots from the sample frame (GRTS sample) to replace those that are no longer within the population of interest. We deviated from the NCCN sampling design in the following ways: 1) we used 450 m elevation bands rather than 300 m bands; 2) we placed limits on the time that we would spend accessing a site from our base camp (2 hours travel, one-way); and 3) we spent the first several weeks of the field season conducting ground and overflight reconnaissance of sites, such that we could more efficiently plan our subsequent travel and could target sites clustered at pre-established access points. In this way, we were able to establish some GRTS sites out of sequence (and thus minimize travel costs) because we knew up front, from the reconnaissance, which sites we would be able to accept as part of the GRTS sample. We generally sample 2-6 plots from a given access point (base camp). In addition, we 4) modified the NCCN plot layout and sampling methods to reduce the time spent at a site (we complete a plot in 4-8 hours; Section 3.2.1.), and 5) adopted a form developed by the Northern Great Plains Network (NGPN) to document the site selection process (A. Symstad, *personal communication*; Section 2.2.; Appendix 7). We opted to sample fewer plots intensively (i.e., one plot per day rather than several), because we felt that the

travel time (on foot) required to ensure that plots are well-dispersed should not exceed the time spent collecting data.

An alternative sampling frame using a 2-stage systematic grid design has been developed by the CAKN (Roland et al. 2004). The advantages of the 2-stage grid design are that it retains information about spatial relationships at a range of scales and therefore enables park-wide inferences regarding vegetation change. It also samples across all communities and, as such, is expected to capture unanticipated change (Roland et al. 2004). The 2-stage grid approach assumes that communities occur at a high enough frequency on the landscape to be adequately sampled. Clustering of sample points into mini-grids concentrates the landscape-scale sampling efforts within confined study areas, with the intent of reducing sampling cost. The U.S. Forest Service Forest Inventory and Analysis (FIA) program also uses a grid design, but FIA methods do not meet SWAN monitoring objectives for understory composition (Woodward et al. 2009; Sanders et al. 2008), nor are data available for parks other than KEFJ (n = 4).

We chose an access-based GRTS design over the systematic grid design, as model simulations based on the LACL landcover dataset (Section 2.1.2.) indicated that the advantages of a two-stage grid approach (park-wide inference) would be outweighed by the high costs associated with sampling. In other words, the large sample sizes required for change detection in any one vegetation class make park-wide inferences of vegetation change from ground-based sampling logistically and fiscally unrealistic in the SWAN. Instead, we are using remote sensing techniques to infer landscape-level changes, where appropriate (Section 1.2.2).

2.1.1. Accessibility

Ground-based monitoring in the SWAN is challenging because the constituent parks are large, remote, and difficult to access except via fixed-wing aircraft, helicopter, or boat. Access can be delayed at any time by weather, and travel time on the ground is frequently compromised by topography (e.g., deep ravines and river channels), dense vegetation, extensive wetlands, and wildlife (e.g., bears). To account for these difficulties, we developed access layers for the parks using path-distance analysis tools in ArcGIS (LACL and KATM; Mortenson and Miller 2008) and/or manual interpretation (KEFJ), following Woodward et al. (2009). We assigned a 3-5 km buffer to entry points into the backcountry (e.g., lakes, landing strips) that was then modified by calculating the cost of travel, in terms of time, to monitoring plots. Travel time was estimated using existing landcover, topographic, and hydrographic layers. Barriers to travel included private inholdings, glaciers, slopes >50º, and major river crossings (Mortenson and Miller 2008).

The access layers developed for vegetation sampling represent 7% of vegetated land area in LACL, 24% in KEFJ, and 31% in KATM. Given the trade-off between sampling across the entire landscape (high cost, low sustainability) and sampling a subset of the landscape that is readily accessible (low cost, high sustainability), we placed a priority on having a sustainable sample population over the long term. For broad-scale, ground-based vegetation monitoring (Sections 2.1-2.3), our inference will be limited to accessible and higher priority areas (cf. Woodward et al. 2009). Targeted sampling will address sensitive communities and areas of management concern that occur infrequently on the landscape and/or are relatively inaccessible (Section 2.4).

2.1.2. Estimated Sample Size Required to Detect Change across all Vegetation Classes

We conducted simulations to investigate the minimum level of change that could be detected when the relative proportion of two landcover classes were changed across fixed time periods. The simulations tested the efficacy of sampling single points versus clusters (mini-grids) of points in a randomized design and estimated sample sizes required to detect minimum levels of change for a known level of change (true change) across all landcover classes. We used landcover class codes assigned to each 30 m × 30 m cell as surrogates for ground vegetation plot data at Time 1. We randomly selected 50% of these cells and changed their landcover class designations for Time 2. Thus, within our simulation context, the change was being applied at the landcover class level. Although this was not a perfect solution, it did allow us to use an empirically based spatial distribution of landcover classes (vegetation) rather than assuming one (e.g., uniform [random], negative binomial, etc.), the latter of which can produce increasingly misleading simulation results the farther away the assumed spatial distribution is from reality.

Prior to running the simulations, we generated an MS Access database for the GIS access layers that included UTM coordinates attributed with elevation and landcover class in each park. The database was imported into SAS (SAS Institute, Inc., 2004, 2006) to assign elevation classes, and then exported as .txt files to S-DRAW (http://www.west-inc.com/computer.php) to select GRTS samples (Appendix C). Elevation classes consisted of 450 m elevation bands (0-450 m, >450-900 m, >900 m) in each park. In LACL, the >900 m elevation band was divided into N and S sections (dividing line = Turquoise Lake, 60.78 ºN (NAD83)), with a pixel size of 25 used for the northern section, and pixel size of 50 for the southern section. A pixel size of .01 was used for the 0-450 m and >450-900 m elevation bands. Differences in pixel size were required to generate a well-distributed sample across the latitudinal gradient, and to minimize clustering during sample selection (sequential selection of points). The cell sizes were 30 m × 30 m in the landcover data set. During our preliminary analyses, we discovered that the fragmentary nature of our underlying vegetation data created problems when selecting GRTS samples. Therefore, we used a range of pixel sizes in S-Draw and visually evaluated the spatial balance of the sample generated from each one. This was essentially a trial-and-error approach. We then used the pixel size that produced the best result for each vegetation class/elevational band combination.

We further divided the 0-450 m elevation band into interior and coastal sites (dividing line = Hickerson Lake, -152.83 ºW) by manually selecting coastal sites in a GIS. We did this rather than generate a separate set of sample points because previous attempts to split the 0-450 m elevation band had resulted in poor sample distributions and clustering during point selection. In KATM, a pixel size of 1 was used for all elevation bands, and separate GRTS populations were generated for spruce and non-spruce landcover classes, for the reasons cited above for LACL (low frequency of suitable sites; maintenance of spatial dispersion; minimize clustering).

We ran simulations to investigate the minimum level of change that could be detected across all landcover classes when either 20% or 50% of a specific class was changed across two time periods (Appendix D). Up to 50 samples of single points, 2×2 grids of points, and 3×3 grids of points were chosen in each simulation run. Points were selected under a GRTS design from specific landcover classes occurring at different frequencies (0.75% - 43%) within each elevation band in LACL. Using the most frequently occurring landcover class, and assuming a true change of 50%, simulation results indicated that at least 12 single points (plots) would have to be selected to have at least an 80% chance of detecting a >0 change with 90% confidence (*W*.

Thompson, unpublished data; Appendix D). Under these same conditions, at least 33 points would have to be selected to meet the >0 criterion when 20% of the landcover class had been changed. As the minimum detectable change was increased from >0, the required number of replicates also increased (e.g., 43 replicates to detect a minimum change of 10% when the true change was 50%). When landcover classes occurred at frequencies ≤16% of the elevation band, change was essentially undetectable with an 80% level of confidence, even with a sample size of 50. Minimum sample sizes were as much as 70% lower for 2×2 and 3×3 grids of points, but the use of grids required that four (2×2) to nine (3×3) times as many points be sampled per sampling unit (i.e., a grid of points versus single points as replicates). As a result, the total number of plots sampled in a grid array would be ≥25% greater than for a random array of single points.

The simulations indicated that by using a GRTS sampling approach across all vegetation classes, as approximated by landcover class, we would have sufficient replication to detect a trend in plot-level data only if a vegetation class occurred at a high frequency (e.g., ≥43%) on the landscape. Furthermore, we would need at least 43 plots to detect a 10% change in that class with 90% confidence when the true change was 50%. Given a field season of 8-10 weeks with a minimum of two days of travel per sampling trip, we assumed that approximately 32-40 plots could be sampled over the course of a year. Thus, it would take two years to accrue a sufficient number of plots across all vegetation classes to detect change over time in one vegetation class in a single elevation band in a single park. At the same time, we would be sampling a number of plots (i.e., in rarer vegetation classes) that would tell us nothing about the change(s) in question, but that would be contributing noise to the trend analysis. A second set of simulations (Section 2.3; Appendix E) examined minimum levels of change in species cover that could be detected with a GRTS sample in a single landcover class.

2.1.3. Constraining the Sample to Selected Vegetation Classes

Limited resources and a need for adequate replication required that we focus ground-based monitoring in relatively broad vegetation classes representative of a range of climate and elevation zones in south central and southwest Alaska (Table 3; Table 4). We have adopted the Woodward et al. (2009) two-stage sampling approach that enables us to focus our sampling on specific vegetation classes without stratifying on vegetation (Section 2.2). Selection criteria for these vegetation classes follow:

- Classes of interest are relatively common in, and representative of, a given elevation band
- Classes are late-seral and/or relatively stable, and thus change is not primarily successional
- Classes are expected to be sensitive to changes in environmental drivers (e.g., climate)
- Classes are of known value ecologically or culturally, and are of interest to management

Table 3. Characteristic vegetation classes (ecosystems) targeted for monitoring in the SWAN.

Elevation Band	LACL	KATM	KEFJ
Low (0-450 m)	Interior closed spruce and spruce woodland (*Picea glauca*)	Interior closed spruce and spruce woodland (*Picea glauca*)	Coastal spruce (*Picea sitchensis*)
Mid (>450-900 m)	Interior spruce woodland (*Picea glauca*)	Interior spruce woodland (*Picea glauca*)	-
Mid (>450-900 m)	Low & dwarf shrub tundra (*Betula glandulosa*)	Low & dwarf shrub tundra (*Betula glandulosa*)	-
High (> 900 m)	Dwarf shrub tundra – alpine	Dwarf shrub tundra – alpine	Dwarf shrub tundra – alpine

Monitoring focuses on questions that could not otherwise be addressed by remote sensing techniques (e.g., low shrub encroachment into tundra; loss of lichen cover; Table 2). Vegetation classes selected for the current phase of monitoring occur along a gradient from relatively warm, wet coastal environments to colder, drier boreal and subarctic environments and high alpine environments limited by temperature and growing season length. Mean annual temperature ranges from -8 °C to 4 °C across the gradient. Mean annual precipitation ranges from 400–600 mm in the western interior to 3000–4000 mm at higher elevations and along the eastern coastlines (Davey et al. 2007).

We did not select alder and willow classes, in spite of their abundance, because these classes are generally representative of early-successional environments, and are spectrally distinct and can be readily identified in even moderate-resolution remotely sensed data. In addition, the shrub classes afford poor visibility on the ground, which becomes a serious safety issue in bear country. Mixed hardwood-conifer and deciduous forest types were not considered at this time for similar reasons (e.g., early to mid-successional; spectral characteristics; safety).

On the Alaska Peninsula, the selected associations include low elevation interior spruce forest (0-450 m); mid-elevation white spruce woodland (450-900 m); mid-elevation low and dwarf shrub communities (450-900 m), and alpine dwarf shrub-fellfield communities (>900 m) (Viereck et al. 1992). Treeline elevation ranges from approximately 450 m to 550 m across the north-south gradient. In western Prince William Sound, coastal rainforest dominates at low elevations, while dwarf shrub tundra communities occupy exposed alpine ridges (DeVelice et al. 1999).

Descriptions of the vegetation classes and anticipated changes follow:

1. *Coastal Sitka spruce forest* – Old-growth Sitka spruce (*Picea sitchensis*) communities between 0-450 m in KEFJ. These forests provide habitat for the marbled murrelet, black bears, and a myriad of other wildlife species, and are mentioned prominently in the enabling legislation for the ANILCA parks. Mountain hemlock (*Tsuga mertensiana*) may be a secondary species in the overstory. Understory species in these communities include blueberry (*Vaccinium ovalifolium*), devil's club (*Oplopanax horridus*), and salmonberry (*Rubus spectabilis*). In KEFJ, closed conifer forest comprises 18% of the vegetated area and 3% of total land area. A smaller percentage of that is old-growth. Although these community types are expected to remain stable through time, changes in understory composition associated with overstory disturbance, or with changing climatic conditions,

could be observed over the long term. Funds permitting, monitoring of old-growth Sitka spruce and/or Lutz spruce (*Picea × lutzii*) could extend to LACL in the future, where coastal spruce forest comprises approximately 1% of land area.

Table 4. Percent cover of landcover classes in the three largest parks of the SWAN. †Landcover classes have been aggregated, where appropriate, to account for differences in landcover interpretation among parks. Percentages are calculated as a proportion of total vegetated land area in the park and rounded to the nearest 1%. ‡Dwarf shrub includes prostrate shrub class (LACL), all dwarf shrub classes (LACL; KATM), and the alpine herbaceous class (KEFJ).

†Landcover Class	LACL	KATM	KEFJ
Coastal spruce	<1	-	18
Interior closed spruce	<1	<1	-
Interior open spruce	5	3	-
Interior spruce woodland	4	2	-
Mixed conifer-hardwood forest	6	2	<1
Deciduous forest	2	7	<1
Alder	23	28	29
Willow	2	11	1
Other shrub	4	3	6
‡Dwarf shrub tundra	21	23	15
Herbaceous meadow	2	8	3
Wet meadow	4	4	-
Lichen	2	<1	-
Gravel & sparsely vegetated	25	7	26

2. <u>*Interior low elevation white spruce forest*</u> – Open and closed white spruce (*Picea glauca*) forest communities between 0-450 m in LACL and KATM. Canopy cover ranges from 25-60% (open canopy) to 60%-100% (closed canopy). Deciduous trees comprise <25% of the total canopy cover. Sites are generally well-drained. Understory species may include Kenai birch (*Betula papyrifera* var. *kenaica*), prickly rose (*Rosa acicularis*), Labrador tea (*Ledum* spp.), and lignonberry (*Vaccinium vitis-idaea*), with alder (*Alnus sinuata*), Bebb willow (*Salix bebbiana*), and field horsetail (*Equisetum arvense*) in wetter sites. These communities are considered stable and some may be very old (Viereck et al. 1992). Low elevation spruce forest comprises approximately 3% of land area in LACL and KATM. Monitoring will focus on changes in stand structure and understory species composition, e.g., in response to spruce bark beetle or other insect activity, and increased warming and drought stress. Changes in fuel loads, seedling and sapling densities, and understory shrub cover will also be documented.

3. <u>*Interior mid-elevation white spruce woodland*</u> – White spruce (*Picea glauca*) woodland communities between 450-900 m in LACL and KATM. Canopy cover ranges from 10-25%. Understory species include dwarf birch (*Betula glandulosa*), Labrador tea (*Ledum* spp.), lingonberry (*Vaccinium vitis-ideae*), and reindeer lichen (*Cladina* spp.). These communities are considered late-seral and are thought to be limited by a combination of temperature and wind exposure (Viereck et al. 1992). In parts of LACL and KATM, they overlie discontinuous permafrost. Rising treeline, permafrost degradation, shrub expansion, frost damage, and/or loss of lichen cover are among the anticipated changes in these communities.

Mid-elevation white spruce woodland comprises approximately 5% of land area in LACL and <1% in KATM. Funds permitting, monitoring could be extended to low elevation (0-450 m) spruce woodland sites in the future.

4. *Interior mid-elevation low and dwarf shrub communities* – Open low scrub and dwarf scrub (shrub) communities between 450-900 m in LACL and KATM. Dwarf birch (*Betula glandulosa*; *Betula nana*), Labrador tea (*Ledum* spp.), lingonberry (*Vaccinium vitis-ideae*), lowbush blueberry (*V. uliginosum*), crowberry (*Empetrum nigrum*), bearberry (*Arctostaphylos alpina*), willows (e.g., *Salix arctica*, *S. polaris*, *S. reticulata*), sedges (e.g., *Carex bigelowii* ssp. *lugens*) and reindeer lichen (*Cladina* spp.) are common species in these classes. These communities are considered late-seral, but may transition into shrub-tussock or shrub birch-ericaceous shrub bogs with increasing moisture, or into dwarf shrub-fellfield communities if moisture decreases and/or wind exposure increases (Viereck et al. 1992). In parts of LACL and KATM, they overlie discontinuous permafrost. Caribou, bears, ground squirrels and many species of birds use these habitats. Shrub expansion, spruce establishment, frost damage, and/or loss of lichen cover are among the possible changes that could occur in these communities. In LACL, they comprise approximately 40% and 12% of land area in the 450-900 m and >900 m elevation bands, respectively. In KATM, they comprise approximately 60% and 38% of land cover.

5. *Alpine dwarf and prostrate shrub communities* – Dwarf and prostrate shrub tundra communities at elevations >900 m in KEFJ, LACL, and KATM. Dominant species on drier sites include mountain avens (*Dryas* spp.), lingonberry (*Vaccinium vitis-idaea*), least willow (*Salix rotundifolia*), and alpine azalea (*Loiseleuria procumbens*). Wetter sites are dominated by partridgefoot (*Luetkea pectinata*), mountain heather (*Harrimanella stelleriana*), arctic willow (*Salix arctica*) and/or Aleutian mountain heath (*Phyllodoce aleutica*). Where soils are well developed, graminoids (e.g., *Carex microchaeta, Hierochloe alpina, Luzula arcuata*) and forbs provide forage for Dall sheep, mountain goats, and marmots. These plant communities are considered stable (Viereck et al. 1992), although alpine areas are expected to be sensitive to climate change (Giorgi et al. 1997, Mote el al. 2003). Dwarf birch (*Betula* spp.) or alder (*Alnus* spp.) may invade as sites become more favorable for seedling establishment (Viereck et al. 1992). Declines in species diversity as a result of local extinctions and shifts in dominance (Walker et al. 2006, Lesica and McCune 2004); increased height and density of shrubs (Walker et al. 2006); decreased lichen cover (Wahren et al. 2005, Cornelissen et al. 2001); and changes in phenology (Welker et al. 1997) are among the potential changes that could occur in high elevation communities. Dwarf and prostrate shrub tundra communities (>900 m) comprise approximately 62% of accessible land area in LACL and 38% in KATM. In KEFJ, dwarf shrub and sparse vegetation communities comprise approximately 9% of ice-free land area.

To determine vegetation class in the field, we use definitions from Viereck et al. (1992) as follows: *coniferous woodland* >75% of total tree cover in coniferous species; canopy cover 10%-25%; *open coniferous forest* >75% coniferous species; canopy cover 25%-60%; *low shrub/dwarf shrub* ≥25% shrub cover (low shrub: 20 cm - 1.5 m; dwarf shrub vegetation: <20 cm). Community types (Viereck Level V classes; Viereck et al. 1992) identified for monitoring are listed in Appendix I.

2.2 Site Selection

The Stage 1 GRTS sample generated within the access layer (Section 2.1.1.) is manually evaluated in a GIS to estimate travel distance from proposed base camps, identify stream crossings and other potential barriers not captured by the path-distance analysis, examine potential vegetation using air photos or other high resolution imagery, and eliminate points separated by less than 200 m (cf. Woodward et al. 2009). The points that are retained become the population for the Stage 2 sample that is evaluated in the field (Woodward et al. 2009). During the field reconnaissance, we use site selection criteria developed by Symstad et al. (2009) and apply the classification keys developed by Viereck et al. (1992) and DeVelice et al. (1999) to determine whether a site falls within the class of interest (SOP 2). In all cases, we exclude areas on slopes >25º to minimize ground disturbance. We thus record attributes for all points visited, as outlined by Woodward et al. (2009), but retain only a subset of sites falling in the vegetation categories of interest for long-term monitoring.

2.3 Recommended Sample Size and Sampling Frequency

We used a second set of simulations to evaluate minimum sample size and sample frequency required to detect a specified level of change in a specific landcover type. These simulations investigated the minimum level of total change in plant cover that could be detected with 95% confidence under a rotating panel design for populations subjected to different levels of true total change (30%, 40%, and 50%) over a 31-year period (Appendix E). We varied the number of plots that would be measured in a given vegetation class, elevation band, and year (n = 6, 8, 12, and 24 plots/year), and ran the simulations at two sampling frequencies (5 and 10 years) to estimate coefficients of variation (CVs) required to capture a minimum detectable total change (MDTC).

We used estimates of interannual variability in 4-6 plots/vegetation class sampled in LACL (Miller et al. 2009; Table 5) and rates of change reported in the literature (Table 5) to select an MDTC of 25% as a reasonable level of total change that could be detected given a true total change of 50% over 31 years. Specifying a MDTC as the benchmark comparison in simulations ensures both an ecologically interpretable quantity and a conservative estimate of sampling effort (i.e., larger samples collected more often). Our goal was to detect a positive or negative 1.6% annual trend (50% MDTC over 31 years) with 95% confidence for the major species that define the vegetation community.

To detect a 1.6% annual trend at a sampling frequency of five years (Table 6), we will sample 8 plots per vegetation class × elevation band × park combination (total = 24-32 plots per year). Under this design, a MDTC of 25% for species cover should be detected when CVs for plot variables are 30% or less (Table 7; Appendix E). A subset of plots targeted for repeat sampling will be visited for two consecutive years every four years to provide an estimate of interannual variability (Table 6). Overstory attributes in Panel 6 will be measured in only the first of the two consecutive years. A strong argument can be made for sampling less frequently (e.g., every 10 years), but doing so would require larger sample sizes (Appendix 4) and preclude any analysis of trends for at least three decades.

Table 5. Interannual variability and rates of change in species attributes reported for high elevation and high latitude ecosystems. Range of values for interannual variability includes the upper end of the range only; all categories included attributes that showed 0% interannual variability. High values for interannual variability in shrub cover in subarctic tundra were attributed to frost damage that occurred between the two sampling years; variation in shrub cover is generally lower. No estimates of interannual variability were available for frequency data.

Ecosystem	Attribute	Range
	-Interannual variability-	
Subarctic tundra[1]	***Shrubs***	
	Cover by growth form	20-45%
	Cover by species	5-45%
	Species occurrence	0-10%
	Graminoids	
	Cover by growth form	70%
	Cover by species	60%
	Species occurrence	50%
Alpine[2]	***Graminoids***	
	Cover by species	15-40%
	Community composition	10%
	-Long-term change-	
Alpine[2]	***Graminoids***	
	Cover by species	~5% per decade
Alpine[3]	***Shrubs***	
	Cover by growth form	1.9-6.6% per decade
Arctic tundra[4]	***Shrubs***	
	Cover by growth form	1.2% per decade
Boreal forest[5]	***Graminoids and forbs***	
	Cover by species	~75-125% per decade[†]

[1]A. Miller, Unpublished data 2007-2008
[2]Bowman et al. 2006. Ecol. Appl. 16:1183-1193
[3]Cannone et al. 2007. Front. Ecol. Environ. 5:360-364
[4]Chapin et al. 2005. Science 310:657-660
[5]Boucher and Mead. 2006. Forest Ecol. Manag. 227:233-246. [†]Rates cited are for a 13-year period following forest disturbance.

Proposed monitoring sites by elevation band and vegetation class are shown for LACL (Fig. 2), KATM (Fig. 3), and KEFJ (Fig. 4). For each park, twelve to twenty points are shown for each stratum. These points represent the first set of sites to be evaluated (lowest in the GRTS selection order), from which eight plots per stratum will be established. The actual number of GRTS points evaluated during site selection may be greater (or less) than 20.

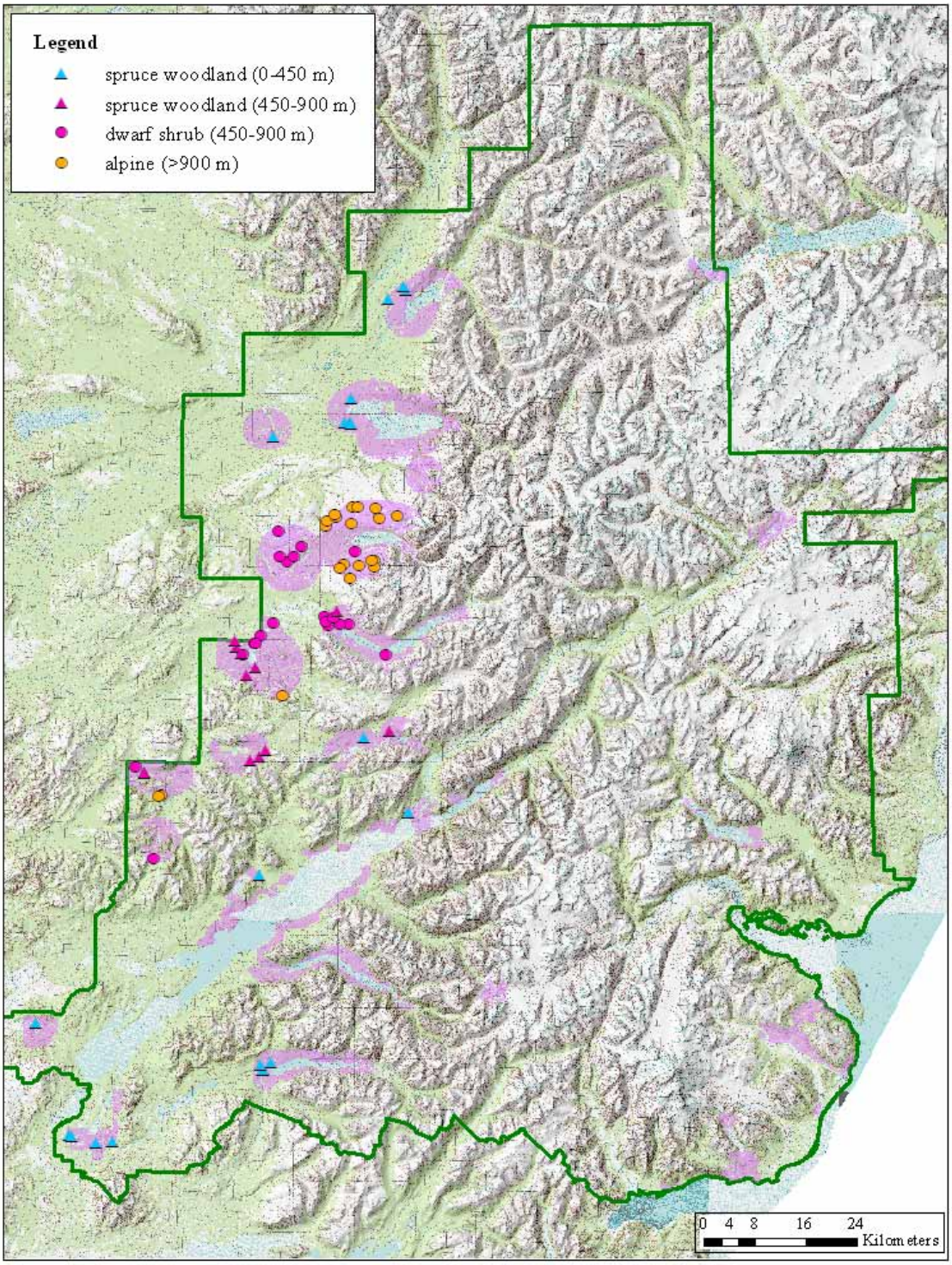

Figure 2. Proposed plot locations in LACL. A GRTS sample was drawn from an access layer defined by slope and terrain features (purple). The sample population was stratified by elevation. Twenty plots per elevation band are shown for low and mid-elevation spruce woodland, mid-elevation dwarf shrub, and alpine vegetation types. Eight plots per stratum will be sampled. Coastal Sitka spruce/Lutz spruce sites (not shown) may be added at a later date.

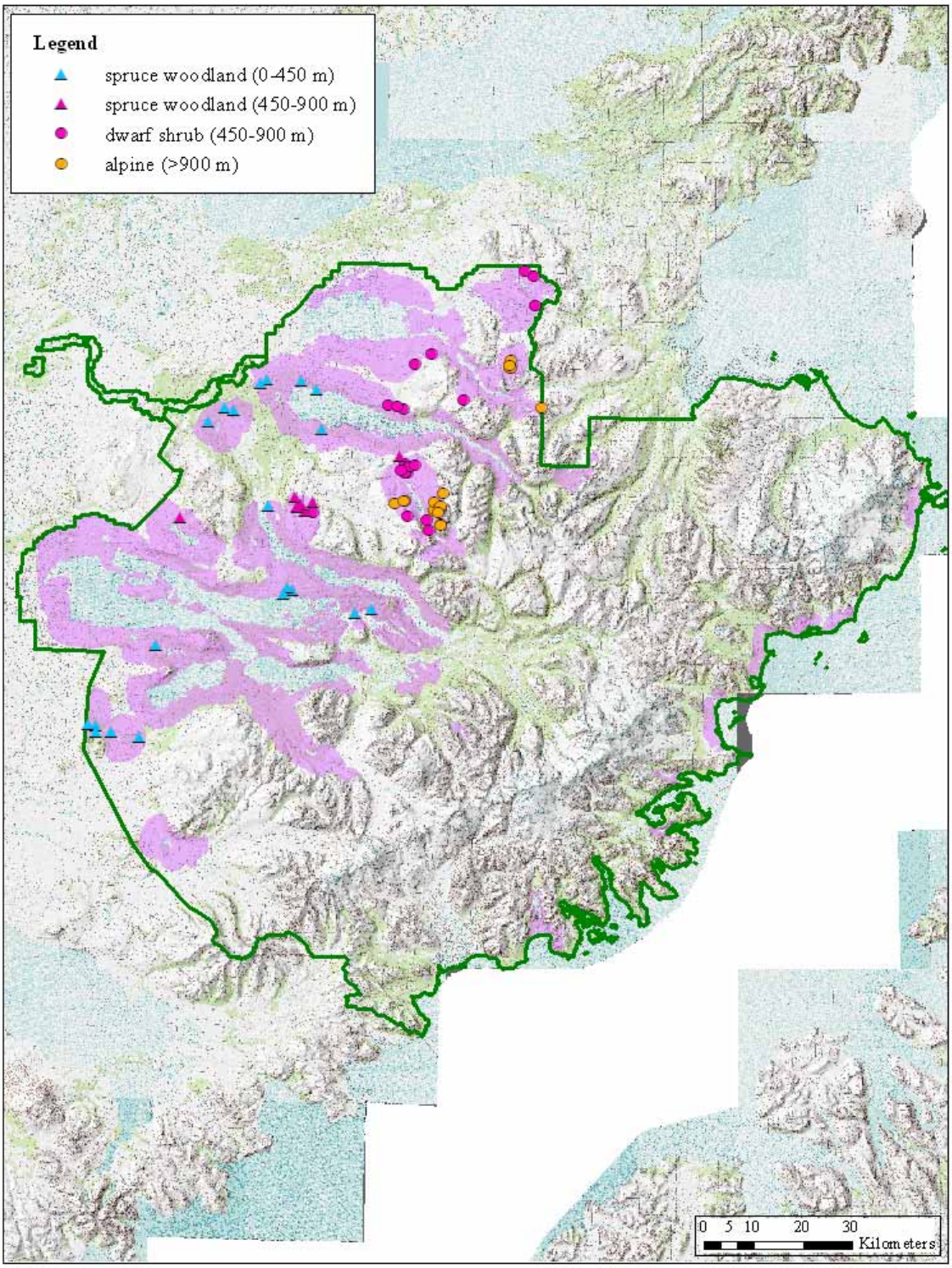

Figure 3. Proposed plot locations in KATM. Access layer is shown in purple, as in Fig. 2. Twenty plots per elevation band are shown for low and mid-elevation spruce woodland, mid-elevation dwarf shrub, and alpine vegetation types. Ten plots are shown for mid-elevation spruce woodland. Eight plots per stratum will be sampled. No coastal sites are planned at this time.

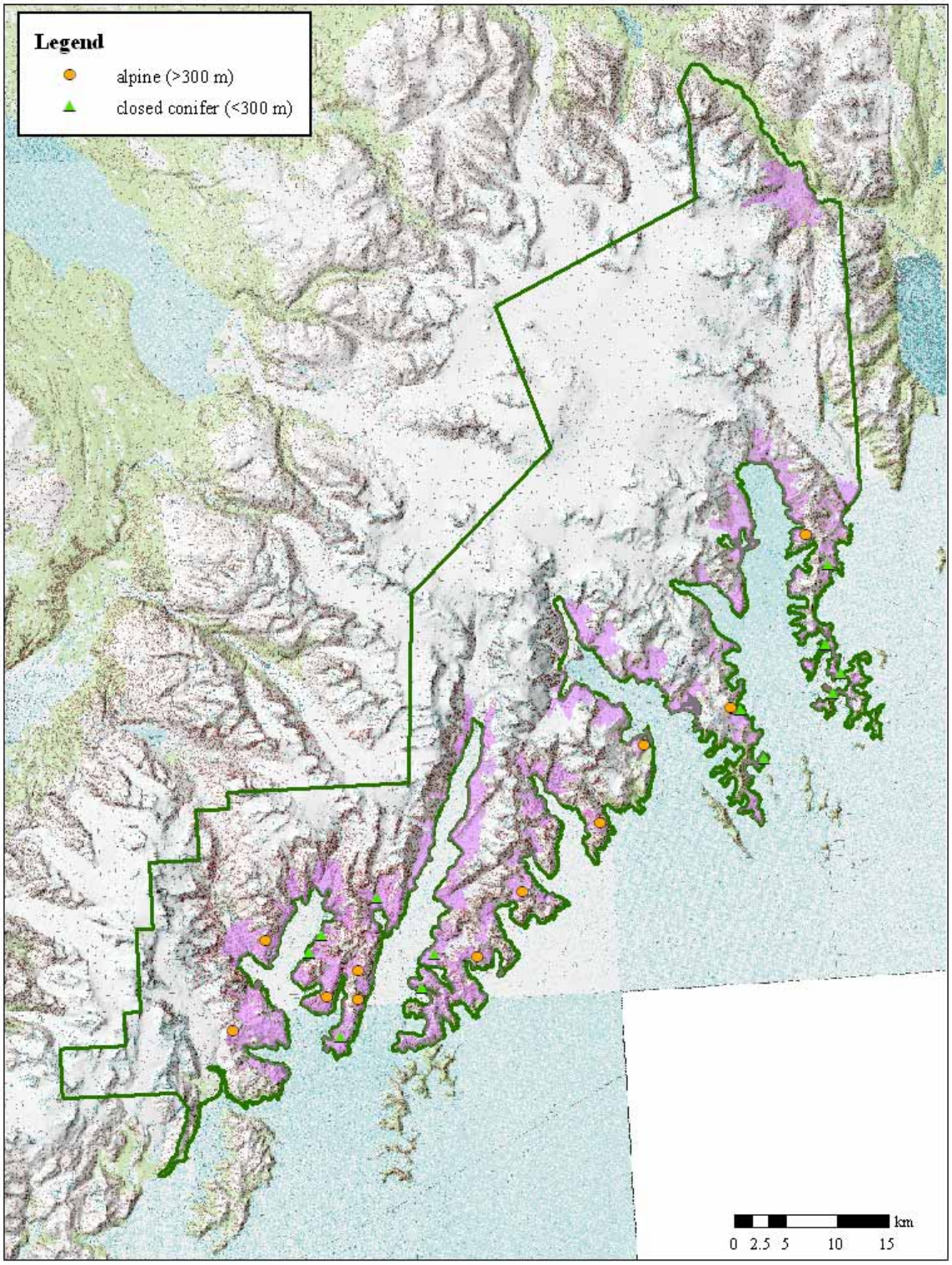

Figure 4. Proposed plot locations in KEFJ. Access layer is shown in purple, as in Fig. 2. Twelve plots per elevation band are shown for low elevation coastal forest and alpine vegetation types. Eight plots per stratum will be sampled.

Table 6. Panel design for monitoring vegetation in the SWAN, in which a panel is a group of plots that is always sampled during the same year (McDonald 2003). Each X in panels 1-5 represents 24 plots or 3 park × elevation band × vegetation class combinations (n = 8 plots per elevation band x vegetation class combination). In Panel 6, which is sampled for 2 consecutive years beginning every 5th year, each X represents 4-6 plots. We expect to sample 1-2 panels per field season, for a total of 24-30 plots per year in a given park.

	Year																				
Panel	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	X					X					X					X					X
2		X					X					X					X				
3			X					X					X					X			
4				X					X					X					X		
5					X					X					X					X	
6					X	X				X	X				X	X				X	X

Table 7. Simulation results showing the probability of detecting different levels of total decline for a true average total decline of 50% over 31 years with 95% confidence (n = 8 plots/year; sampling frequency 5 years; Appendix 4). Values in bold font indicate at least an 80% chance of detecting the stated minimum detectable total change. The <0% change category represents the traditional definition of statistical power, i.e., the chance of detecting a change regardless of its magnitude, given that a change occurs.

	Estimated percent (%) chance of detecting the listed or smaller total change given a true average total change of -50%[a]										
CV ($\hat{p}$) (%)	<0%[b]	≥-5%	≥-10%	≥-15%	≥-20%	≥-25%	≥-30%	≥-35%	≥-40%	≥-45%	≥-50%
5	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**99**	7
10	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**98**	70	6
15	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**99**	**83**	44	7
20	**100**	**100**	**100**	**100**	**>99**	**99**	**96**	**88**	63	31	7
25	**>99**	**>99**	**>99**	**99**	**98**	**95**	**87**	72	46	22	6
30	**99**	**99**	**98**	**95**	**92**	**84**	73	58	36	19	7
35	**96**	**94**	**92**	**88**	**82**	73	60	47	29	16	6
40	**91**	**88**	**84**	79	72	60	49	38	24	14	6
45	**86**	**82**	76	70	64	53	44	34	22	14	6
50	**81**	76	70	64	57	47	38	29	19	12	6

2.4 Targeted Sampling in Sensitive Communities

Rare habitats of management concern are addressed under sensitive communities. Field methods are the same as those used in the GRTS design (SOP 3-11), but sampling is targeted in community types of interest. Site selection is accomplished using air photos, high resolution satellite imagery, and associated tools in a GIS environment, and site number and locations are finalized during overflights and/or field visits. Plot locations are randomized within the area(s) of interest, with a revisit interval of 10 years. Data from the sensitive communities sites are analyzed independently of the GRTS sites assigned within the access layer, and inferences regarding community change in targeted areas are thus limited to the targeted area(s) of interest.

As of 2009, long-term monitoring sites have been established on nunataks (n = 11), in spruce bark beetle-affected forest stands (n = 8), and in salt marsh complexes (n = 3). In salt marshes, a number of communities are sampled across an environmental gradient, as outlined in a separate protocol (Jorgenson et al. 2009). The cost of sampling sensitive communities has ranged from <$10,000 to approximately $35,000 during the years spanning 2005-2008. Sampling bouts have

been limited to 1-2 weeks and have been scheduled between GRTS sampling trips, or have been scheduled independently with a separate crew of specialists.

2.5 Change Detection

Long-term monitoring will provide an estimate of ecosystem response to environmental change. Summary statistics for species-level nested frequency data and point-intercept cover data, and for ocular estimates of cover by growth form, will be calculated by plot for each sampling date (SOP 12; Appendix F). Methods for change detection (Appendix G) rely on a Bayesian approach. Analyses will address the following questions:

1) Does species composition (richness, diversity) within and among plots show a directional change across sampling dates? Do species cover and frequency show a directional change through time?

Changes in species richness (species counts), diversity, and cover within sampling frames may be estimated between two points in time using repeated measures analysis or Bonferroni-corrected paired t-tests. Changes in frequency data can be measured using nonparametric (e.g., chi-square) tests (SOP 12).

2) Does species composition converge or diverge among plots through time?

Changes in species composition may be evaluated across sampling frames using nonmetric multidimensional scaling (NMS) or other ordination techniques (SOP 12). Vectors linking measurements at different points in time can then be used to display the direction of change for each plot. Differences in the direction of vectors among plots or regions can be evaluated by standardizing plot vectors to a common origin, and/or by using a multiresponse permutation procedure (MRPP) with Euclidean distance to test whether the direction of change in species composition varies among regions (cf. Boucher and Mead 2006). Differences in mean vector length (magnitude of change) can be evaluated among regions using analysis of variance (ANOVA) and a-posteriori multiple comparisons. The limitation to this approach is that it requires a large number of samples across time.

A null model approach (cf. Schaefer et al. 2005) has been used to separate significant temporal change from the underlying variability at a site where multiple years of data are available. The model is based on the empirical relationship between species abundance and the coefficient of variation (CV) of abundance over time. Community change over time is assessed by comparing expected community structure (from randomly generated communities) to target samples. The benefit of the approach is that the expected communities can be analyzed with any metric of community similarity, and that the approach requires only a few samples to detect change. Regressions of similarity indices against time can provide evidence of a directional change (convergence or divergence) in species composition among plots (e.g., Inouye and Tilman 1995).

3 Methods

Details regarding field methods, data processing, and data delivery are included in the SOPs. An outline of the annual work cycle (Table 8) and description of work components are outlined

below. Unless otherwise noted, field methods are identical for broad-scale monitoring of ***vegetation and composition*** and targeted sampling of ***sensitive communities***.

3.1 Preparation for field season

3.1.1. Recruiting

The Project Lead will be responsible for recruiting and hiring. Crew members should have botanical experience, preferably with the flora of Alaska, extensive backcountry experience, and be very physically fit. Recruiting should begin in December-January so that hiring and background checks can be completed by the beginning of the field season.

Table 8. Annual work cycle for ground-based vegetation monitoring. Tasks are outlined by project stage. Responsibility for task completion, and timeline for execution and/or completion of tasks, is shown below.

Project Stage	Task Description	Responsibility	Timing
Preparation (*Section 3A*)	Announce seasonal biotech positions	Project Lead	by Jan 15
	Scheduling and logistics, including ordering equipment and supplies	Crew Leader	by Apr 15
	Submit permit applications and mimimum tool justifications, if applicable	Crew Leader	by Apr 15
	Hire seasonal field crew	Project Lead	by Apr 15
	Prepare project workspace	Data Manager/Crew Leader	by May 15
	Distribute field calendars, including flight requests, to park staff	Crew Leader	by June 1
	Load data dictionary and plot coordinates into GPS units (SOP 1)	Crew Leader	by June 1
	Prepare and print field maps (SOP 1)	Crew Leader	by June 1
	Implement working database copy	Data Manager	by June 1
	Print hard copies of data forms	Crew Leader	by June 1
	Database/GPS training as needed for field crew	Data Manager/GIS Specialist	by June 1
	Bear safety training; aviation training for field crew	Law Enforcement	by June 15
	Field sampling protocols; calibrate cover estimations among crew members	Project Lead/Crew Leader	by June 30
Data Collection (*Section 3B*)	Field data collection (SOPs 2-10)	Field Technicians	June-Aug
	Review data forms	Field Technicians	daily
	Review Trimble Rover files	Crew Leader	daily
	Review data forms	Crew Leader	weekly
	Process voucher specimens (SOP 11)	Field Technicians	daily
	Crew de-briefings - operations	Crew Leader	monthly
Data Entry & Processing (*Sections 3C*)	Download, differentially correct, export & review GPS data (SOP 11)	Crew Leader	every 7-10 d
	Download/process photos (SOP 11)	Field Technicians	every 7-10 d
	Data entry/data review	Field Techs/Crew Leader	every 7-10 d
	Data review – QA/QC & validation using DB tools	Data Manager/Crew Leader	by Sept 30
	Upload lat/longs to database	Data Manager/Crew Leader	by Sept 30
	Complete in-house specimen determinations	Field Techs/Crew Leader	by Oct 15
	Send specimens to UAF for final determinations	Crew Leader	by Oct 15
	Deliver mounted specimens to NPS curators	Crew Leader	by Nov 15
Metadata (*Section 3C*)	Identify sensitive information contained in the data set	Data Manager	by Oct 31
	Update project metadata records	Crew Leader/Data Manager	by Oct 31
Data Verification & Delivery (*Section 3C*)	QA/QC field data & deliver to Data Manager	Project Lead	by Nov 30
	Upload into master database, SWAN Digital Library [1]	Data Manager	by Jan 15
	Update GIS data sets and associated metadata records; store in SWAN Digital Library	Data Manager/GIS Specialist	by Mar 15
Data Analysis (*Section 3D*)	Summary statistics (all years); change detection (after 3rd iteration) derived from final data files (SOP 12)	Project Lead /Biometrician	by Mar 15
Reporting (*Section 3D*)	Export automated summary reports from database	Data Manager	by Mar 15
	Generate maps for annual report	Project Lead /Data Manager	by Mar 15
	Complete annual report following NRPM guidelines	Project Lead/Biometrician	by Apr 15
Product Delivery (*Section 3D*)	Draft annual report to Network Coordinator for review	Project Lead	by Apr 30
	Upload completed report to SWAN Digital Library [1]	Data Manager	by May 30
	Create NatureBib [3] record, post to NPS clearinghouse	Data Manager	by June 15
	Update NPSpecies [4] records	Data Manager	by Dec 15

	Submit data sets to NPS Data Store [2]	Data Manager	after 2 yrs
Records Management (*Section 3D*)	Store finished products in SWAN Digital Library [1]	Data Manager	upon receipt
	Review, save and/or delete interim project files following upload of final report to SWAN Digital Library [5]	Project Lead	by May 30
Season Close-out (*Section 3D*)	Inventory equipment and supplies	Crew Leader	by Sep 15
	De-brief field crew	Project Lead/Crew Leader	by Sep 15
	Document needed changes to field sampling protocols, analysis & reporting procedures, or database	Project Lead/Crew Leader/Data Manager	by Apr 15

[1] The SWAN Digital Library is a hierarchical digital filing system stored on the SWAN file servers (Mortenson 2005). Network users have read-only access to files, except where sensitivity of data may preclude general access.
[2] NPS Data Store is a clearinghouse for natural resource data and metadata (http://science.nature.nps.gov/nrdata). Only non-sensitive information is posted. Refer to the protocol section on sensitive information for details.
[3] NatureBib is the NPS bibliographic database (http://www.nature.nps.gov/nrbib/index.htm). The application has the capability of storing and providing public access to image data (e.g., PDF files) associated with each record.
[4] NPSpecies is the NPS database and application for maintaining park-specific species lists and observation data (http://science.nature.nps.gov/im/apps/npspp/index.htm).
[5] NPS Director's Order 19 provides a schedule indicating the amount of time that the various kinds of records should be retained. Available at: http://data2.itc.nps.gov/npspolicy/DOrders.cfm

3.1.2. Logisitics, Data Uploads, and Preparation of Working Database

The Crew Leader is responsible for all aspects of field preparation (SOP 1), except where noted. Beginning in late February or March, the Crew Leader will inventory and test field equipment; order any needed equipment or supplies; arrange for housing and computer access for the field crews; load plot coordinates and data dictionaries into the GPS; and apply for a research permit (http://science.nature.nps.gov/research). Field emergency plans will be distributed to dispatchers prior to each round of field work. Pending completion of the monitoring database, the Data Manager will upload a working copy of the database for use by technicians in the field.

3.1.3. Training

The Project Lead and Crew Leader will train seasonal field crews each year during the first half of June. Prior to field work, crew members must complete Basic Aviation Training (B-3) and bear safety training, and at least one crew member must be shotgun certified. Data collection will occur from late June through early September in 5- to 10-day tours and will include one office day approximately every 10 work days for data management and equipment maintenance. Crews will be stationed in one park for the duration of the field season. The Project Lead will work with the crew on an as-needed basis for 3-6 weeks during the summer, and will be available at the beginning and end of each tour to answer questions and address concerns.

3.2 Field methods

3.2.1. Plot Layout

Plot layout follows a simplification of the design used by the NCCN (Woodward et al. 2009); i.e., a 50 m × 50 m (0.25 ha) monitoring plot encloses an intensively sampled inner plot of 30 m × 30 m (0.09 ha) (Fig. 5; SOP 2). The inner plot is approximately one-tenth the area of FIA and NCCN plots (Woodward et al. 2009), and is roughly 4.5-fold greater in size than plots used in the CAKN (Roland et al. 2004). During the pilot testing phase, we qualitatively evaluated different plot dimensions. We found that a 30 m × 30 m inner plot was large enough to capture variation in forested stands, but small enough to fall within relatively homogeneous areas of vegetation, and thus seemed appropriate to sample a range of vegetation types. The 30 m × 30 m area also coincides with the pixel size for Landsat imagery, which we are using in a separate project to document landscape-level change.

The SW corner of the 30 m × 30 m inner plot is permanently marked with an aluminum stake and stamped monument cap (cf. Roland et al. 2004; Fig. 6), and the five remaining 30-m transect endpoints are marked with labeled wooden stakes. Galvanized steel spikes (6″) pounded to below the soil surface at the NW, NE, and SE corners aid in relocation. The rationale for using square plots is outlined in Woodward et al. (2009).

The 30 m × 30 m intensive inner plot is divided into fifteen 4-m^2 nested quadrats located at 7-m intervals along the 30-m transects (Figs. 5 and 7). Plot boundaries are oriented along cardinal directions. Travel along transects is limited to ≥ 1 m from the outer edge of transect lines (i.e., west side of Transects 1 and 2, east side of Transect 3) to minimize trampling.

3.2.2. Plot Descriptive Data

Physical attributes recorded at each plot include slope angle and azimuth, elevation, topographic position, disturbance regime, slope shape, drainage characteristics and evidence of frost action, fire, and human or animal disturbance (SOP 3). Biotic plot variables that are recorded include vegetation classification, landcover classification, and dominant species.

3.2.3. Plot Photos

At each plot, we photograph (1) each 30-m transect from the 0-m and 30-m endpoints, (2) the 0-m baseline (SW to SE plot corners of the 30 m × 30 m inner plot), and (3) each 0.25-m^2, 1- m^2, and 4- m^2 nested quadrat (SOP 4). In addition, we opportunistically take photos that show the location of the plot in the larger landscape.

3.2.4. Species Composition

Vascular plant abundance and vegetation structure in the permanent plots are quantified using point-intercept transects recorded at 50-cm intervals along the 30-m transects, within five vertical strata (≤ 20 cm; >20-50 cm; >50-100 cm; >100-400 cm; >400 cm; SOP 5; modified from Roland et al. 2004), resulting in 180 point counts per plot. Bryophytes (mosses, liverworts), lichens, and litter are recorded as separate classes. Unknown species, previously undocumented species, and/or species of conservation concern are collected following protocols established by the University of Alaska Museum of the North (Appendix H). All vascular and non-vascular species are recorded using USDA codes (http://plants.usda.gov/), where applicable. Presence/absence of vascular species is recorded in nested frequency plots (4-m^2, 1-m^2, and 0.25-m^2; SOP 6; modified from Roland et al. 2004). Due to time constraints, occurrence of non-vascular species is recorded only in the 1-m^2, and 0.25-m^2 quadrats.

Cover by growth form is recorded in 4-m^2 quadrats using ocular estimates of cover in 1% increments (SOP 6). We minimize observer effects by using 2-m quadrat frames gridded into 1% sections as recommended by Sykes et al. (1983); using pairs of observers; and estimating actual cover rather than using cover classes. Estimates to 1% are most precise when cover is very high (95-100 %) or very low (e.g., 0-5%), but we do not expect estimates to be precise at 1% in any part of the range.

3.2.5. Tree Measurements

The structure of the tree layer is quantified through seedling counts in 4-m^2 quadrats (SOP 6); sapling counts in the 30 m × 30 m inner plot (SOP 7); measurement of all trees ≥ 12 cm dbh in

the 30 m × 30 m plot (SOP 7); and coring of the four largest trees in the outer 10-m buffer of the plot (SOP 8; all methods modified from Roland et al. 2004). Tree canopy cover is estimated at the plot center and four outer corners using a densiometer (SOP 7). These data allow us to characterize stand structure as stem densities per size class and basal area per species, and also provide information on forest condition, including insect activity, pathogens, physical damage and related factors. Monitoring objectives for forested stands are outlined in Section 1.3.

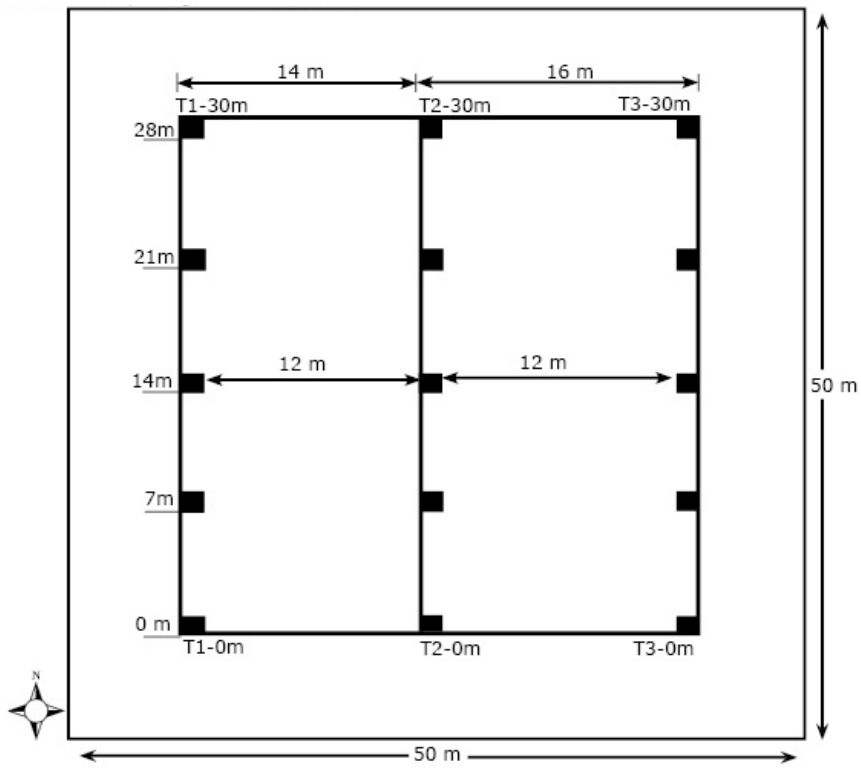

Figure 5. SWAN plot layout (not to scale). The intensively sampled inner plot (30 m × 30 m) consists of three parallel transects oriented along cardinal directions. Nested quadrats (black) are spaced at 7 m intervals, from 0 m to 28 m, along each transect. Species frequency is measured in nested 4-m^2, 1-m^2, and 0.25-m^2 plots. Species cover is measured by point-intercept at 50 cm intervals along transects. Tree seedling counts are conducted within 4-m^2 quadrats. Mature trees are cored within a 10-m wide buffer surrounding the plot, and trees are mapped across the entire 50 m × 50 m (0.25 ha) plot.

Figure 6. Plot monument stamped with the plot id number marks the SW corner of the inner 30 m × 30 m plot.

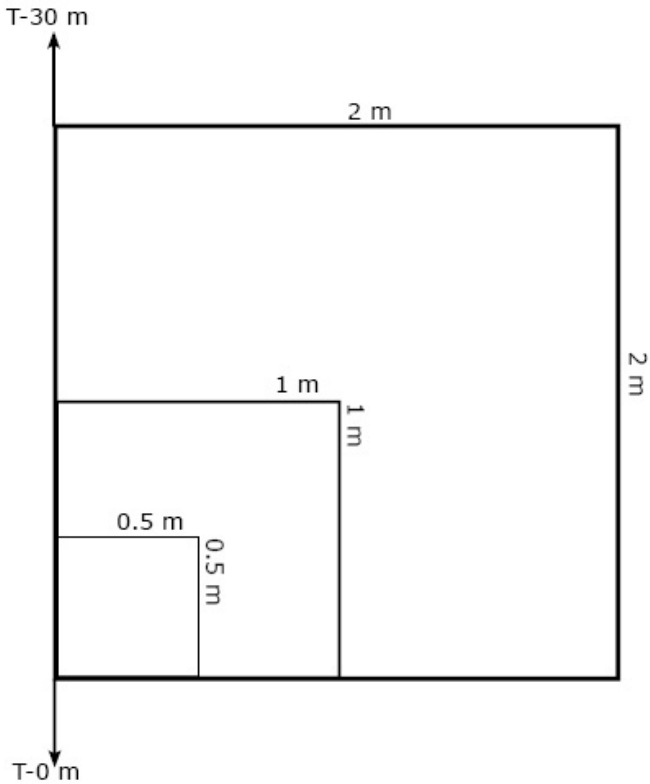

Figure 7. Layout of nested quadrats. Five nested quadrats are located at 7-m intervals along each 30-m transect, for a total of 15 quadrats per plot. Quadrats at the 0-m end of the transect are oriented in the SW corner on Transects 1 and 2, and in the SE corner on Transect 3.

3.2.6. Coarse Woody Debris, Litter and Duff

Cover of coarse woody debris and litter are quantified along point-intercept transects and in the $4m^2$ quadrats. The depth of duff and litter layers are estimated as part of the soil description (SOP 9). The size and decay class of logs (≥7.5 cm diameter) and fine fuels (<7.5 cm diameter)

are measured at forested sites using a modification of FIA methods (SOP 10; modified from Woodward et al. 2009) and the line-intersect method (Van Wagner 1968; Brown 1974).

3.3 End-of-season procedures

3.3.1. Processing of Collections

Taxonomic determinations and preparation of voucher specimens (SOP 11) should occur prior to data upload into the master database.

3.3.2. Equipment Inventory

Field season close-out should include an inventory of equipment and filing of all field notes and data forms (SOP 11). Notes should document any deviations from established protocols, highlight observations of interest, and provide suggestions for improving the training or field season procedures for the future.

4 Data Processing, Analysis and Reporting

4.1 Project Information Management Overview

Project information management includes the following steps, as outlined in the SWAN Data Management Plan (Mortenson 2006):

- *Preparation* – Training, logistics planning, print forms and maps
- *Data acquisition* – Field trips to acquire data
- *Data entry & processing* – Data entry and uploads into the working copy of the database, GPS data processing, etc.
- *Quality review* – Data are reviewed for quality and logical consistency
- *Metadata* – Documentation of the year's data collection and results of the quality review
- *Data certification* – Data are certified as complete for the period of record
- *Data delivery* – Certified data and metadata are delivered for archival and uploaded to the master project database
- *Data analysis* – Data are summarized and analyzed (SOP 12; Appendix F, G)
- *Product development* – Reports, maps, and other products are developed
- *Product delivery* – Deliver reports and other products for posting and archival
- *Posting & distribution* – Distribute products as planned and/or post to NPS clearinghouses
- *Archival & records management* – Review analog and digital files for retention
- *Season close-out* – Review and document needed improvements to project procedures or infrastructure, complete administrative reports, develop work plans for the coming season

4.2 Database Design and Data Management

The proposed database structure for SWAN represents a modification of the MS Access database developed for the CAKN (Roland et al. 2004; Fig. 8; Appendix J). Automatic entry of identification field values through the use of nested sub-forms will allow for quality control and the automation of several important database functions. Digital images recorded at each sample site will be entered and may be viewed from within the database. Database development (SQL) is expected to begin in the winter of 2009-2010.

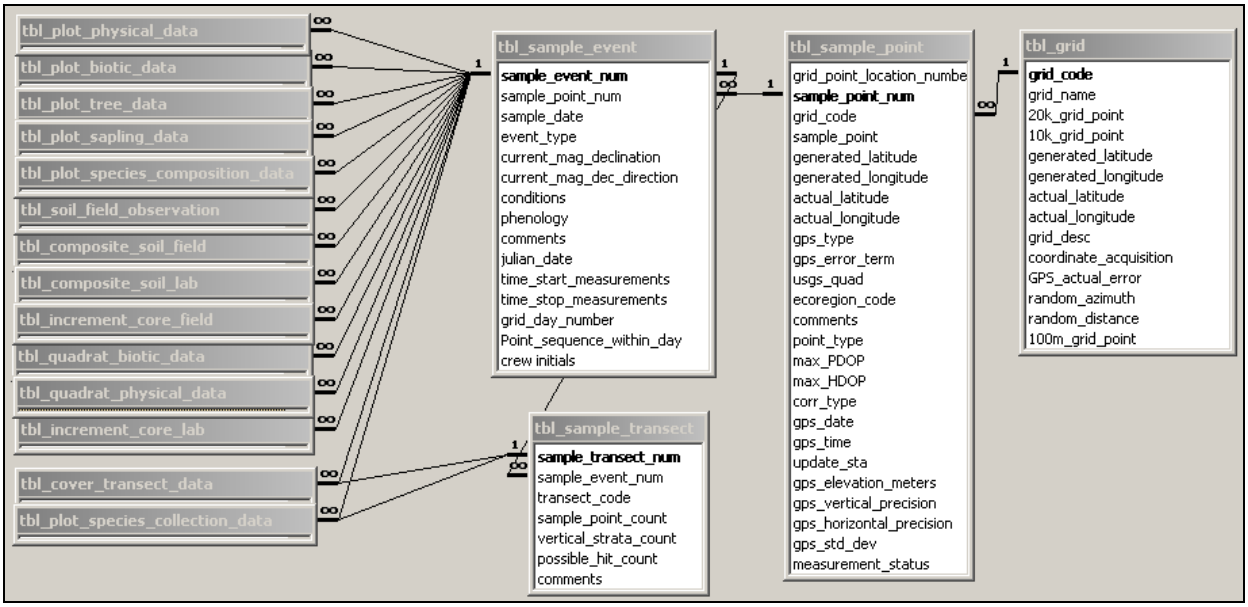

Figure 8. Summary of CAKN database structure (Roland et al. 2004) as a model for proposed SWAN database. The SWAN database will build on this structure but use site locations, rather than mini-grids, as a primary key. The master database is expected to run on SQL server.

The database will be divided into two components – one for entering, editing and error-checking data for the current season (i.e., the working database copy), and another that contains the complete set of certified data for the monitoring project (i.e., the master project database). A functional comparison of these two components is provided in Woodward et al (2009).

Each of these components will be based on an identical underlying data structure (tables, fields and relationships). The working database will be implemented in Microsoft Access to permit greater flexibility when implementing on computers with limited or unreliable network access. The master database will likely be implemented in Microsoft SQL Server to take advantage of the backup and transaction logging capabilities of this enterprise database software.

The working database application will have separate screens for data entry, data review, and quality validation tools. The master database application will contain the analysis and summarization tools, including pre-formatted report output and exports to other software (e.g., for analysis and graphics production).

During the field season, each crew will be provided with their own copy of a working database into which they enter, process, and quality-check data between sampling trips (i.e., field data collection is on paper forms, as of 2009). Once data for the field season have been reviewed for QA/QC, they will be uploaded into the master database, which is then used to inform all reporting and analysis. This upload process is performed by the Data Manager, using a series of pre-built append queries.

4.2.1. Data Backups
Data must be backed up every day that new data are entered. The backup files should be compressed to save drive space, and may be deleted after the data have passed a quality review and been uploaded into the master database.

4.2.2. Data Verification
At regular intervals and at the end of the field season the Crew Leader and/or Data Manager should inspect the data being entered to check for completeness and catch avoidable errors. The Data Manager may also periodically run the Quality Assurance Tools that are built into the front-end working database application to check for logical inconsistencies and data outliers.

The working database application facilitates this process by showing the results of pre-built queries that check for data integrity, data outliers and missing values, and illogical values. The user may then fix these problems and document the fixes. Not all errors and inconsistencies can be fixed, in which case a description of the resulting errors and why edits were not made is then documented and included in the metadata.

4.2.3. Geospatial Data
The Project Lead and GIS Specialist will work together to review the surveyed coordinates and other geospatial data for accuracy. The purpose of this joint review is to make sure that geospatial data are complete and reasonably accurate, and also to determine which coordinates will be used for subsequent mapping and field work.

4.2.4. Metadata
The Data Manager and GIS Specialist will facilitate Federal Geographic Data Committee (FDGC)-compliant metadata development by creating and parsing metadata records from the information provided by the Project Lead.

4.3 Data Reduction and Analysis
For most measurements, the plot is used as the unit of replication within elevation band, and data reduction will consist of pooling or averaging values across transects or quadrats (Appendix F). Tree canopy cover, tree density and mortality are presented as a plot-wide percentages based on count data. Plot means will be averaged across sites to derive a grand mean and variance for each vegetation × elevation combination.

To quantify interannual variability in plot attributes, we will measure one set of plots in two consecutive years beginning every fifth year (Panel 6; Table 6) and then rest them for three years (cf. Woodward et al. 2009; Symstad et al. 2009). Bayesian hierarchical models will be used to estimate trends (SOP 12; Appendix G). Due to the inherent variability in ecological systems, obtaining a precise estimator of trend often requires many repeat observations. A minimum of 10-15 years of sampling was recommended to detect a trend in water quality data collected by the U.S. Environmental Protection Agency (Urquart et al. 1998), and at least 20 years to describe a trend in most variables associated with vegetation change in the northern Great Plains (Gitzen et al. 2009). Simulations run on pilot vegetation data collected in the SWAN suggest that interannual variability may be lower in subarctic ecosystems, but that detection of long-term trends will likely require 20-30 years of data, depending upon the magnitude of change.

4.3.1. Reporting and Product Development

The Project Lead will submit an Investigator Annual Report online, and produce a detailed annual summary report and a cumulative five-year summary report after each complete rotation of the panel design. Contents of the annual and five-year reports are summarized in Woodward et al. (2009). An example of an annual report for a SWAN data set is provided by Miller et al. (2009). Guidance on formatting can be found on the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/NRPM/index.cfm).

4.3.2. Records Management

All project files should be reviewed, organized, and/or purged by the Project Lead, in consultation with the Data Manager, on an annual basis following guidelines stipulated in NPS Director's Order 19. Project responsibilities and annual timelines are summarized in Table 8.

5 Operational Requirements

5.1 Personnel Requirements and Qualifications

Personnel needs are outlined in Table 10. The staffing scenario assumes that a field crew of one GS-7/9 biological technician or botanist (term – crew leader) and two GS-5 biological technicians (seasonal – crew members/field technicians) can complete three to four panels (elevation band × vegetation type × park) per field season. The staffing scenario does not account for the additional personnel required for short-term side projects (e.g., revisit of sensitive communities), as support for those projects will be garnered through collaboration with park resource specialists and ongoing assistance agreements. The Project Lead (PI) is expected to spend approximately 0.1-0.2 FTE in the field, with the remaining time allocated to data analysis, reporting, recruiting and outreach.

The Crew Leader must have strong taxonomic skills and extensive backcountry experience. Familiarity with Alaska/Yukon, Rocky Mountain, and/or Pacific Northwest floras is desirable, as is field experience in Alaska. Previous experience supervising field crews in vegetation surveys is also desired. The Crew Leader and Field Technicians must be physically fit and prepared to spend extended periods of time in the backcountry.

5.2 Annual Workload and Field Schedule

Responsibilities for the annual work flow are outlined in Table 8. Field crews are recruited in January-February and hired by mid-March. Seasonal training occurs during the first week of June, and field work occurs from approximately mid-June through late August. Species determinations, data entry, QA/QC and data analysis should be completed by January, and an annual report generated by the project lead by late April. Preparation of five-year reports is expected to take additional time.

5.3 Facility and Equipment Needs

Each panel will be completed in a single park in a single year (Table 6), and field work will rotate among the three largest parks (KATM, LACL, KEFJ) over consecutive field seasons. Housing for crews (3-4 persons/crew), access to government computers, and transportation to and from field sites will be required during the field season (June-August). Field crews will be stationed at the park in which the majority of field work will occur. Seasonal employees will be

responsible for rent in NPS housing. SWAN will provide round-trip transportation from Anchorage to the duty station at the start and end of the field season, and meals and equipment in the field (bear fence, bear canisters, tents, stoves, water filters, etc.). Crew members will need to provide their own personal gear and clothing.

5.4 Startup Costs and Budget Considerations

Major costs associated with this project are for field crew salaries and transportation to/from the field. Equipment costs are expected to be minimal. Estimated flight hours per season are expected to range from 60-80 hours, including reconnaissance flights, in the early phases of monitoring, to 35-40 hours once sites are established. As of 2009, hourly rates for OAS charters ranged from $420-$640/hr, plus fuel, resulting in an annual operating budget for flights alone of approximately $25,000-$30,000. Use of DOI aircraft will reduce these costs, as will collocation of sites. In 2009, salary for a full-time GS-7 biological technician ranged from $41,000-$53,500. Salary for a seasonal GS-5 biological technician ranged from $12,000-$15,000 for the three month period, not including overtime. Thus, the minimum budget for one year (salary for three biological technicians + flights), not including PI salary or travel, is estimated to be approximately $90,000-$108,000 (FY2009). If necessary, costs could be reduced in a couple of ways: the sampling could be scaled back either by 1) reducing the number of field personnel, and thus likely reducing the number of sites sampled in a given year, or 2) increasing the sampling interval (e.g., from five to ten years).

Table 9. Staffing needs for SWAN ground-based vegetation monitoring. Staffing scenario assumes that the Project Lead (PI) is a full-time NPS employee with 1 field crew (GS-7 term biological technician or botanist + 2 GS-5 biological technicians).

Staff	Grade	PP1-6	PP10-12	PP13-14	PP15-19	PP20	PP21-23	PP24-27	FTEs
Project Lead (Ecologist)	GS-12	Data analysis Reporting Outreach Recruiting		Training Data collection	Data collection (PP15)		Data review (PP21)	Data analysis Reporting Outreach Recruiting	0.6
Crew Leader	GS-7		Field prep	Training Data collection	Data collection	Close-out Data review	Voucher prep Taxonomic ids		0.5-0.6
Seasonal 1	GS-5			Training Data collection	Data collection	Close-out Data review			0.3
Seasonal 2	GS-5			Training Data collection	Data collection	Close-out Data review			0.3
Total									**1.7-1.8**

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Appendix A: Standard Operating Procedures

SOP 1: Pre-field procedures

SOP 2: Plot establishment

SOP 3: Plot attributes

SOP 4: Photos

SOP 5: Cover estimates

SOP 6: Frequency estimates

SOP 7: Tree measurements

SOP 8: Tree cores

SOP 9: Soils

SOP 10: Coarse woody material

SOP 11: Sample processing and post-field procedures

SOP 12: Downloading and processing HOBO data

SOP 13: Data analysis and reporting

Vegetation Monitoring Protocol for the Southwest Alaska Network (SWAN)

Standard Operating Procedure (SOP) # 1

Pre-field procedures – Field preparation
Version 1.0 (December 2008)

Revision History Log:

Version No.	Revision Date	Author	Changes Made	Reason for Change

Procedures:

I. Plan activities

1. Prepare packets of data sheets and maps for each sampling session.

   a. Photocopy data sheets onto 2-sided Rite-in-the-Rain® paper and collate into sets for each 10-day sampling period.

   b. Print maps that show GRTS point locations in potential sampling areas. Record magnetic declinations for each area (http://www.ngdc.noaa.gov/geomagmodels/Declination.jsp); all compasses will need to be set to this (these) declinations in order to record bearings as true north in the field.

2. If you are preparing for a repeat visit to a site, laminate a complete set of the plot photos. Include, at minimum, photos of the transect lines, 4-m^2 quadrats, plot monument location, and temperature sensor location, if applicable.

3. Download a PDOP almanac for the Trimble GPS unit. Position Dilution of Precision (PDOP) must be less than 6 to achieve desired precision. To download the PDOP almanac and map it using Pathfinder Office, do the following:

   a. Open your internet browser and on the address line type: ftp://ftp.trimble.com/pub/eph/ - press enter. Double click on the following file: current.ssf – check the date to make sure it is current.

   b. Save this to your computer in the following location: C:/ Program Files/ Common Files/Trimble/Almanacs.

c. Open Pathfinder office by double clicking on the icon on the desktop – the *Select Project* window will appear. Select or create a project corresponding to the sampling area.

d. On the file bar, click on *Utilities* and choose *Quick Plan* from the drop-down menu.

e. Select Date by clicking on the calendar. Click on *Prev Month* or *Next Month* if the wrong month is displayed. Press **ok** to close the dialog box.

f. *Edit Point* defines the latitude and longitude of the location where observations are taken. Click on keyboard and enter the general latitude and longitude (degrees and minutes) of your field site. Do not fill in the fields for height or seconds. Close *Edit Point* by pressing **ok.**

g. The *Status* window will open, summarizing the information. Confirm and close the window.

h. You will now be in the *Plan: session #* window. Click on *Graphs* and choose *Number of SV's and PDOP* to get a graphical image of the number of visible satellites and the PDOP for the specified day and time. If your PDOP is above 6, that's too high and the GPS unit will reject readings. This also occurs when there are less than 4 satellites available. Therefore, you must schedule your field work for a date and time when PDOP is less than 6 and there are 4 or more satellites available.

i. Make PDOP graphs for the first half of the field season. Export these to Acrobat Distiller and print them. Laminate these for field use and place into the packets of data sheet described above. You will repeat this procedure to make PDOP graphs for the rest of the field sites midway through the season.

II. Inventory and prepare field supplies

1. Repair or replace damaged field equipment. Order field supplies according to the list below.

   a. Repair tents and apply additional seam sealer, if applicable.

   b. Test the camping stoves to make sure they are in working order. Purchase white gas. Three quarts can usually cover a crew of three for a 10-day sampling trip.

   c. Order monument caps and stakes:

      Surv-Kap® inc.
      P.O. Box 27367
      Tucson, AZ 85726 U.S.A.
      www.surv-kap.com
      Tel: 1.800.445.5320 Fax: 1.520.792.2030

Item number: TFS-3¼-18
Description: 18″× ¾″ dia. triple-fluted (TF) aluminum stake with 3¼″ dome cap

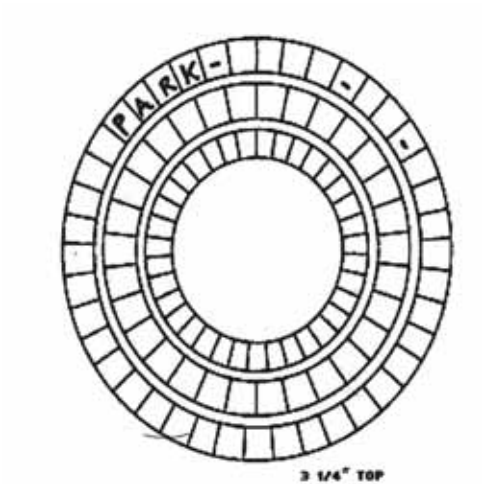


Figure 1.1. When ordering the monument caps, have Surv-Kap pre-stamp the outside row of the monument cap with the park code(s) of interest:

e.g., **LACL**-_ _ _ _-_ _-_ _ _

Year, elevation band, and GRTS number will be stamped onto caps in the field, once it is known that a plot will be sampled.

2. Update the field set of dichotomous botanical keys with any current or newly-acquired keys. Additionally, inspect the filed keys for condition and repair or replace as necessary.

3. Prepare a plant press with adequate foam blotters and cardboard pieces. Be sure that there is sufficient newspaper to press up to 100 vascular plant specimens per sampling trip (one specimen per page).

4. Print, fold and number sufficient nonvascular plant specimen envelopes for each trip – enough for up to 400 specimen collections per sampling trip. Pre-label with NPS accession and catalog numbers.

5. Inspect and clean the 5-gallon water jugs and the bear-resistant food containers (BRFC) – distribute enough food containers among crew; usually 3 of the smaller size BRFC's are sufficient for one person for one 10 day sampling trip.

6. Charge all batteries that will be used in the field, including batteries for the Trimble, the digital camera and the satellite phone.

III. Equipment

Per technician:

— 2 Fine-point Sharpie permanent markers
— 3 mechanical pencils w/ lead refills
— 1 metal clipboard
— 1 hand lens
— 1 compass
— 1 clinometer

— 1 can bear spray + holster
— Rite-in-the-Rain field notebooks for the season – up to four per crew member per season

Per crew:
— Trimble GPS with charged battery and appropriate files loaded, with pelican case
— Garmin GPS – w/ *generated* (1st sample) or *actual* point locations (subsequent samples)
— Transect staff with densitometer
— Laser rangefinder
— 16″ fine-gauge knitting needles or pins for low stature point-intercept work
— Aluminum monument caps & fluted stakes (1 cap + stake per plot)
— 16″ wooden stakes (5 per plot)
— 6″ galvanized nails (3 per plot)
— Stamp kit for monument caps
— Hammer
— Rubber mallet
— 3 × 30-m tapes
— 2 × 50-m tapes
— 2 × Digital cameras + memory cards, with soft case
— Waterproof plastic cases for GPS and camera
— 2 × Dry-erase board + pens
— Flagging tape
— Extra AA and D-cell batteries
— Retractable metal tape measure (e.g., 2 m)
— Trowel
— Hori-horis
— Spherical densiometer
— 20 each quart and gallon size Ziploc freezer bags
— Quadrat frames – 0.25-m^2; 1 and 4-m^2
— Soil depth probe
— Collection container (Tupperware® and sealable plastic bags)
— Plant presses w/ blotters, ventilators & papers for 200 specimens (per sampling trip)
— 3 × DBH tapes (cm)
— 3 × Increment borers 10″ and 14″ with extra spoon extractors and WD-40
— Plastic straws
— Lighters
— Electricians tape
— Plastic ‘quiver’ for storing cores and empty straws
— Pre-numbered aluminum tags + galvanized nails
— Stapler
— Fuels gauge

Laminated sheets:
— Maps showing GRTS point locations, as generated from ArcGIS
— USDA-NRCS species codes for SWAN vascular and non-vascular plants

— Viereck codes
— Canopy classes
— Crown length classes
— Pathology codes
— Physical damage codes
— Decay classes
— Soils codes

Data sheets, maps and field emergency plans:
— 15 sets of datasheets per 10-day sampling session
— USGS quadrangle maps (1:63,000)
— Emergency field plan(s) with maps (for Dispatch)

Communal camping gear:
— Bear fence (poles, line, grounding rod and charger; D-cell batteries)
— Grass clippers for fenceline
— Hand-held radio plus batteries (2 extra sets)
— Satellite phone with extra battery and after-hour emergency phone numbers
— Waterproof hard case (pelican case) for satellite phone
— Stove and fuel bottle(s)
— White gas
— Cook set(s)
— Water filter(s)
— Lighters + boxed matches
— Large bear-proof can(s)
— Backpacker-sized bear-proof cans
— Trash compactor bags
— Duct tape
— Cook tent (optional)
— First-aid kit
— 5-gallon water jug
— Tents

Office Equipment:
— Laptop loaded with all required software and files (e.g., ArcGIS; Pathfinder Office; DNR Garmin; GPS PhotoLink; copy of database; image files; SOPs and Appendices, including class codes and species codes)
— Keyboard and mouse for laptop
— Dissecting microscope and kit
— Card reader for downloading photos
— A/C adaptor for charging sat phone batteries
— External hard drive for file backups

Vegetation Monitoring Protocol for the Southwest Alaska Network (SWAN)

Standard Operating Procedure (SOP) # 2

Plot Selection & Establishment

Version 1.0 (December 2008)

Revision History Log:

Version No.	Revision Date	Author	Changes Made	Reason for Change

Procedures:

I. Plot selection

1. *Office Evaluation* - ArcGIS is used to view points generated from the GRTS sample (hereafter referred to as 'GRTS points'). The access layer developed for each park is intended to eliminate barriers to travel, but all points should be reviewed in a GIS prior to field reconnaissance.

2. *Field Evaluation* – A site is rejected for the following reasons (Symstad et al. 2009):

   a) **Site is dangerous or prohibitively difficult to access** – e.g., travel is through extensive areas of poor visibility (e.g., >200 m of dense vegetation with ≤10 m visibility) and/or high brown bear densities; access requires dangerous plane or boat landing, difficult stream crossing(s), or travel through steep (≥50° slope) terrain

   b) **Travel time to site is excessive** - one-way travel time from nearest access point >2 h

   c) **Site is dangerous or prohibitively difficult to work on** – e.g., sites that occur in areas of poor visibility or high bear densities; loose rock above or underfoot; hazard trees

   d) **Site occurs on private property** – e.g., sites that occur within private inholdings or within 100 m of private lodges or cabins. The GIS access layer should have eliminated most, if not all, of these areas.

   d) **Site could be damaged by establishment of a monitoring plot** – e.g., plot establishment would result in long-term (>1 year) damage to vegetation and/or substrate. Sites with slope >25° are excluded. If species of conservation concern are present at the site, extreme care must be taken to protect the population and surrounding substrate.

e) **Site is located within 100 m of a GRTS point higher in the selection order** – i.e., for GRTS points that occur in close proximity to one another, use the point highest in the selection order and drop subsequent points if they occur in the same community type.

A permanent plot is established if the site (50 m × 50 m) meets the following criteria in the field:

a) **Plant community is a targeted type for the selected elevation band** (Appendix I)
b) **Vegetation is homogeneous and representative of the surrounding area** (e.g., ≥100 m radius)
c) **Slope angle does not exceed 25 degrees**
d) **Non-targeted inclusions (e.g., streams, outcrops, etc.) comprise ≤ 10% of the plot**
e) **Mean tree age ≥80 years for low elevation spruce forest communities** (Woodward et al., 2009); **mean tree age ≥50 years for mid-elevation spruce woodland communities** (A. Miller, unpublished data, Katmai National Park & Preserve, 2007).

A reconnaissance data sheet is completed in the field only for sites (GRTS points) that are not selected for monitoring. Temporary rejection criteria include conditions that are present at the time of reconnaissance, but that could change through time (e.g., land ownership, access constraints, temporary hazards; Symstad et al. 2009). Because of the high cost associated with travel, every attempt should be made to minimize the number of sites rejected. An offset of up to 100 m is acceptable if an adjacent 50 m × 50 m area would meet criteria for acceptance.

II. Upload GPS Points from ArcGIS

1. In the office, load GRTS points into a Garmin GPS (e.g., Garmin Map76S), as follows:

a) Connect the GPS via a comport and open ArcMap
b) In ArcMap, highlight the layer to be transferred in the Table of Contents
c) If multiple .shp files will be loaded from ArcMap with the same identifier (e.g., FID assigned by ArcMap), create a unique id column in the attribute table. Highlight the new field (e.g., *'GRTS'*) → calculate values → type in a park code or unique prefix plus the FID (e.g., *"LACL-02-"&[FID]*) → ok. This will generate a unique identifier for each GRTS point.

2. Transfer points from ArcMap to DNR Garmin:

a) Open DNR Garmin
b) Set the projection in DNR Garmin (File → Set projection) prior to transferring the file from ArcMap. Projection and datum must be the same in the Garmin as they are in ArcMap (Projection: Alaska Albers Equal Area Conic; Datum: NAD83).
c) Load the points onto the Garmin GPS unit:
   i) File → Load from → Arc → Layer; or, alternatively,
   ii) File → File type → .shp → browse to .shp file
   iii) Select the identifier that will be assigned to each point (e.g., *'GRTS'*).

3. Transfer points from DNR Garmin to the Garmin Map76S select Waypoint → Upload

See also: http://inpakroms03web/RGR/helpdesk/cheat/GPSDataStepsIntoArcGIS_AK2006.doc (accessed 5/14/08).

III. Navigate to site

1. In the field, select the GRTS point that you will travel to in the Garmin waypoints folder, select the "Go To" tab and press enter. Your point should appear on the screen with a map and a distance to the point. Select a navigation mode (i.e., compass screen, map screen, etc.).
2. Navigate to within 1-2 m of the GRTS point using USGS quad sheets and the GPS. Refresh the 'Go To' often as you approach the point.

IV. Plot establishment

1. Using criteria in Section I, above, determine whether the point will be retained as a long-term monitoring plot.
2. For sites that meet plot criteria, install a permanent marker consisting of a ¾ ″ diameter, 18″ aluminum stake and 3 ¼ ″ diameter monument cap (Surv-Kap, Inc.) within 1-2 m of the GRTS point. Keep all personnel and gear at least 20 m south or west of this point to avoid ground disturbance within the plot. The monument cap should be stamped with the park code, year, and five digit plot code assigned by the GRTS sample (e.g., LACL-2008-02-042) prior to attaching it to the stake. Pound both cap and stake to within 5 cm of the ground surface using a rubber mallet.
3. Establish three, parallel 30-m transects on a bearing of 0 ºN (true north) as shown in Fig. 2.1. The plot monument marking the SW corner of the plot will serve as the 0-m endpoint for Transect 1. All other transect endpoints will be marked with 16″ wooden stakes labeled with permanent ink (T1-30 m, T2-0 m, T2-30 m, T3-0 m, T3-30 m) and 6″ galvanized spikes or short sections of rebar installed below the ground surface. Keep the tapes taut at the ground surface and ensure that the transect measures exactly 30 m in length (i.e., account for length of tape used to secure the 0-m end of transect). Walk to the outside of transect (tape) lines to avoid trampling in the plot. Tapes stretched along the northern (30-m) and southern (0-m) ends of the plot should be used to verify that the transects are parallel and located at a distance of 14 m and 30 m east of T1, respectively (Fig. 2.1).

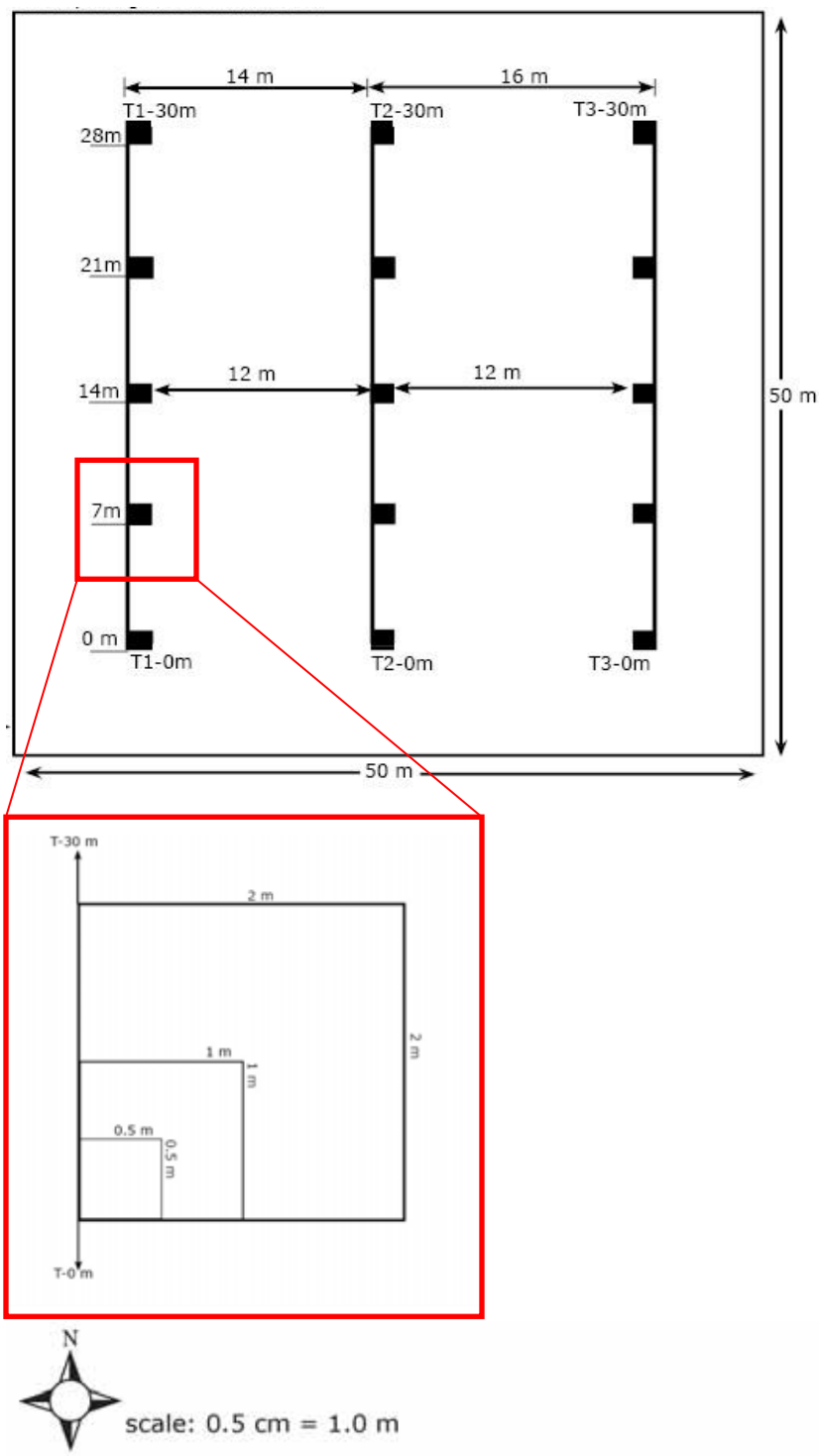


Figure 2.1. Layout of SWAN vegetation monitoring plot with monitoring transects oriented 0° true north. Plot dimensions are 30 m x 30 m, with Transects 1 and 3 forming the west and east boundaries of the plot, respectively. The SW corner of the plot (T1-0m) is marked with a labeled monument cap. All other transect endpoints are marked with labeled wooden stakes. Trees are cored within the outer 10 m band that forms the 50 m x 50 m plot.

Five 4-m^2 nested quadrats are located at 7-m intervals along each transect, as shown boxed in red. Nested quadrats are used to record species occurrence (frequency) and cover by growth form (SOP 6). Cover by species is recorded at 0.5 m intervals along each transect using point-intercept measurements (SOP 5).

When establishing plots and/or conducting plot measurements, observers should position themselves to the ***west*** of Transects 1 and 2, and to the ***east*** of Transect 3 to minimize plot disturbance.

4. Record the location of the transect endpoints using a Trimble GeoXT or comparable GPS device with sub-meter accuracy. Set the antenna height to 10 cm and hold the GPS unit completely still while logging points. Use the highest precision possible; e.g., a maximum PDOP of 6.0 and at least 4 satellites. Collect at least 20 waypoints at each transect endpoint. If you must reduce the precision of the GPS to attain more satellites, increase the number of data points that you log for each point. Record the rover file id, the lat/long (NAD83;

decimal degrees) and the elevation (m) at the monument stake on the summary data sheet (SOP 3). A data dictionary developed for point collection requires the following input:

- Plot SW (monument cap)
- Transect endpoint (endpoints for Transects 1-3)

5. For forested plots, a 10 m buffer around the 30 m × 30 m monitoring plot will be marked with pin flags (outer dimensions 50 m × 50 m; Fig. 2.1). The lat/long coordinates of the outer corners of the 50 m × 50 m plot do not need to be recorded.

V. Equipment

- 3 ¼″ monument cap (with park code and 5-digit plot id)
- 18″ aluminum monument stake
- extra stake and cap (sometimes the caps do not fit the stakes)
- 5 wooden stakes
- 8 pin flags
- Trimble GeoXT or comparable GPS unit
- hard rubber mallet
- compass (1 per technician) set to appropriate declination
- 5 fiberglass reel tapes, each a minimum of 30 meters length
- Permanent ink marker (e.g., Sharpie)
- Stamp kit
- Small hammer
- Flagging
- Electrical tape

VI. Literature cited

Symstad, A.J., R. Gitzen, D. Licht, C.L. Wienk, and A. Thorstenson. 2009. Plant community composition and structure monitoring protocol for the Northern Great Plains I&M Network – Draft. U.S. Dept. of Interior, National Park Service, Rapid City, South Dakota.

Woodward, A.E., Hutten, K.M., Boetsch, J.R., Acker, S.A., Rochefort, R.M., Bivin, M.M., and L.L. Kurth. 2009. Forest vegetation monitoring protocol for national parks in the North Coast and Cascades Network: U.S. Geological Survey Techniques and Methods 2-A8, 228 pp.

Vegetation Monitoring Protocol for the Southwest Alaska Network (SWAN)

Standard Operating Procedure (SOP) # 3

Plot Attributes – Physical & Biotic Characteristics

Version 1.0 (December 2008)

Revision History Log:

Version No.	Revision Date	Author	Changes Made	Reason for Change

This Standard Operating Procedure provides instructions for recording physical and biotic characteristics of the 50 m × 50 m permanent monitoring plots.

Procedures:

I. Plot data sheet

If any of the fields on this sheet are equal to zero, enter 'none.' If any of the fields are unknown to the observer, enter 'unknown' ('unk'). Do not leave fields blank.

Date: The calendar date on which field sampling is performed

Park: Four-letter park code (LACL, KATM, or KEFJ)

Plot ID: Elevation band (01, 02, or 03) plus GRTS id; e.g., '*01-016* 'denotes GRTS point no. 16 (firing order = 16) for elevation band no. 1 (0-450 m)

Crew: Names of all crew members involved in sampling the plot

Time: The time plot work starts, using military time (00:00 – 24:00 hrs)

GPS: Make and model (e.g., Trimble GeoXT)

Elevation: Elevation in meters from the Trimble GPS at the monument stake (T1-0m)

Plot Slope (°): Use a clinometer to measure the slope angle of the plot. Hold the clinometer parallel to the ground and trained on an object above the ground at eye height. Check that the value you measure for slope is the same facing both uphill and downhill. The reading on the clinometer is the percent slope (right scale) or slope angle (left scale). In the upslope direction, the reading will be (+), while in a downslope direction it will read (-). Often, an upslope and downslope measurement will be averaged to determine average slope steepness, but the

direction of the reading (+ or -) is not included; on a uniform slope, if + and - reading were averaged, the average would always be zero.

Plot aspect (º): Record plot aspect using a compass with magnetic declination set for the area in which you are working (http://www.ngdc.noaa.gov/geomagmodels/Declination.jsp). Record the declination used. All bearings will be recorded using true north. Hold the compass flat, point it directly perpendicular to the slope contour, directed downslope, and measure the true azimuth of the slope.

Endpoint coordinates: Record the latitude and longitude for each transect endpoint (T1-0m, T1-30m, T2-0m, T2-30m, T3-0m, T3-30m) using a Trimble GPS (e.g., Trimble GeoXT), or comparable, with sub-meter accuracy. Record the Rover file name for each set of plot coordinates, as lat/longs will be differentially corrected at a later date.

Dominant species: Briefly survey the plot and list the three most abundant taxa (by cover) in each of the following categories using USDA-NRCS codes (http://plants.usda.gov/) for vascular and nonvascular plants.

Viereck Class IV - V: Record the Viereck code (Viereck et al., 1992) to at least Level IV that best describes the plot. Vegetation within the plot should be homogeneous and should contain no more than one Level IV class.

Parent material: Record the parent material, such as granitic bedrock, mixed alluvium, etc.

Evidence of humans: Record any signs of humans or human activity visible from the plot.

Drainage: Choose the category (listed below) that most closely describes the drainage characteristics of the soil at a site. Steep slopes are well drained due to water running off the inclined surface, whereas the drainage characteristics of gently sloping sites and flat areas are mostly a function of the permeability of the substrate. Permeability ranges from very well-drained on coarse gravels to extremely impeded drainage on permafrost and/or soils with high clay content.

- Rapid – runoff/ hill-slope
- Rapid – coarse, permeable substrate
- Impeded – low permeability
- Saturated soil (water-table at or near soil surface)
- Scattered standing water
- Aquatic

Slope position: Select the most appropriate category on the data sheet (listed below) that provides the location of the plot relative to the surrounding topography:

- Ridgetop
- Saddle
- Upper 1/3 slope

- Middle 1/3 slope
- Lower 1/3 slope
- Valley bottom - specify whether on colluvium, stream terrace, or active floodplain

Slope type: concave, convex, planar, undulating

Microrelief type: Select the type of micro-relief evident in plot from the following pick-list, which is also listed on the datasheet; reference the NRCS Glossary of Landform and Geologic Terms (NSSH Part 629; http://soils.usda.gov/technical/handbook/contents/part629.html) for a description of the specific landform.

- Bedrock outcrops
- Mass-movement - erosional surface; e.g., gully, slump scar, debris flow
- Mass-movement - depositional surface; e.g., rock slide, talus pile
- Turf hummock; e.g., tussock formations (*Eriophorum* or *Carex*)
- Earth hummock; e.g., micro-relief due to physical processes, such as solifluction lobes and frost heaves
- Moss hummock; e.g., micro-relief due to moss accumulation
- Depressions; e.g., nivation hollows, thermokarst.
- Animal burrows
- Planar surface - level, non-hummocky terrain

Evidence of fire: List any evidence that a fire has occurred in the plot area, including charcoal, burnt trees, healed or fresh fire scars, down wood with scorch marks or charcoal, or other evidence of fire in the vicinity.

Evidence of wind: Record any direct physical evidence of wind on the vegetation or substrate; e.g., krumholz, dune formations, etc.

Wind exposure: Assign one of the following categories based on the apparent exposure of the plot to prevailing wind:

- Exposed = the plot has no shelter from prevailing winds; e.g., an open ridge top or an open flat area that is distant from windbreaks
- Moderate = the plot has some protection from wind in the form of topographic relief, but is generally open and exposed to prevailing wind currents, and protection is from only one direction.
- Protected = the plot is substantially protected from prevailing wind in two directions; e.g., the plot is situated in the lee of ridge top.
- Sheltered = the plot is sheltered for prevailing winds from three directions. Reserve this category for spots that likely receive very little strong wind because of their position on the landscape.

Notes: Record any additional information that is pertinent to the plot in the 'Notes' sections on pages 1 and 24 of the data sheets, including the following:

- *Structure*: Record any observations about the structure or composition of the plot.
- *Successional status*: Record the successional status of the plot and surrounding area.

- *Disturbance*: Record any evidence of disturbance to the vegetation, including animal activity, and/or signs of stress in the vegetation (e.g., heart rot, broken tops, red needles, etc.).
- *Phenology*: Record all observations regarding phenology, residual snowpack, standing water (e.g., from snowmelt), and/or frost damage.

II. Field notebook

1. Every technician will keep a field notebook. The lead technician is responsible for ensuring that a complete set of plot observations are compiled and transferred to the data sheets at the end of every day. Ancillary information should be included in the notebooks, if applicable:
    - *Wildlife:* Include any sightings of animals, with a complete description of what the animal was doing, how long it was in view, where it was sighted, etc.
    - *Weather conditions*
    - *Travel time to/from site*
    - *Notes regarding route to site, hazards, etc.*

2. The lead technician will keep detailed notes regarding issues that arise during plot selection, establishment, and sampling.

III. Equipment

- USDA-NRCS codes for vascular and nonvascular species (http://plants.usda.gov)
- Complete key to Viereck et al. (1992)
- Trimble XT GPS unit or comparable unit
- Clinometer
- Compass
- Plot overview data sheet

IV. Literature cited

Viereck, L.A., Dyrness, C.T., Batten, A.R., and K.J. Wenzlick. 1992. The Alaska vegetation classification. U.S. Forest Service, Pacific Northwest Region, General Technical Report PNW-GTR-286, 278 pp.

Woodward, A.E., Hutten, K.M., Boetsch, J.R., Acker, S.A., Rochefort, R.M., Bivin, M.M., and L.L. Kurth. 2009. Forest vegetation monitoring protocol for national parks in the North Coast and Cascades Network: U.S. Geological Survey Techniques and Methods 2-A8, 228 pp.

Vegetation Monitoring Procedure for the Southwest Alaska Network (SWAN)

Standard Operating Procedure (SOP) # 4

Digital Photography

Version 1.0 (December 2008)

Revision History Log:

Version No.	Revision Date	Author	Changes Made	Reason for Change

Repeat photos are extremely valuable for documenting changes in vegetation and landscape attributes through time. This SOP describes general methods for photo-documentation of permanent plots.

Procedures:

1. Use a medium resolution format for photos. The typical file size of photos ranges between 400 KB – 1 MB. Rarely will you need to store images in the highest resolution format for routine photo-documentation.

2. Use a dry-erase board to index all photos. This step is essential to verify plot photos. The board should include the following information: park, plot ID, date, and transect number. Additional information will include direction (east, west, north and south), plot frame size, or other pertinent information required for that particular photo. ***Always photograph the dry-erase board before the subject.***

3. Table 4.1 outlines the photos required for each plot. Additional detail is provided in SOP #6 (nested frequency).

Equipment:

- Camera with waterproof case; extra batteries; and memory cards ≥ 1 GB
- Dry-erase board and dry-erase pens
- Silica desiccant to store with the camera during wet weather
- Backup camera with all accessories

Table 4.1. Photo requirements at each plot.

Image	Total # of images	Comments
Plot overview	Varies	Should include key landscape features that will help to relocate the plot in the future.
Monument cap at T1-0m	At least 1	From the S-SW looking toward the monument. Photograph from several meters away to capture surrounding features that would help to relocate the monument.
Southern baseline	1	From T1-0m looking east (90°)
Transect lines	2 per transect	Photograph each transect from the T-0m and T-30m endpoints. Set the photo frame so that the transect fills about 80% of the frame with a 20% skyline.
Nested quadrats (SOP 6)	15 per transect	Fill the photo frame with the plot frame starting with the $0.25m^2$ plot. Take additional photos using the same technique for the $1m^2$ and $4m^2$ plots. You will have to adjust your position slightly to account for the increased size of the plot frame.
Ecotones	Varies	Photograph any ecotones that occur within the plot or very close to the plot and document any noteworthy physiographic features in relation to the plot

Vegetation Monitoring Procedure for the Southwest Alaska Network (SWAN)

Standard Operating Procedure (SOP) # 5

Species Cover

Version 1.0 (December 2008)

Revision History Log:

Version No.	Revision Date	Author	Changes Made	Reason for Change

This Standard Operating Procedure provides instructions for using point-intercept measurements to estimate vegetative cover and structure in the permanent 30 m × 30 m plot. Horizontal and vertical distribution of plant cover are recorded at defined intervals along the three 30-m transects.

Procedures

I. General guidelines

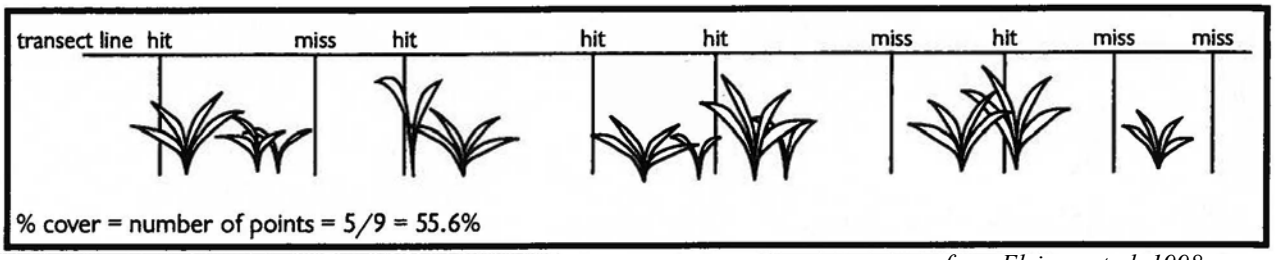
1. Cover measurements are recorded along the three 30-m transects. One person calls out 'hits' along the point-intercept transect (reader), while a second person records the observations (recorder).
2. To the extent possible, the reader and recorder should stay outside of the 30 m × 30 m intensive plot to avoid trampling vegetation inside the plot (i.e., reader and recorder should stand to the west of Transects 1 and 2 and to the east of Transect 3). Measurements should be made to the inside of the plot (i.e., ***east*** of the tape on Transects 1 and 2, and ***west*** of the tape on Transect 3).
3. Photograph each transect prior to measurement. Record the date, plot ID, transect no. and distance along transect (0 m or 30 m) on the dry-erase board (Fig. 5.1.a). Second, photograph the transect line from the recorded endpoint, sighting down the entire transect, if possible, and including the skyline, as shown (six photos, total; Fig. 5.1.b).

Figure 5.1. Photograph the dry-erase board with the complete plot information (a), then photograph the transect line (b).

II. Point-intercept measurements

1. Transect tapes should be firmly anchored, straight and taut, with meter increments facing up.
2. Starting at the south (0-m) end of a transect, the reader drops a pin perpendicular to the ground at 0.5 m intervals along the tape, starting at 0.5 m and ending at 29.5 m. In taller vegetation (≥50 cm), use a sampling rod (Figure 5.3). In low-stature vegetation, a rigid pin will suffice. The reader calls out species that are "hit" within each height class at each point (Fig. 5.2). USDA-NRCS four-character plant codes are used to record vascular species (http://plants.usda.gov/). Write out the complete Latin name for any species for which the USDA code is unknown. Height classes are as follows: (1) <50 cm, (2) 50 – 100 cm, (3) 1 – 4 m, and (4) >4 m. Cover codes (Table 5.1) are used to record hits for non-vascular plants and substrate classes.

Figure 5.2. Point-intercept method of measuring cover.



from Elzinga et al. 1998

Table 5.1. Cover codes for non-vascular plants and substrate classes.

Non-vascular feature	Code	Notes
Moss	M	Enter it as a class, not by species
Lichens	LI	Enter it as a class, not by species
Standing dead	SD	Consists of non-living, woody plant parts held above the ground surface, including dead branches on all, or portions of, shrubs or trees.
Downed wood	DW	Downed wood (on ground surface) with diameter > 1 cm.
Litter	LT	Detached leaves, branches, etc., on the ground surface, and standing dead material on graminoids. Includes woody fragments on the ground surface < 1 cm diameter and animal scat.
Cryptogamic crust	CR	Soil crust comprised of cyanobacteria, lichens, mosses and fungi. Use if soil is stabilized (not bare ground) but free-living mosses or lichens are not distinguishable.
Bare ground	BG	Bare mineral soil (sand, silt clay matrix). The bare ground category is reserved for open soil that does not support a protective layer of plant growth. Do not record bare ground for soils that occur under moss or lichens.
Gravel	G	The code is "G"; this consists of ground surface covered with rock fragments sized from 2mm to 64 mm (6.4 cm ~ 2.5 inches)
Rock	RK	Consists of a ground surface covered with rock fragments sized larger than 64 mm (6.4 cm ~ 2.5 inches).
Standing water	SW	Consists of standing water occupying the surface of the ground
Running water	RW	Consists of running water occupying the surface of the ground

3. For frost-damaged plants, record (FD) following the species code; e.g., if *Ledum palustre* ssp. *decumbens* is encountered with frost damage (red needles) in the current year, record it as LEPAD (FD). Frost damage hits must be recorded separately from non-damaged hits.
4. For standing dead material (e.g., standing dead trees or shrubs, in which the entire plant is dead), record (SDD) following the species code, as in (3), above. For standing dead branches attached to a living plant, record (SDL) following the species code. The SDL designation should be limited to branches that are terminally dead, but not to dead portions of a branch if the apical meristem is live.
5. For each unknown species encountered, collect a specimen from outside of the 30 m × 30 m plot, following guidelines in Appendix H. Assign a tracking identifier (e.g., catalog and accession no.) to each specimen, and provide a detailed description of the collection on the datasheet.
6. Instructions for use of the sampling rod are outlined in Roland et al. (2004) and summarized as follows:

   a. Place the base of the sampling rod on the ground adjacent to the tape. Level the rod using the bubble level on the pin bracket, and ensure that the pin will be aligned at the desired location on the transect tape. The base of the sampling rod must be at the same level as the surface where the pin will touch the ground. Extend the rod to 2 m to measure overstory vegetation.

   b. Record hits as follows: For the overstory vegetation, record only vegetation that actually is within the point target on the densitometer viewer. For the understory vegetation, record data only when the point of the pin intersects the vegetation. Enter only one hit for any given species per height class, even if you intercept it multiple times. At the ground level, it is possible to record multiple cover classes (e.g., litter, moss, and lichen) if they overlay one another. In addition, record the type of underlying, non-living substrate (e.g., litter, gravel, bedrock, soil).

Figure 5.3. Sampling rod used to measure species cover by the point-intercept method in vegetation ≥50 cm tall. A level and densitometer attached to the rod are used to ensure that the rod is held vertically, and that overstory vegetation intercepted in the densitometer is recorded as a 'hit.' Species cover is recorded within each height class (0-50 cm; >50-100 cm; >1-4 m; >4 m).

Photo from Roland et al. (2004).

III. Equipment

- Sampling rod and extra pins
- 3 × 30 m fiberglass reel tapes
- 2 m metal tape
- Percent cover data sheets (3 copies)
- USDA codes for vascular and nonvascular species (Appendices 10-11).
- Ziploc collection bags
- Sharpie to label bags
- Camera
- Dry-erase board & dry-erase pens

As of 2009, sampling rods were constructed by Jon Holmgren:

Jon's Machine
350 Goldstream Rd.
Fairbanks, Alaska 99712
(907) 457-5000

IV. Literature cited

Roland, C., Oakley, K., Debevec, E.M., and P. Loomis. 2004. Monitoring vegetation structure and composition at multiple spatial scales in the Central Alaska Network (Version 1.0). National Park Service, Inventory & Monitoring Program, Alaska Region, Anchorage, Alaska, 50 pp.

Vegetation Monitoring Protocol for the Southwest Alaska Network (SWAN)

Standard Operating Procedure (SOP) # 6

Frequency

Version 1.0 (December 2008)

Revision History Log:

Version No.	Revision Date	Author	Changes Made	Reason for Change

This SOP provides instructions for measuring species occurrence (frequency) and cover by growth form. Measurements are made in nested quadrats arrayed along the three 30-m transects.

Procedures:

I. General Guidelines

1. Five nested quadrats (0.25 m^2, 1 m^2 and 4 m^2; Fig. 6.1) are sampled along each of the three 30-m transects (15 quadrats total). The quadrats are established on the east side of Transects 1 and 2, and the west side of Transect 3, as shown in SOP 2, Fig. 2.1.

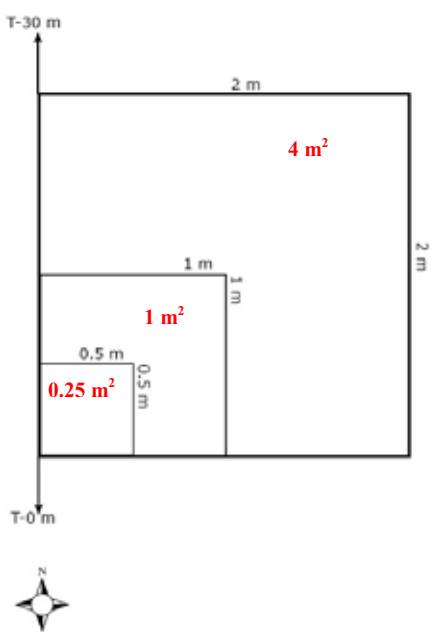


Figure 6.1. Nested quadrats (0.25-m^2, 1-m^2 and 4-m^2) are placed systematically at 7-m intervals along each 30-m transect. The 0.25-m^2 and 1-m^2 quadrats are located in the southwest corner of the 4-m^2 quadrat on Transects 1 and 2, as shown. On Transect 3, the 0.25-m^2 and 1-m^2 quadrats are located in the southeast corner of the 4-m^2 quadrat, as measurements are taken to the west of the transect (SOP 2).

Presence/absence of species is recorded within each quadrat frame, starting with the 0.25-m^2 frame. Cover by growth form is recorded in the 4-m^2 quadrat using ocular estimates. USDA-NRCS species codes are used to record vascular and non-vascular species.

2. As with cover measurements (SOP 5), the reader and recorder should stand to the west of Transects 1 and 2 and to the east of Transect 3 while recording frequency. While the reader may need to step around the 4-m^2 quadrat to document all species, one should never step inside of the quadrat.
3. Quadrats must be placed exactly at 7-m intervals (i.e., the southern edge of the nested quadrats should be located at 0, 7, 14, 21, and 28 m) along each transect to ensure accurate relocation on subsequent sampling dates. Quadrat frames should be aligned at their SW (Transects 1 and 2) or SE (Transect 3) corner and must lie squarely against the transect tape and parallel to the ground surface. Any deviation from the normal placement of the quadrats must be recorded in the plot notes.
4. Photograph the nested quadrat once it has been established. As in SOP 5, record the date, plot ID, transect and quadrat number on the dry-erase board (Fig. 6.2.a), and photograph it prior to photographing the quadrat frames. Each quadrat frame should be photographed from a height of ca. 1.3 m over the top of the quadrat(s), with the intent of filling the photo frame (Fig. 6.2.b-c). The photo of the 4-m^2 frame should be taken from the corner in which the frames are nested (SW or SE; Fig. 6.2.d).

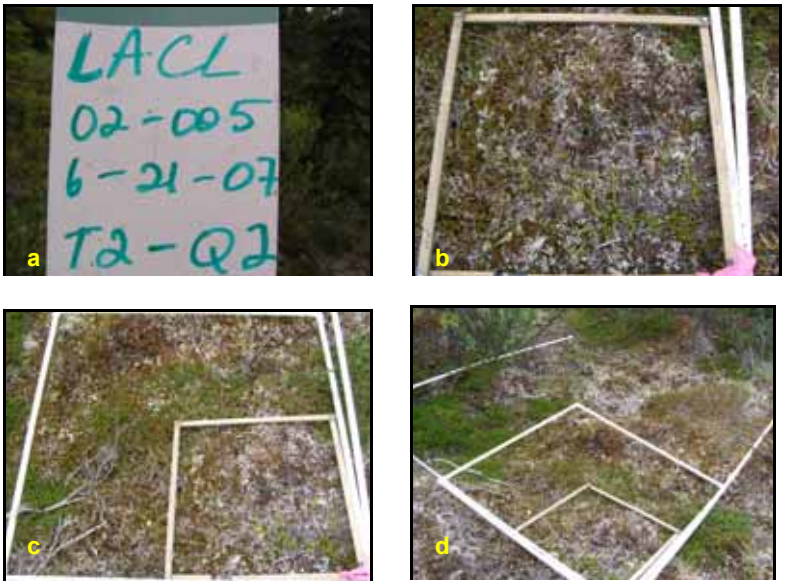
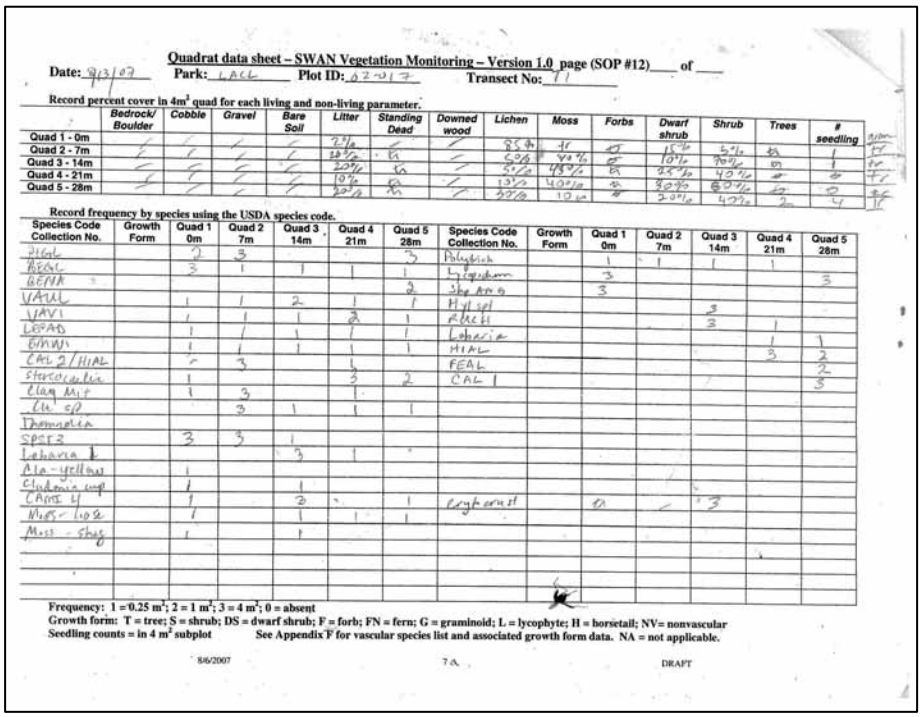


Figure 6.2. Nested quadrat photos. The dry-erase board with complete plot information is photographed first (a); followed by the 0.25-m^2 quadrat (b); 1-m^2 quadrat (c); and 4-m^2 quadrat (d).

II. Frequency measurements

1. Record the occurrence of all vascular and non-vascular species that occur within each quadrat frame, starting with the 0.25-m^2 quadrat and moving out to the 1-m^2 and 4-m^2 quadrats. A species' presence is indicated by its frequency code, as follows: 0.25 m^2 = **1**; 1 m^2 = **2**; 4 m^2 = **3**. For example, all taxa that occur in the 0.25-m^2 frame will be assigned a frequency of 1. Once all species have been identified in the 0.25-m^2 frame, the reader will move on to the 1-m^2 quadrat frame and assign any new species encountered a frequency value of 2 (Fig. 6.3). USDA-NRCS four-character plant codes are used to record vascular and non-vascular species (http://plants.usda.gov/). The complete Latin name should be recorded for any taxa for which the USDA code is

unknown or unavailable. Vascular species are recorded in all quadrats; nonvascular species are recorded in the 0.25-m^2 and 1-m^2 quadrats only.



Quadrat data sheet – SWAN Vegetation Monitoring – Version 1.0 page (SOP #12)____ of ____

Date: 9/3/07 Park: LACL Plot ID: 02-017 Transect No: 11

Record percent cover in 4m^2 quad for each living and non-living parameter.

	Bedrock/ Boulder	Cobble	Gravel	Bare Soil	Litter	Standing Dead	Downed wood	Lichen	Moss	Forbs	Dwarf shrub	Shrub	Trees	# seedling
Quad 1 - 0m					2%			95%	45	0	15%	5%	0	
Quad 2 - 7m					20%	0		50%	90%	0	10%	90%	0	1
Quad 3 - 14m					20%	0		50%	45%	0	95%	40%	0	
Quad 4 - 21m					10%	0		15%	40%	0	90%	60%	0	0
Quad 5 - 28m					20%	0		50%	10	0	30%	40%	0	4

Record frequency by species using the USDA species code.

Species Code Collection No.	Growth Form	Quad 1 0m	Quad 2 7m	Quad 3 14m	Quad 4 21m	Quad 5 28m	Species Code Collection No.	Growth Form	Quad 1 0m	Quad 2 7m	Quad 3 14m	Quad 4 21m	Quad 5 28m
PIGL		2	3			3	Polytrichum		1	1	1	1	
ABGL		3	1	1	1	1	Hylocomium		3				3
BENA						2	Sphagnum		3				
VAUL		1	1	2	1	1	Hylocom				3		
VAVI		1	1	1	2	1	Pleurozium				3	1	
LEGRO		1	1	1	1	1	Lobaria					1	1
ERNA		1	1	1	1	1	HIAL					3	2
CAL 2/HIAL		1	3		1		FEAL						2
Stereocaulon		1			3	2	CAL 1						3
Cladonia		1	3		1								
CLA sp			3	1	1	1							
Dermatocarpon													
SPEC 3		3	3	1									
Lobaria L				3	1								
Ala-yellow		1											
Cladonia cup		1		1									
CAMI L		1		3		1	Cryptorusti		0		3		
Moss - lipe		1		1	1	1							
Moss - shag		1		1									

Frequency: 1 = 0.25 m^2; 2 = 1 m^2; 3 = 4 m^2; 0 = absent

Growth form: T = tree; S = shrub; DS = dwarf shrub; F = forb; FN = fern; G = graminoid; L = lycophyte; H = horsetail; NV= nonvascular

Seedling counts = in 4 m^2 subplot See Appendix F for vascular species list and associated growth form data. NA = not applicable.

8/6/2007 7A DRAFT

Figure 6.3. Example of a datasheet showing frequency values for species recorded along a transect in Lake Clark National Park and Preserve. USDA-NRCS codes are used to designate vascular and non-vascular species. For each nested quadrat along the 30-m transect, a frequency value is recorded if the species is present in either the 0.25-m^2 quadrat (frequency = 1), the 1-m^2 quadrat (frequency = 2) or the 4-m^2 quadrat (frequency = 3). A species' presence in the smallest quadrat is always recorded, even if it occurs in all three quadrats. If the species is absent in all three quadrats, the field is left blank.

2. Trees and other single-stemmed plants must be completely rooted within the greater 4-m^2 quadrat to be considered present. Shrubs and other multiple-stemmed plants must be at least partially rooted within the 4-m^2 quadrat. *Overhanging leaves or branches of a plant not rooted in the quadrat will not be considered an occurrence in the nested frequency measurements.*

3. For each unknown species encountered, collect a specimen from outside of the 30 m × 30 m plot, following guidelines in Appendix H. Assign a tracking identifier (e.g., catalog and accession no.) to each specimen, and provide a detailed description of the collection on the datasheet.

III. Percent cover by growth form

1. Estimate the percent cover of species by growth form using ocular estimates in the 4-m^2 quadrat frame. Use growth forms (habits) assigned by USDA-NRCS (http://plants.usda.gov/) to determine species' groupings. For example, *Salix alaxensis* and *Ledum palustre* ssp. *decumbens* are designated as shrubs by NRCS, even though *Salix* may grow as tall as neighboring trees and *Ledum* may exhibit nearly prostrate growth. For these estimates, quantify anything that is within the 3-dimensional boundary of the quadrat (imagine the *z* dimension to extend beyond the highest strata in the plot). *Overhanging leaves or branches are counted in the cover estimates, even if the plant itself is not rooted in the plot.* Note that in this sense, cover estimates differ from the frequency measurements (Section II.2). As such, total cover of vegetation in the 4-m^2 quadrat may exceed 100 percent, due to overlapping and overhanging foliage. The area represented by each 20 cm × 20 cm square in

the 4-m^2 quadrat frame equals 1 percent of the total plot. Crew members should practice, and calibrate, their cover estimates using the quadrat frame and Fig. 6.4.

Percent graminoids: Estimate the total percent cover of all grasses and sedges in the 4-m^2 quadrat.

Percent dwarf shrub: Estimate the total cover of all dwarf shrub species.

Percent shrub: Estimate the total cover of all shrub species.

Percent trees: Estimate the total cover of trees, including overhanging branches.

Number of seedlings: Record number of tree seedlings (any tree species less than 1.37 m tall) in the quadrat.

2. Record percent cover of the ground layer (substrate types) in the 4-m^2 quadrat frame, as in (1), above. Cover estimates for the ground layer must total 100 percent.

Percent cryptogamic crust: Estimate the total percent cover of cryptobiotic crust in the 4-m^2 quadrat. Free-living lichens and mosses should be quantified separately.

Percent moss: Estimate the total cover of all moss, including moss occurring under other growth forms.

Percent lichen: Estimate the total cover of all lichens, as for moss.

Percent bedrock: Estimate the total cover of all continuous exposed bedrock

Percent cobble: Estimate the total cover of all rock fragments larger than 6.4 cm (~2.5 inches) diameter.

Percent gravel: Estimate the total cover of all rock fragments between 2 mm-64 mm diameter.

Percent bare soil: Estimate the total cover of all bare soil and rock fragments less than 2 mm diameter.

Percent litter: Estimate the total cover of litter in the quadrat. Litter consists of all downed and dead plant herbaceous material, plus all woody material less than 1 cm diameter, lying on the soil surface.

Percent standing dead: Estimate the total cover of all non-living plant parts held above the ground surface, including dead standing grasses, shrubs, trees, and dead limbs on live trees.

Percent wood: Estimate the total cover of dead, downed wood greater than 1 cm diameter.

IV. Equipment

- 0.25 m^2, 1 m^2 and 4 m^2 quadrat frames
- Frequency data sheets
- Camera & memory cards
- Dry-erase board or diving board
- Erasable markers or pencils
- Collection bags
- Sharpies
- USDA species codes for vascular and non-vascular species
- Hand lens
- Taxonomic key(s)

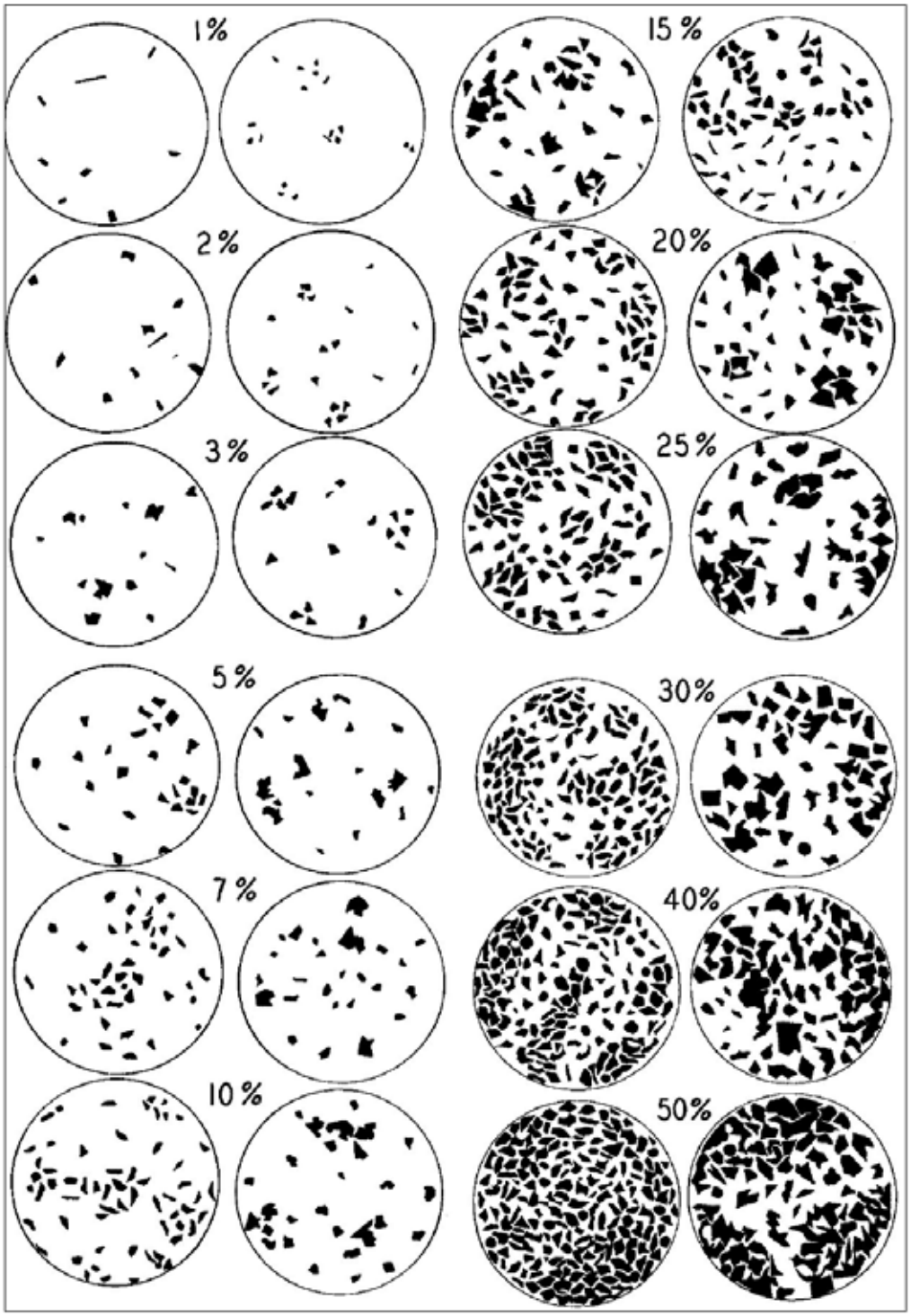


Figure 6.4. Reference scatter plots for cover estimation (from Terry and Chilingar 1955).

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Vegetation Monitoring Protocol for the Southwest Alaska Network (SWAN)

Standard Operating Procedure (SOP) # 7

Tree measurements

Version 1.0 (December 2008)

Revision History Log:

Version No.	Revision Date	Author	Changes Made	Reason for Change

This SOP provides instructions for measuring trees and saplings in the 30 m × 30 m plot with the objective of estimating tree density, basal area, and size-class distribution for tree species. Methods are adapted from Roland et al. (2004), Woodward et al. (2009), and USFS Forest Inventory and Analysis field procedures for Alaska (FIA 2003).

Procedures

I. Definitions

DBH (diameter at breast height) = 1.37 m above the ground
Seedling = any tree species < 1.37 m tall
Sapling = any tree species ≥ 1.37 m tall and DBH < 12.0 cm
Tree = any tree species ≥ 12.0 cm DBH (Table 7.1)
Condition Class = 'live' or 'dead' individual

Table 7.1. Tree species

Species	Authority	USDA Code	TSN
Picea glauca	(Moench) Voss	PIGL	183295
Picea mariana	(P. Mill) B.S.P.	PIMA	183302
Picea sitchensis	(Bong.) Carr.	PISI	183309
Picea × lutzii	Little	PILU	194777
Tsuga mertensiana	(Bong.) Carr	TSME	183402
Betula papyrifera	Marsh.	BEPA	19489
[1]*Betula papyrifera* var. *kenaica*	(W.H. Evans) A. Henry	BEPAK	19493
Populus tremuloides	Michx.	POTR5	195773
[2]*Populus balsamifera* ssp. *balsamifera*	L.	POBAB2	22454
Populus balsamifera ssp. *trichocarpa*	(Torr. & Gray ex Hook.) Brayshaw	POBAT	22455

[1]Syn: *Betula kenaica* W.H. Evans (USDA Code: BEKE2; TSN: 195224; accepted local name in NPSpecies)

[2]Syn: *Populus balsamifera* L. (USDA Code: POBA2; TSN: 22453; also accepted by NPSpecies)

II. Tree and sapling measurements

2. Following the completion of cover and frequency measurements, map all trees ≥12 cm DBH in the 30 m × 30 m plot. Viereck et al. (1992) define Level III forest classes as follows: needleleaf woodland (10-24% canopy cover), open forest (25-60% cover), and closed forest (60-100% cover). In forested sites with canopy cover >25%, map the largest trees first. In each half of the plot, locate the trees by referencing their position relative to the closest transect line, and record the approximate N/S distance along the transect to the nearest 0.1 m. Use a laser rangefinder or tape to record the E/W distance from the N/S point on the transect (Fig. 7.1). Map distances to the center of the tree bole, at ground level. Minimize trampling in the plot by working in one half of the plot at a time, starting at one end (e.g., south) and working toward the other end. To the extent possible, avoid walking within 2 m of transect lines, where quadrats are sampled.

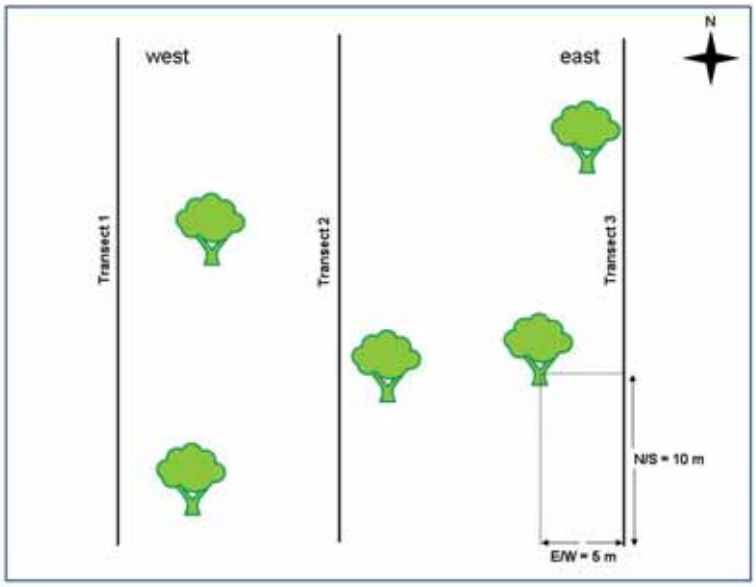


Figure 7.1. Mapping trees off of the X-Y grid formed by transect lines. Trees must be rooted ≥50% within the plot to be mapped. ***Map variables:*** **½ plot** is recorded as the eastern (**E**) or western (**W**) half of the plot. **Transect** is recorded as the nearest transect (**T1, T2,** or **T3**) along which the north-south distance is measured. **Distance N/S** is recorded as the distance from 0 m (southern endpoint) in meters along the transect tape. **Distance E/W** is recorded as the distance in meters between the transect line and the tree bole.

In the example shown:
½ plot = E
Transect = T3
Distance N/S = 10 m
Distance E/W = 5 m
(*X-Y coordinates:* X=25 m; Y=10 m)

2. Record the following data by tree for all trees in the plot:
   - **Species:** USDA species code (Table 7.1)
   - **½ plot:** west (**W**; between T1-T2) or east (**E**; between T2-T3) half of plot (Fig. 7.1)
   - **Transect:** transect along which the N/S distance (Y-coordinate) is measured (**T1**, **T2**, or **T3**; Fig. 7.1)
   - **Dist N/S:** distance in meters along the transect, from 0 m, that forms the Y-coordinate (Fig. 7.1)
   - **Dist E/W:** distance in meters, perpendicular to the transect, measured from the transect to the center of the tree bole; i.e., the X-coordinate (Fig. 7.1)
   - **X-Y Coordinates:** calculated from the ½ plot designation and N/S & E/W measurements (see example above)
   - **DBH:** Diameter at breast height (1.37 m) measured in cm using a DBH tape (Fig. 7.2). Trees must be ≥ 12 cm DBH to qualify for mapping. See notes regarding DBH measurements below (3).
   - **Height:** Estimate tree height to the nearest 0.1 m using a laser rangefinder or clinometer (Figs. 7.3-7.5)
   - **Cond (L/D):** Record if the tree is live (**L**) or dead (**D**)
   - **Crown class:** Record crown class code (Table 7.2; Fig. 7.6)

- **Crown length:** Record the percent of tree bole occupied by live crown (Table 7.3)
- **Pathogens:** Record pathogen code (Table 7.4), if applicable. Record 'NONE' if no damage is evident.

3. *Diameter at breast height (DBH):* For trees forked at or below breast height (≤1.37 m), both forks will be measured and assigned the same tree number with a letter suffix. For example, if a tree has two forks at 1.37 m, label the tree '12A' and '12B' on the data sheet, and record the diameters for each separate fork. However, if a fork has a departure angle of greater than 45° from the bole, the fork is classified as a limb, and only the largest, upright leader should be measured.

Diameter tapes are calibrated so that when the tape is wrapped around the circumference of a tree, the tape is actually showing the diameter of the tree [C (circumference) = π (diameter); Fig. 7.2]. The other side of the d-tape is the lineal tape. A common error is to read the lineal side of the tape instead of the d-tape side. Be sure to check your reading of the tape to make sure the number you have called out for diameter actually makes sense.

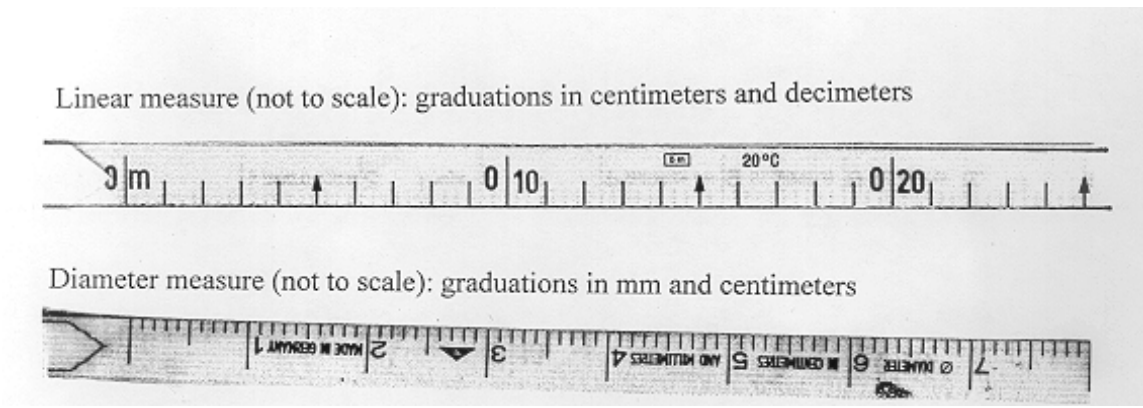


Figure 7.2. Linear (top) and diameter (bottom) sides of a diameter tape.
http://www.cfr.washington.edu/Classes.ESC.221/Classes.Esc.221.BAK/skills/VegTerrain%20Field%20Procedures.doc.htm

4. *Tree height:* Use a laser rangefinder, following manufacturer's directions, to estimate tree height to the nearest 0.1 m.

5. *Sapling density and biomass:* Tally the number of saplings in the eastern and western half of the plot by species and condition code (live/dead), as above. Record '0' if there are no saplings in a particular species × condition category. In stands with canopy cover ≤25%, record DBH and height for all saplings. In stands with canopy cover >25%, record sapling DBH and height for saplings ≥4 cm DBH and tally all saplings of lesser DBH.

6. *Assign crown class and condition codes to trees in plot:* Descriptions adapted from the U.S. Forest Service Forest Inventory & Analysis (FIA; 2003) program follow.

Table 7.2. Crown class codes

Crown class code	Crown class name	Crown class description
1	Open Grown	Trees with crowns which have received full light from above and all sides throughout their lifespan, particularly during early development. Their forms or crown shapes have not been influenced by other trees.
2	Dominant	Trees with crowns extending above the general level of the crown canopy and receiving full light from above and partly to the sides; taller than the average trees in the stand, with crowns well developed but possibly crowded on the sides.
3	Codominant	Trees with crowns at the general level of the crown canopy and receiving full light from above but comparatively little from the sides; usually with medium-sized crowns and somewhat crowded on the sides.
4	Overtopped	Trees with crowns entirely below the general level of the crown canopy, receiving no direct light from above or from the sides. Includes small trees and regeneration under forest canopy.
5	Dead tree	Tree is dead, either standing dead or dead and down.

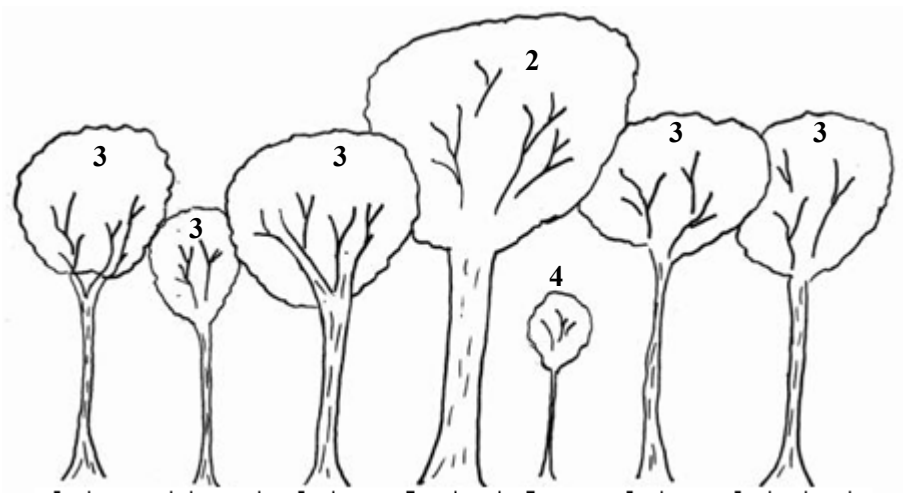


Figure 7.6. Crown classes for closed forest; crown class codes from Table 7.2.
Environment Canada Ecological Monitoring and Assessment Network (http://www.eman-rese.ca Cited 30 December 2008)

Table 7.3. Crown length codes

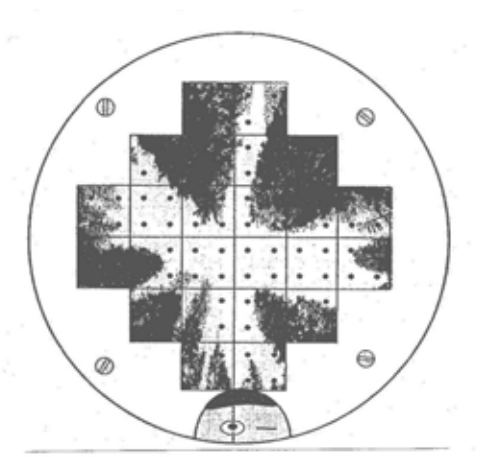
Crown length code	Crown length percent
1	1 - 25
2	26 - 50
3	51 - 75
4	76 - 100

Table 7.4. Pathogen codes (adapted from Roland 2004)

Pathogen code	Pathogen/damage description
BAPE	Bark peeling
BRRU	Broom rust
COFU	Conk fungi
DELE	Dead leader
DYIN	Dying
OOPI	Oozing pitch
SPTR	Split trunk
WOUN	Wound
SPBE	Spruce bark beetle
SPEN	Spruce engraver
LEMI	Leaf miner

III. Canopy Cover

1. Use a spherical densiometer to take a reading in each of the four cardinal directions (N/S/E/W) at the four corners of the plot (T1-0 m; T1-30 m; T3-0 m; T3-30 m) and at plot center (T2-15 m). Hold the instrument level and far enough away from your body so that your head is just outside of the mirrored grid (approximately 30-45 cm away from your body). Record the number of dots NOT occupied by canopy (Fig. 7.7). Multiply the total count by 1.04 to obtain the percent of overhead area not occupied by canopy. Subtract 100 from this value to estimate the canopy cover in percent. Average the four readings (N/S/E/W) to provide an estimate of canopy cover from that point. Record calculated percent cover (not the point counts) on the data sheet.



Sample spherical densiometer reading.
The above example shows 48 shaded points.
(From Pleus & Schuett-Hames, 1998)

Figure 7.7. Example of a densitometer reading used to estimate canopy cover. In this case, 48 of 96 grid points are not occupied by canopy.

Thus, 48 × 1.04 = 49.92 and
% canopy cover = 100 - 49.92 = 50.08, or 50%

http://www.clallam.net/streamkeepers/assets/applets/CanopyCl.pdf

IV. Basal Area and Biomass Calculations

Calculate basal area for trees within the 30 m × 30 m (0.09 ha) inner plot as follows:

$$\text{Basal area (cm)} = \pi \times (\text{DBH}/2)^2$$

Calculate aboveground live and dead biomass (trees and saplings) of white spruce using allometric equations derived for *Picea glauca* (Harding and Grigal 1985):

$$\text{Dry mass (kg)} = 0.069 \times (\text{DBH (cm)})^{2.324} \times (\text{height (m)})^{0.210}$$

V. Equipment

- Tree and sapling data sheets (1 per plot)
- Laser range finder with field instructions
- Clinometer
- 30 m reel tape
- 2 Diameter tapes (metric)
- Compass
- Spherical densitometer
- Increment borers

VI. Literature cited

Forest Inventory and Analysis (FIA). 2003. Field procedures for the coastal Alaska inventory. USDA Forest Service, Pacific Northwest Research Station, Forestry Sciences Lab, Region 10, Alaska. Anchorage, Alaska, 182 pp.

Harding, R.B., and D.F. Grigal. 1985. Individual tree biomass estimation equations for plantation-grown white spruce in northern Minnesota. Can. J. For. Res. 15:738-739.

Roland, C., Oakley, K., Debevec, E.M., and P. Loomis. 2004. Monitoring vegetation structure and composition at multiple spatial scales in the Central Alaska Network (Version 1.0). National Park Service, Inventory & Monitoring Program, Alaska Region, Anchorage, Alaska, 50 pp.

Viereck, L.A., Dyrness, C.T., Batten, A.R., and K.J. Wenzlick. 1992. The Alaska vegetation classification. U.S. Forest Service, Pacific Northwest Region, General Technical Report PNW-GTR-286, 278 pp.

Woodward, A.E., Hutten, K.M., Boetsch, J.R., Acker, S.A., Rochefort, R.M., Bivin, M.M., and L.L. Kurth. 2009. Forest vegetation monitoring protocol for national parks in the North Coast and Cascades Network: U.S. Geological Survey Techniques and Methods 2-A8, 228 pp.

Vegetation Monitoring Protocol for the Southwest Alaska Network (SWAN)

Standard Operating Procedure (SOP) # 8

Tree cores

Version 1.0 (December 2008)

Revision History Log:

Version No.	Revision Date	Author	Changes Made	Reason for Change

This SOP provides instructions for collecting tree cores and fuels data with the objective of obtaining an estimate of forest stand age and CWD fuel loads. Methods are adapted from Woodward et al. (2009), USFS Forest Inventory and Analysis field procedures for Alaska (FIA 2003), and the point intersect methods of Van Wagner (1968) and Brown (1974). Trees will be cored only once, at the time of plot establishment. Fuels measurements will be repeated at every subsequent site visit.

Procedures:

I. Tree cores

1. Core only white (*Picea glauca* = PIGL), black (*P. mariana* = PIMA), Sitka (*P. sitchensis* = PISI) or Lutz (*Picea* × *lutzii* = PILU) spruce trees.
2. Collect cores only from trees ≥12 cm DBH that fall between the 30 m × 30 m inner plot and 50 m × 50 m outer plot boundary (i.e., from the 10-m wide buffer surrounding the 30 m × 30 m inner plot). Core the largest diameter tree near each plot corner.
3. Record the distance (m) and azimuth of each cored tree relative to the nearest plot corner.
4. Tag the tree with a pre-numbered aluminum tag. Record the tag number on the datasheet.
5. Core the tree at a height of approximately 30 cm above ground level, and above any butt swell or other abnormality in the tree bole. For trees in sloping terrain, core from the side of the tree. For leaning trees, core on the uphill side. It may be necessary to remove some lower branches to get at the base of the tree.
6. If possible, the core should include the pith and the outer bark. If a core is substantially off-pith, collect a second core that comes closer to intersecting the center of the tree. Place the core in 1-2 protective straws and label the straw with the **plot id, date, tag number, DBH** (cm), and **height above root crown (ARC)**, in cm. Secure both ends of the straw with electrical tape or a lighter.
7. For each tree cored, record the following:

- **Tag #:** Record the number on the pre-labeled aluminum tag used to mark the cored tree
- **Species:** USDA species code (**PIGL**, **PIMA**, **PISI** or **PILU**)
- **Cond (L/D):** Record if the tree is live (**L**) or dead (**D**)
- **Transect endpoint:** Record closest transect endpoint (e.g., T1-30), from which a distance and azimuth to the tree are measured
- **Dist:** distance in meters from transect endpoint to cored tree
- **Azimuth:** azimuth from transect endpoint to cored tree (declination set to true north)
- **DBH:** Diameter at breast height (1.37 m) measured in cm using a DBH tape.
- **Core height:** Height above root crown (ARC) at which tree was cored, usually 30-40 cm
- **Tree Height:** Estimate tree height to the nearest 0.1 m using the laser rangefinder
- **Notes:** Include pathogen/damage codes (SOP 7), if applicable. If the largest tree(s) have rotten pith and do not yield complete cores, make a note of that and core one or more smaller trees.

II. Ladder Fuels

1. For each tree cored, record the following regarding ladder fuels:
   - **Tag #:** As above, in Section I
   - **Crown radius:** Estimate crown radius from the center of the bole to the mean branch length (m)
   - **Height to dead ladder fuel:** Estimate the height from the ground to the lowest dead branch (m)
   - **Height to live ladder fuel:** Estimate the height from the ground to the lowest dead branch (m)
   - **Height to main crown:** Estimate the height from the ground to the main crown of the tree (m)

III. Equipment

- Tree Data sheets (1 per plot)
- 10” and 14” increment borer and extra spoons (extractors)
- WD-40 and rags for cleaning borers
- Plastic straws (4 per plot plus extras) and extra fine-tipped sharpies
- Electrical tape and cigarette lighters
- Plastic ‘quiver’ for storing cores and empty straws
- Loggers tape of at least 16 m length
- Diameter (DBH) tapes (cm)
- Laser range finder

IV. Literature cited

Forest Inventory and Analysis (FIA). 2003. Field procedures for the coastal Alaska inventory. USDA Forest Service, Pacific Northwest Research Station, Forestry Sciences Lab, Region 10, Alaska. Anchorage, Alaska, 182 pp.

Woodward, A.E., Hutten, K.M., Boetsch, J.R., Acker, S.A., Rochefort, R.M., Bivin, M.M., and L.L. Kurth. 2009. Forest vegetation monitoring protocol for national parks in the North Coast and Cascades Network: U.S. Geological Survey Techniques and Methods 2-A8, 228 pp.

Vegetation Monitoring Protocol for the Southwest Alaska Network (SWAN)

Standard Operating Procedure (SOP) # 9

Soil sampling

Version 1.0 (December 2008)

Revision History Log:

Version No.	Revision Date	Author	Changes Made	Reason for Change

This SOP provides instructions for field soil descriptions adjacent to the 30 m × 30 m permanent plots. The objective for measuring soil parameters is to obtain data relating soil attributes to plant growth and ecosystem function for each permanent plot – data are ancillary and will not be included in trend estimates. Soils will be collected only once, at the time of plot establishment.

Procedures

I. Excavate and photograph soil profile

1. A soil sample will be collected only in areas that have received clearance during the permitting process. ***No soils will be collected near known archeological sites.***
2. Soils descriptions will be completed adjacent to, and outside of, one of the cardinal corners of the 30 m × 30 m plot. Use a trowel to expose a 30 cm soil profile (measured from the base of the vegetation), taking care not to disturb the soil structure (Fig. 9.1).
3. Photograph the soil profile with a measuring tape in place for scale (0 cm at base of vegetation). Refill the exposure and replace vegetative mat to minimize site disturbance when descriptions are completed.

II. Soil description

1. Draw and label a sketch of the soil profile consistent with field descriptions (e.g. Figure 9.1)
2. Record the maximum depth of observation in the soil profile, in cm
3. Record depth (from surface) of each of the following layers in the soil profile:

   A. Ground surface cover – The ground surface is covered to some extent at least part of the year by vegetation, rock fragments, and/or litter (Figure 9.1). Fresh litter is defined as detached, undecomposed plant material lacking weathered mineral particles.

Table 9.1. Fresh litter codes

code	Litter description
CL	Coniferous litter
DL	Deciduous litter (incl. shrub litter)
GH	Graminoid/Herbaceous litter
LT	Litter (undifferentiated)
WD	Woody debris

Table 9.2. Living mat codes

code	Living mat description
DS	Dwarf shrub
MO	Moss
LI	Lichen
ML	Moss and lichen
GR	Graminoid (rhizomatous/turf)

Table 9.3. Rock fragments codes

code	Rock fragments description
G	Gravel (2 mm < ∅ < 76 mm)
R	Rock (∅ ≥ 76 mm)

B. Organic layer – An organic layer is typically present below living vegetation (Figure 9.1). It is dominated by the presence of organic material in varying stages of decomposition. Often the color differs from that of fresh litter, and fungal mycelium may be present. Some original plant material will be recognizable, but will usually be modified by decay processes. The mineral fraction of the organic layer is only a small percentage of the weight of the material. One or more organic horizons may be present. If significant changes in color, nature of organic material, or degree of decomposition are present, describe each organic horizon separately.

Table 9.4. Organic layer codes

code	Organic layer description
AL	Deciduous Leaves (incl. shrub)
CN	Coniferous Needles
GH	Graminoid/Herbaceous
LI	Lichen
ML	Moss & Lichen
MO	Moss
OT	Other (describe)
UN	Unknown
W	Wood

C. Mineral soil - exists below the organic horizon (when present) and is at least 80 percent by weight mineral grains. There are almost no recognizable decomposing plant parts, but roots and woody debris may be present (Figure 9.1). One or more mineral soil horizons may be present. If significant changes in color or texture are present, describe each mineral soil horizon separately.

III. Soil sample

Collect approximately 100 g dry weight equivalent (approximately 100 cc) of mineral soil from the top 10-20 cm of the soil profile. Remove living plant material and undecomposed organic matter (duff) from the soil plug and transport out of the field in a labeled quart-sized Ziploc freezer bag. Soils should be sieved (2 mm) and air dried within 48 h after leaving the field. Soil analyses will include texture, SOM content, total C and N, and pH.

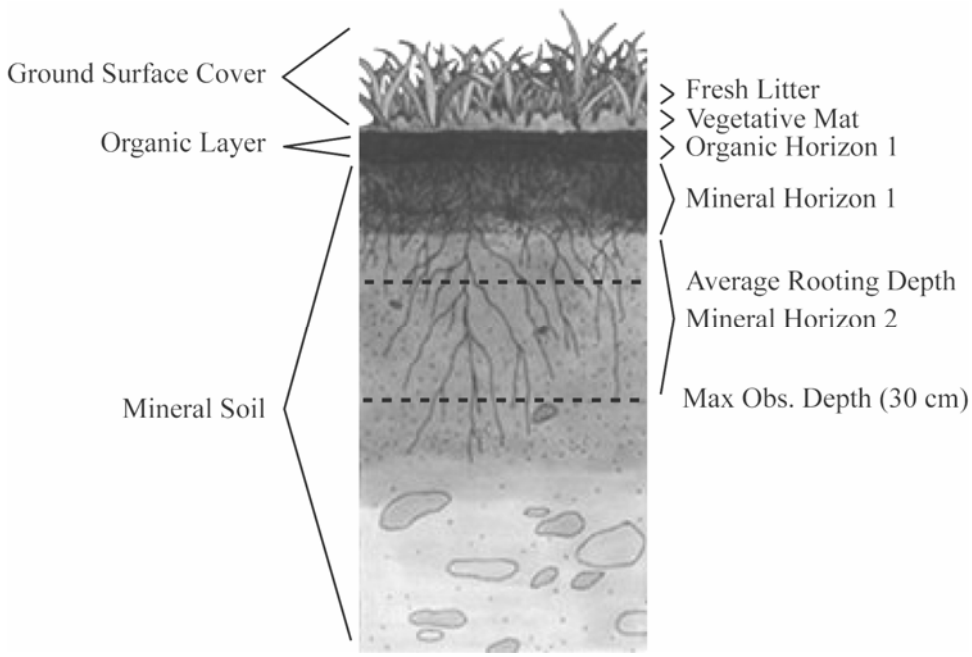


Figure 9.1. Soil profile showing ground surface cover, organic layer, and mineral soil. Layer names are shown on the right. Three mineral soil horizons are shown in this illustration; however, in the interest of time and relevance, only the layers in the uppermost 30 cm of the profile would be described in accordance with this SOP.

IV. Depth to hard surface

1. Identify and record depth to hard surface adjacent to all four 30 m × 30 m plot corners. Probe to the hard surface using a 3-mm to 5-mm diameter, 1-m metal rod inserted several times at each plot corner.
   i. **Maximum depth** – Record maximum depth (cm) to hard surface
   ii. **Hard surface code** – Record composition of hard surface (Table 9.10). Rock fragments are identified by sharp, high-pitched vibrations/sound and depths are typically variable. Frozen ground is identified by a dull, low-pitched vibration/sound. Ice crystals may be present at tip of rod when extracted. Depths to frozen ground are typically more regular than depth to rock fragments.

Table 9.10. Hard surface codes:

code	Composition of hard surface
R	Rock Fragment
B	Bedrock
F	Frozen Ground

V. Temperature sensor installation

1. A temperature sensor will be installed at a subset of readily accessible, permanent plots to monitor soil temperature (based on rank in the GRTS selection).
2. The sensor should be programmed to collect hourly temperature observations following the manufacturer's instructions.
3. Deploy sensor approximately 1 m due west of the plot monument at a depth of 10 cm (measured from the base of vegetation). Tie a piece of flagging to the sensor to aid in

relocation; flagging should be long enough to reach to the soil surface. The sensor should make contact with the soil at 10 cm depth (no air pockets), and the intact vegetation and soil plug should be replaced over the top of the sensor and pressed firmly into place.

4. Record the sensor make, model and serial number. As of 2009, HOBO Pro v1 loggers (http://www.onsetcomp.com/) were being used (temperature range: -20 to 70 °C; precision: ± 0.2 °C), and were installed with the long axis parallel to the soil surface (horizontally). Record the date and time the temperature sensor was deployed. Record the sensor location using a GPS with sub-meter precision (e.g., Trimble GeoXT), and describe its exact location (e.g., 1 m from plot monument at 275°).
5. If the sensor is downloaded or removed during a revisit, record the date and time of data retrieval or removal. Sensors will be downloaded every 1-2 years. Data management and data processing guidelines for continuous (logger) data are outlined in SOP 12.

VI. Equipment

- Measuring tape and small ruler
- Soils data sheet and data tables
- Soil probe (1 m, 0.5 cm diameter)
- Trowel or hori-hori
- Temperature sensor (pre-programmed; optional)
- Digital camera
- Sample bags (e.g., quart Ziplocs)

Vegetation Monitoring Protocol for the Southwest Alaska Network (SWAN)

Standard Operating Procedure (SOP) # 10

Measurement of Coarse Woody Material

Version 1.0 (December 2008)

Revision History Log:

Version No.	Revision Date	Author	Changes Made	Reason for Change

This SOP outlines procedures for estimating coarse woody material (CWM) along 30 m transects. Methods are adapted from Woodward et al. (2009) and USFS Forest Inventory and Analysis field procedures for Alaska (FIA 2003). Estimation of CWD loads follows equations outlined in Van Wagner (1968) and Brown (1974).

Procedures – General:

Down woody components measured in this study will be limited to coarse woody debris (CWD), fine woody debris (FWD), duff and litter, and will be measured at a selected subset of forested sites. CWM is sampled using the line intersect sampling method (also called planar intersect method). In this method, transects are established, and individual pieces of CWD or FWD are tallied if the central axis of the piece is intersected by the transect.

I. Definitions

CWD

In this inventory, CWD includes downed, dead tree and shrub boles, large limbs, and other woody pieces that are severed from their original source of growth and lying on the ground. CWD also includes dead trees (either self-supported by roots, severed from roots, or uprooted) leaning > 45 degrees from vertical. For multi-stemmed trees, only tally stems that are dead, detached, and on the ground, or dead and leaning > 45 ^{o} from vertical.

Table 10.1. Coarse woody debris (CWD) requirements for tallying a piece that intersects the transect.

CWD Type	Lean	Diameter	length
Decay Class 1-4	> 45 ^{o} from vert	$\geq$ 7.5 cm	$\geq$ 1 m long
Decay Class 5	> 45 ^{o} from vert	$\geq$ 12.5 cm and $\geq$ 12.5 cm high	$\geq$ 1 m long
Dead tree	> 45 ^{o} from vert	$\geq$ 7.5 cm	$\geq$ 1 m long

CWD does **not** include:

- Woody pieces < 7.5 cm in diameter at the point of intersection with the transect.
- Dead trees leaning 0 to 45 degrees from vertical.
- Dead shrubs, self supported by their roots.
- Trees showing any sign of life.
- Stumps that are rooted in the ground (i.e. not uprooted). Thus, using this method, stumps < dbh are not recorded in the tree tally or the DWM survey.
- Dead foliage, bark or other non-woody pieces that are not an integral part of a bole or limb (bark attached to a portion of a piece is an integral part).
- Roots or main bole below the root collar

FWD

In this inventory, FWD includes downed, dead branches, twigs, and small tree or shrub boles that are not attached to a living or standing dead source. FWD can be connected to a larger branch, as long as this branch is on the ground and not connected to a standing dead or live tree. Only the woody branches, twigs and fragments that intersect a transect are counted. FWD can be connected to a down, dead tree bole or down, dead shrub. FWD can be twigs from shrubs and vines. FWD must be no higher than 6 feet above the ground to be counted. Further subdivisions of FWD are outlined in Table 10.2.

Table 10.2. Fine woody debris (FWD) size class, and transect length and measurement location

Category of FWD	Size Class	Diameter range	Transect length (slope distance)	Transect location (slope distance)
Small FWD	1	0.3 cm to 0.6 cm	2 m	5 m to 7 m
Medium FWD	2	>0.6 cm to 2.5 cm	2 m	5 m to 7 m
Large FWD	3	>2.5 cm to 7.5 cm	3 m	5 m to 8 m

FWD does **not** include:

- Woody pieces ≥ 7.5 cm diameter at the point of intersection with the transect.
- Dead branches connected to a live tree or shrub, or to a standing dead tree or shrub.
- Dead foliage (i.e. pine or fir needles, or leaf petioles).
- Bark fragments or other non-woody pieces that are not an integral part of a branch, twig, or small bole.
- Small pieces of decomposed wood (i.e. chunks of cubical rot).

II. Locating and establishing line transects

Transects (30 m) are established as outlined in SOP 2. LWD tallies are conducted after point-intercept and nested frequency plots have been sampled. Formulas used to estimate biomass from the data contain an adjustment for slope. It is helpful to have a size gauge available until your eye is 'trained' to recognize the 3 size classes. Examples include a plastic or cardboard card with 3 notches cut for each size class, or a set of 3 dowels representing each size class.

III. Sampling methods for coarse woody debris

1. Coarse woody debris (CWD) is sampled if the central longitudinal axis intersects the transect.

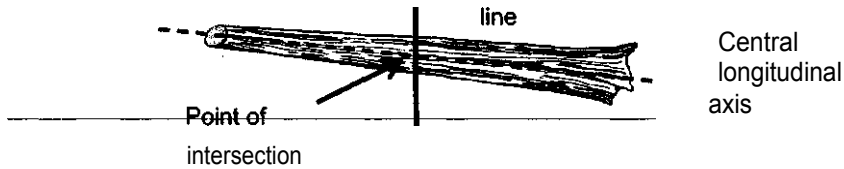


Figure 10.1. CWD tallied when central longitudinal axis intersects the transect.

2. Tally dead trees IF they are leaning > 45 degrees from vertical. Do not tally live trees or standing dead trees and stumps that are still upright and leaning < 45 degrees from vertical. Most CWD will be lying on the ground.
3. The minimum length of any tally piece is 1 meter. When CWD pieces are close to 1 meter, measure the length to the nearest 1 cm to determine if it is ≥ 1 meter.
4. Decay class (Table 10.3) of the piece determines whether or not the piece is tallied.

For decay classes 1 to 4: Tally pieces ≥ 7.5 cm in diameter at the point of intersection with the transect. The piece must be ≥ 1 meter in length and ≥ 7.5 cm or more in diameter along that length (Fig. 10.2).

For decay class 5: Tally pieces ≥ 12.5 cm in diameter at the point of intersection and ≥ 12.5 cm high from the ground. The piece must be ≥ 1 meter in length and ≥ 12.5 cm or more in diameter along that length. The reason for treating decay class 5 pieces differently is that they are difficult to identify, especially when heavily decomposed. Only pieces that still have some shape and log form are tallied; humps of decomposed wood that are becoming part of the duff layer are not tallied. Do not record diameter at the small end and diameter at the large end for decay class 5.

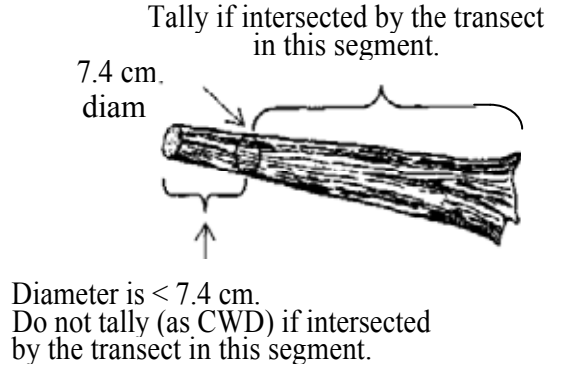


Figure 10.2. Tallying CWD for Decay Classes 1-4

5. Tally pieces created by natural causes or human activities (such as cutting) if it has not been piled. Pieces that are part of a windrow or log jumble at the bottom of a steep-sided ravine in which individual pieces are impractical to tally separately, shall be estimated and noted as an estimate.
6. Tally a piece only if the point of intersection occurs above the ground. If one end of a piece is buried in the soil, the piece ends at the point where it is no longer visible. Measure the diameter and length at this point.

7. If the central longitudinal axis of a piece is intersected by two transect lines, tally the piece each time it is intersected (uncommon situation; Fig. 10.3).

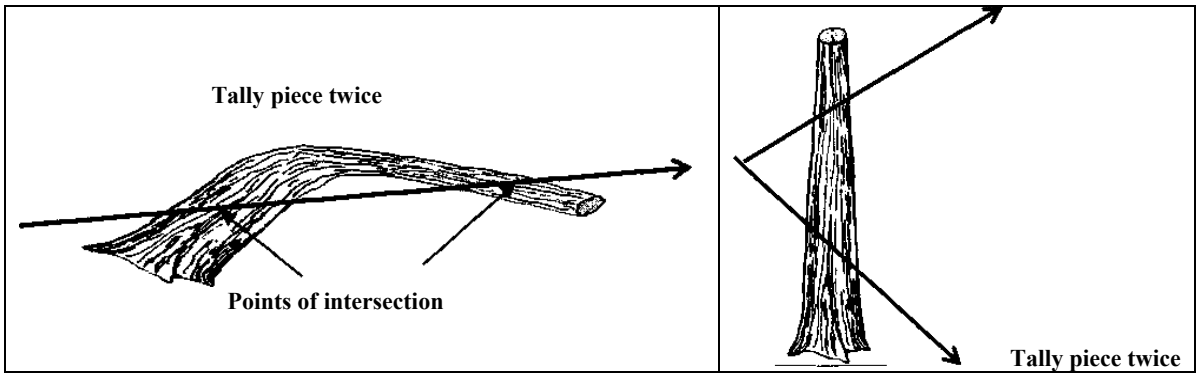


Figure 10.3. CWD tally rules: intersections.

8. If a piece is fractured across its diameter or length, and would pull apart at the fracture if pulled from either end or sides, treat it as two separate pieces. If judged that it would not pull apart, tally as one piece. Tally only the piece intersected by the transect line.
9. Do not tally a piece if it intersects a transect on the root side of the root collar. Do not tally roots.
10. When a transect crosses a forked down tree bole or large branch connected to a down tree (Fig. 10.4), tally each qualifying piece separately. To be tallied, each individual piece must meet the minimum diameter and length requirements.
11. In the case of forked trees, consider the "main bole" to be the piece with the largest diameter at the fork. Characteristics for this fork such as length and decay class should pertain to the entire main bole. For smaller forks, or branches connected to a main bole (even if the main bole is not a tally piece) characteristics pertain only to that portion of the piece up to the point where it attaches to the main bole (Figure 10.4).

IV. Sampling methods for fine woody debris

Fine Woody Debris (FWD) is only sampled when intersected by a transect. Pieces are counted and recorded by size class (Table 10.2)
Notes:

- Only count a piece of FWD if it intersects a transect.
- Only sample FWD that intersects a transect from the ground to a height of 2 meters.
- Do not count conifer needles or non-woody parts of a tree or shrub.
- Do not count rotted pieces of a larger log.
- Individual diameters are not recorded for FWD.

Accurate counts of FWD can be conducted efficiently up to about 50 pieces for small and medium size classes, and up to 20 pieces for the large size class. After that, crews can begin estimating counts in a systematic fashion. Transects that fall on very dense FWD where counting is nearly impossible, can be sub-sampled and calculated. For example, an accurate count can be conducted on a 0.5 meter-section of the transect and then multiplied by 4 to provide an estimate for the 2 meter transect, as long as the crew feels that the remaining

transect has a similar density of FWD pieces. If a transect intersects an unusually large pile of material, crews should make their best estimate and describe the situation in the comment section.

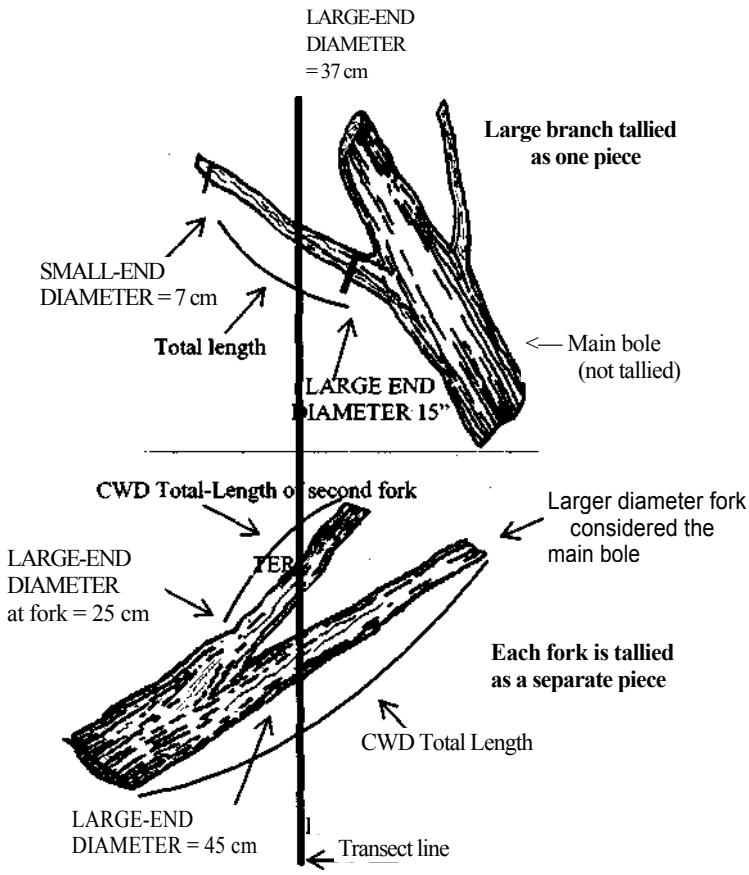


Figure 10.4. CWD tally rules for forked trees.

If rocks, logs, or other obstructions are present along a transect, include any FWD that is present on top of these obstructions in the respective FWD counts. If the obstructions are so large (huge boulder) that the top surface cannot be seen, assume the count is zero in this area, and continue counting if there is transect line beyond the boulder.

V. Sampling methods for irregularly-shaped or broken down woody material

If a transect intersects the log at the decayed or splintered end (i.e. the portion where it is not considered part of the log because it is falling apart), record the diameter at this location as the intersect diameter, but record the large end and small end diameter according to established rules (i.e. at the points where they best represent the log volume). If the splintered end appears to be two separate pieces (i.e. a major split located just at the end) treat it as one log and take a

diameter around the end (take two measurements if it is odd shaped; Fig. 10.4). Length is measured between the large and small end diameters.

Transect Diameter:
Record the diameter at the point where a transect intersects the longitudinal center of the piece. The diameter is recorded to the nearest centimeter. If the diameter is close to 7.5 cm, measure the diameter to the nearest 2-3 mm to determine if the piece is actually ≥ 7.5 cm and a valid tally piece.

Small Diameter:
Record the diameter at the small end of the piece. The diameter is recorded to the nearest centimeter. The diameter at the small end occurs either at 1) the actual end of the piece, if the end has a diameter ≥ 7.5 cm, or 2) at the point where the piece tapers down to 7.5 cm in diameter. If the end is splintered or decomposing (sloughing off), measure the diameter at the point where it best represents the overall log volume (Fig. 10.5).

Large Diameter:
Record the diameter at the large end of the piece. The diameter is recorded to the nearest centimeter. The large end will occur either at a broken or sawn end, at a fracture, or at the root collar. If the end is splintered or decomposing (sloughing off), measure the diameter at the point where it best represents the overall log volume (Fig. 10.5).

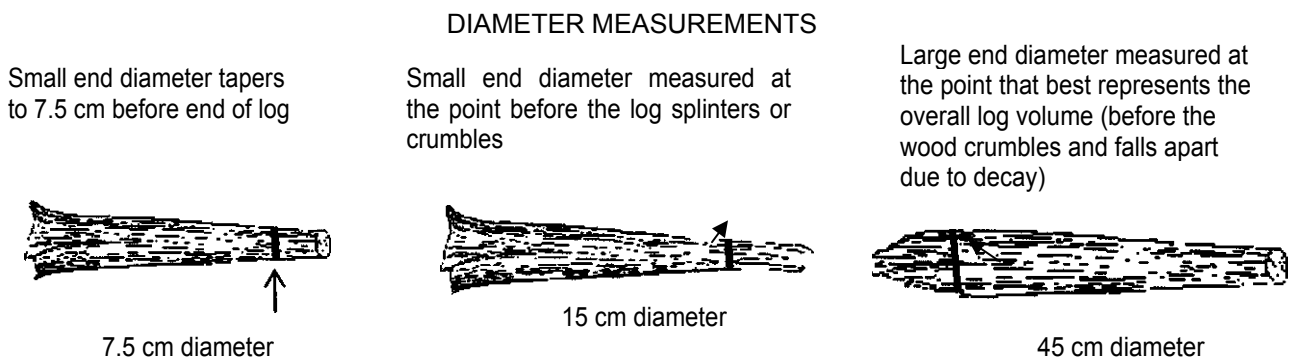


Figure 10.5. Measuring the length of a splintered log

Total Length:
Record the total length of the piece that lies between the piece's recorded small and large end diameters (Fig. 10.5). For Decay Class 5, small and large end diameters are not recorded for a log, therefore the length is measured between the two physical ends of the log. For curved logs, measure along the curve. The minimum log length is 1 meter before it is a valid tally log. CWD total length is recorded to the nearest centimeter.

Decay Class:
Record a 1-digit code indicating the decay class of the piece (Table 10.3). Code the decay class which predominates along the recorded CWD TOTAL LENGTH of the piece (Table 10.3).

Table 10.3. Log Decay Class Descriptions (developed for Douglas-fir).

Class	Bark	Structural Integrity	Texture of Rotten Portions	Color of Wood	Invading Roots & Vegetation	Branches and Twigs
1	Intact	Sound, freshly fallen, intact logs	Intact, no rot; conks of stem decay absent	Original color	Roots absent; no vegetation	If branches are present, fine twigs are still attached and have tight bark
2	Intact	Sound	Mostly intact; sapwood partly soft (starting to decay) but can't be pulled apart by hand	Original color	Roots absent; no surviving vegetation	If branches are present, many fine twigs are gone and remaining fine twigs have peeling bark
3	Sloughing	Heartwood sound; piece supports its own weight	Hard, large pieces; sapwood can be pulled apart by hand or sapwood absent	Reddish-brown or original color	Roots in sapwood only; conifer seedlings	Branch stubs will not pull out
4	Detached or absent	Heartwood rotten; piece does not support its own weight, but maintains its shape	Soft, small blocky pieces; a metal pin can be pushed into heartwood	Reddish or light brown	Roots through-out; TSHE < 15 cm dbh, small shrubs, moss	Branch stubs pull out
5	Detached or absent	None, piece no longer maintains its shape, it spreads out on ground	Soft; powdery when dry	Red-brown to dark brown	Roots through-out; TSHE to 200 cm dbh, shrubs, some large, moss	Branch stubs and pitch pockets have usually rotted down

Note: CWD decay class 5 pieces can be difficult to identify because they often blend into the duff and litter layers. They must still resemble a log, therefore, the first tally rule is that they must be > 12.5 cm in diameter, > 12.5 cm from the surface of the ground, and at least 1 meter long. Decomposed logs that are slightly elevated 'humps' on the ground are not tallied.

The chart above was developed primarily for Douglas-fir in the Pacific Northwest. At the present time, there are no other charts available to use to describe decay classes for other species or locations. Concentrate on the structural integrity and texture when estimating a decay class for CWD logs. Decay classes for white spruce will differ from those above.

If a log is case hardened (hard, intact outer sapwood shell) but the heartwood is rotten, code this log as a CWD decay class 2 with a hollow piece. CWD decay class 1 should be reserved for 'freshly fallen' logs that are completely intact (i.e. recent windfalls, or harvest).

Hollow pieces

Record 'Y' (yes) if the piece is hollow, or 'N' (no) if the piece is not hollow (Fig. 10.6). A piece is considered hollow if a cavity extends at least 0.6 meters along the central longitudinal axis of the piece, and the diameter of the entrance to the cavity is at least ¼ of the diameter of the piece where the entrance occurs. The entrance occurs at the point where wood is present completely around the circumference of the cavity. The length of the cavity begins at that point.

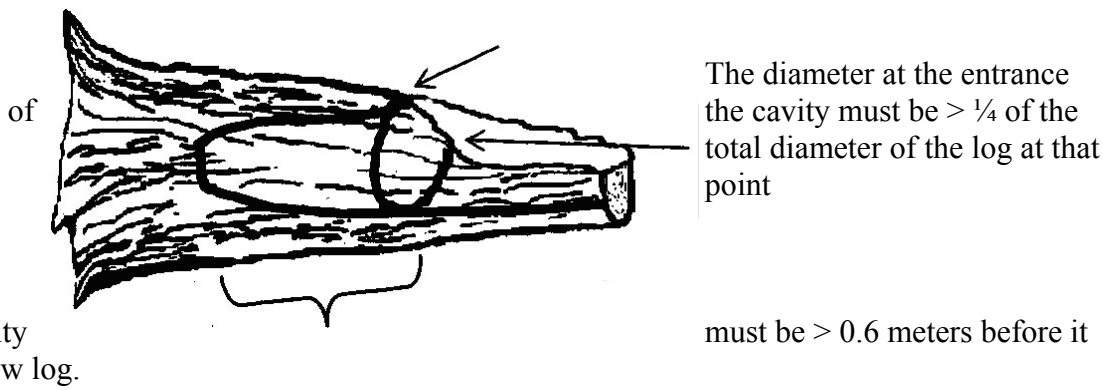


Figure 10.6. Hollow log with cavity.

Fire charred:

Record the approximate % of the log's surface that has been charred by fire. Only examine the visible surface of the log.

FWD – Fine Woody Debris:

Tally the number of pieces within each size class along each transect. Write the total count per transect in the space beside the tally. If there is no tally on a transect, enter zero's for the count. Count only what can be seen from a "bird's-eye view"; do not dig under any litter or debris to count pieces not normally seen. If a transect intersects an unusually large pile of material, crews should make their best estimate and describe the situation in the comment section.

Load calculations:

Coars woody debris (CWD) loads are quantified using the line-intersect method (Van Wagner 1968, Brown 1974), and assuming a specific gravity of 0.34 g/cm^3 for white spruce (Taylor et al. 1982):

$$\text{Volume of wood per unit area (m}^3\text{/ha)} = V = [\pi^2 \times \Sigma\,(\text{diameter (m)})^2]/[8 \times (\text{transect length (m)})]$$

$$\text{Weight per unit area (kg/ha)} = V \times \text{specific gravity (kg/m}^3\text{)}$$

IV. Literature cited

Brown, J.K. 1974. Handbook for inventorying downed woody material. USDA Forest Service Gen. Tech. Rep. No. INT-16.

Forest Inventory and Analysis (FIA). 2003. Field procedures for the coastal Alaska inventory. USDA Forest Service, Pacific Northwest Research Station, Forestry Sciences Lab, Region 10, Alaska. Anchorage, Alaska, 182 pp.

Taylor, F.W., Wang, E.I.C., Yanchuk, A., and M.M. Micko. 1982. Specific gravity and tracheid length variation of white spruce in Alberta. Canadian Journal of Forest Research 12:561-566.

Van Wagner, C.E. 1968. The line-intersect method in forest fuel sampling. Forest Science 14:20-26.

Woodward, A.E., Hutten, K.M., Boetsch, J.R., Acker, S.A., Rochefort, R.M., Bivin, M.M., and L.L. Kurth. 2009. Forest vegetation monitoring protocol for national parks in the North Coast and Cascades Network: U.S. Geological Survey Techniques and Methods 2-A8, 228 pp.

Vegetation Monitoring Protocol for the Southwest Alaska Network (SWAN)

Standard Operating Procedure (SOP) # 11

Post-field procedures – Sample processing and equipment inventory

Version 1.0 (December 2008)

Revision History Log:

Version No.	Revision Date	Author	Changes Made	Reason for Change

This SOP outlines procedures for proper processing and storage of collections, and for data entry and backups.

Procedures - General:

I. Processing of soil samples

1. Sieve and air dry soils upon return from field.

2. Store dried soils in ziploc labeled with the park, date, plot id, and plot location (lat/long).

3. At the end of the field season, mail the soil samples to the UAF soils lab in Palmer, AK, for processing. As of 2009, our contact at the Experiment Station is

Laurie Wilson
University of Alaska
Agricultural and Forestry Experiment Station
533 East Fireweed
Palmer, AK 99645
Email: pnlaw@uaa.alaska.edu
Tel: (907) 746-9482

II. Processing of vascular and nonvascular plant collections

1. Transfer vascular plant specimens into a fresh plant press if they are wet. Otherwise, specimens may remain in the press that was used in the field. Ensure that specimens inside the press dry quickly by setting the press outside on a warm, breezy day, or inside, in front of a fan. This facilitates drying, prevents mildewing, and retains the natural colors of the specimens. Nonvascular specimen envelopes constructed of acid-free cotton archive-quality paper should also be placed in a warm, well-ventilated area to facilitate quick drying and prevent mold or mildew from forming. Liverwort specimens must be refrigerated to prevent degradation of oil bodies and other sensitive structures. Specimen envelopes that have been damaged should be replaced to ensure the data recorded on them are retained.

2. Dry specimens that can be removed from the plant press will be organized by genus into folders (for vascular plant specimens) and into specimen boxes (for nonvasculars). Some liverwort taxa will need to be refrigerated rather than stored in specimen boxes. Field collection sheets and packets will be inspected to ensure that required information, including collector, collection date, collection number, and site are on the specimen.

3. Once the field season is complete, the specimens will be examined in the herbarium and identified according to the most recent accepted taxonomic keys for the project. Often, multiple keys will be helpful in determining the identity of a particular specimen. The first cut at specimen identification is performed by one or more lead technicians on the project.

4. A NPS-ANCS accession and catalog number will be assigned to each collection. All collections will be documented in a file organized by park and field season, to be submitted with the collections to the NPS curators (Table 10.1).

Table 11.1. Required fields for vascular and non-vascular collections

FIELD	DESCRIPTION
Family	Family that specimen belongs to, following USDA-NRCS PLANTS
Trinomial	Taxonomic name following USDA-NRCS nomenclature, unless otherwise specified
Associated species	For non-vascular specimens, incidental taxa that may be present in the voucher collection. For vascular specimens, list other species present in the community.
USGS quadrangle	USGS quadrangle name
Locality description	Brief description of collection site area
Microhabitat description	Brief description of microhabitat in which the collected specimen occurs
Plant description	For non-vascular specimens, noteworthy properties of the collected specimen (e.g., chemical test results for certain lichen taxa)
locality name	official name of collection site area
Plot id	Plot id
Latitude	Degrees decimal minutes, NAD 83
Longitude	Degrees decimal minutes, NAD 83
Elevation	Meters
Slope	Degrees
Aspect	Degrees (true north)
Collector	Person who collected the specimen
Collection number	Unique alpha-numeric collection identifier assigned by collector
Determined by	Name of person responsible for official determination (e.g., from ALA)
Determination date	Date of official determination
Verified by	Name of person responsible for re-verifying the official determination, if applicable
NPS accession number	For NPS-ANCS+ database/NPS archives
NPS catalog number	For NPS-ANCS+ database/NPS archives

5. Preliminary NPS identifications will be verified by botanists at the University of Alaska Museum Herbarium (ALA), or by other specialists (e.g., an authority for a particular group), as recommended by ALA. The SWAN will maintain an ongoing CESU Task Agreement with ALA for taxonomic determinations. Once determinations by ALA are complete, all specimens will be returned to SWAN and archived at NPS facilities, unless ALA requests a permanent loan. As of 2009, our contact at ALA is

   Carolyn Parker
   University of Alaska Museum of the North - Herbarium
   907 Yukon Dr.
   PO Box 756960
   Fairbanks, AK 99775
   Email: fnclp1@uaf.edu
   Tel: (907) 474-7109

6. After final determinations are received from ALA, the original field data sheets will be annotated prior to data entry. Herbarium labels will be prepared in the following format:

Plants of Denali National Park and Preserve, Alaska

EMPETRUM NIGRUM L.

Healy D-5 Quad: 63 45.463'N, 149 22.495'W Denali National Park & Preserve - ridge 2 km W of Mt. Margaret and 4 km N of Park road, approx. 5 km NW of Savage River Campground, Alaska Range, Alaska Steep, eroding, northwest-facing site on a spur ridge at the headwaters of a creek flowing into Savage Basin. Most of the area is mixed dwarf shrub (CASSIOPE TETRAGONA, DRYAS OCTOPETALA and SALIX ARCTICA) with interspersed rocky patches and a few stunted SALIX PULCHRA.

Carl Roland 5601 10 July 2002

Central Alaska Network vegetation monitoring program Acc.# DENA 00512

Primrose Ridge mini-grid pt. #16 2002 Cat. # DENA 103656

7. The project manager will maintain and update a master database with the accepted taxonomy for the project. This database will be archived each year in order to facilitate any changes in species nomenclature that may need to occur in the future. Nomenclature for this project will follow that of the *Flora of North America* and the USDA-NRCS PLANTS database.

8. Specimens will be mounted onto archival herbarium paper for vascular plants, and into acid-free archival specimen packets for nonvascular plants, and transferred to herbarium cabinets at the NPS Regional Office and/or in the affiliated park for storage. Specimen data is entered into ANCS+, the NPS cataloging database.

III. Processing Tree Cores

1. Transfer tree cores from straws to core mounts as outlined by the Grissino-Mayer lab (http://web.utk.edu/~grissino/mounts.htm; accessed 5/19/2010). Core mounts can be purchased (see URL for sources) or constructed from 9 mm × 9 mm hardwood strips.

2. Request NPS-ANCS accession and catalog numbers for the tree core collection. Label all mounted cores with accession and catalog numbers, and submit to the NPS curators along with a digital (.xls) file documenting collection information (site location, date of collection, tree species, tree age, etc.).

IV. Digital Images

1. Download, GPS PhotoLink, and archive digital images. Instructions for using GPS PhotoLink are provided at http://science.nature.nps.gov/im/units/mwr/documents/GeoTagPhotos_QStart_Handout.pdf (accessed 5/19/2010). Document photo contents in an interim .xls file (Table 10.2) and transfer data to ThumbsPlus.

Table 11.2. Required fields for interim photo log

FIELD	DESCRIPTION
Date	Date stamp on photo
Photo id	Frame no. assigned by camera software
Plot id	If applicable
Latitude	For plot photos, degrees decimal minutes of plot SW corner; NAD 83
Longitude	For plot photos, degrees decimal minutes of plot SW corner; NAD 83
Description	Description of photo contents (e.g., Transect/Quadrat No.), including direction of camera view, if applicable
Photographer	Photographer
Camera	Make/model of camera
Notes	Relevant notes, if applicable

2. Organize images in folders by plot. Panoramic photos should be saved to a separate subfolder within each image folder. Save a backup of all files to an external drive.

3. Verify that two sets of the images have been saved and then delete all images from the camera's memory card(s). Organize photo equipment for the next excursion to the field.

V. GPS data

1. Download the GPS data from the Trimble after each trip. To do this, complete the following:

    a. Place the GeoXT on the receiver cradle, which should be connected to the PC. Open Pathfinder Office and the specific folder created for the plots that were sampled.

    b. Click on *Utilities* and then *Data transfer*….

    c. Click on the *Receive* tab. Click *Add* and select *Data File*. Select the files for the site and click *Open*. Click *Add* for a second time, and select *Almanac*. Click *OK*.

    d. Click on *Transfer All*. When the transfer is complete, check to make sure the files transferred successfully to the designated folders.

2. Once the data is downloaded, post-process it. In order for post-processing to occur, the data files must have been closed on the Trimble for at least one hour. Do not delay post-processing until the end of the field season. To post-process, follow these steps:

    a. Click on *Utilities* and then *Differential Correction.*

    b. Click *Browse* and select all of the raw (.ssf) files that you just downloaded.

    c. Click on *Internet Search,* then *New*, and then select to copy a list from the internet. Press *Ok*.

    d. Select a base provider, usually the one closest to the field sites that is functional. Under *Provider Properties*, click on *Base Station*. Select "*use reference position from base file*". Click *OK*.

    e. Click *Ok* to perform the internet search. View *Reference Position* and click *OK*. You will be at the Differential Correction main screen. Click on *Settings*. Under *Output*, select "*Corrected Only"*. Under *Code Processing*, Select "*With Velocity Filtering*" and "*Correct Velocity Records*". Close the box.

f. Click *OK* to start the differential correction of the site data. The goal is to have 100% of the data points differentially corrected. If errors occur, try to use a different base provider. View the corrected data in Pathfinder Office. It will be located in the folder specified for the plot(s) recently sampled. The file extension for differentially corrected points is .cor.

3. Back-up a copy of the raw and the corrected files to an external drive.

4. Leave the Trimble on the cradle until it is fully charged. DO NOT delete data from the Trimble until the end of the field season, when all data have been downloaded, differentially corrected, backed up, and viewed and corrected, if necessary, in a GIS.

VI. Data sheets

1. Upon return from the field, sort the data sheets by plot, indicate 'DATA NOT COLLECTED' on any blank sheets, photocopy one complete set, and scan the originals. Originals and photocopies will be filed with the SWAN vegetation program, in Anchorage. Photocopy and scan each field notebook for reference during data entry. Scanned notes will be filed with the scanned data sheets in each plot folder.

Additional Procedures – End of Field Season:

I. Inventory field gear

1. After the field season is completed, conduct an inventory of all gear. Complete the Equipment Inventory checklist (Attachment 1). Inspect each item for any repairs or replacement parts that are needed. Record on the data sheet in the appropriate column. Specify the brand and model of each backpack and tent on the datasheet to facilitate repair.

2. Provide a list of equipment needs to the project manager so that items can be repaired or replaced before the start of the next field season.

II. Organize and store field equipment

1. After the field season is completed, clean all field gear. Wash and thoroughly dry all sleeping bags, and store them loosely in the large storage bags. Clean out all backpacks and tents and hang them out to dry thoroughly before storing them.

2. Remove any remnant gas from the camp stoves before placing them into storage.

3. Wash all bear-proof cans and dry thoroughly before storing. Thoroughly dry all water containers.

4. Remove all dried plant specimens from the presses. Loosely secure the straps so the press will not be compressed while in storage.

5. Remove all files from the Trimble and Garmin GPS units, and all images from the camera memory cards AFTER the data have been saved on at least 2 media. All sensitive and electronic equipment will be stored in Anchorage between field seasons.

Attachment 1. Equipment Inventory checklist – end of season inventory

Date: _____ Initials: _____

Equipment	Quantity	Repairs or Replacement needed? Be specific
Metal clipboards		
Hand lens		
Compass		
Clinometer		
Laser rangefinder		
Densiometer		
Bear spray		
Rite-in-the-Rain field notebooks		
Trimble GPS		
Garmin GPS		
Flagging tape		
Monument caps + fluted stakes		
Stamp kit for monument caps		
16″ wooden stakes		
6″ galvanized nails		
Hammer		
Rubber mallet		
30-m fiberglass reel tapes		
50-m fiberglass reel tapes		
Digital camera + memory cards		
Waterproof plastic case		
Memory cards (1 GB or greater)		
Dry-erase board + pens		
Waterproof plastic case		
Soft case for camera		
Case for memory cards + accessories		
16″ fine-gauge knitting needles or pins		
Transect staff with extra pins		
Metal tape measure (e.g., 2 m)		
Trowel		
Densiometer		
Laser rangefinder		
0.25m^2 quadrat frames		
PVC sections - 1m^2 and 4m^2 plot frames		
1-m soil probe		
Collection containers		
Hori-hori		
Plant presses		
DBH tapes (cm)		
18″ increment borer		
10″ increment borer		
Extra spoon extractors		
WD-40		
Plastic straws		
Lighters		
Electricians tape; duct tape		
Storage container for cores		
Pre-numbered aluminum tags + nails		

Date: _____ Initials: _____

Equipment	Quantity	Repairs or Replacement needed? Be specific
Handheld radio + batteries		
Satellite phone		
Pelican case for satellite phone		
Bear fence (poles, line, charger)		
Grass clippers		
Camp stoves – Coleman 4-burner		
Camp stoves – backpacking stove		
White gas		
Cook set(s)		
Water filter/pump(s)		
Lighters		
Large bear-proof cans		
Backpacker-sized bear-proof cans		
Cook tent (mega-mid)		
First-aid kit(s)		
5-gallon water jugs		
Large capacity backpack(s)		
Daypack(s)		
2-man tent with fly		
3-man tent with fly		
USGS quad sheets (1:63,000)		
Extra data sheets		
Extra batteries (AA, D-cell)		

Vegetation Monitoring Protocol for the Southwest Alaska Network (SWAN)

Standard Operating Procedure (SOP) # 12

Post-field procedures – Data processing for HOBO downloads

Version 1.0 (October 2009)

Revision History Log:

Version No.	Revision Date	Author	Changes Made	Reason for Change

This SOP outlines procedures for HOBO data downloads, data entry, analysis, and backups.
Authors: Jeff Shearer and Claudette Moore, SWAN freshwater ecologists
Date: December 31, 2009

Procedures - General:

This standard operating procedure describes the process for using proprietary software to download and export data collected with automated data loggers for archiving and analysis purposes. Automated data loggers record continuous observations of soil temperature (hourly) at selected vegetation monitoring plots. Disadvantages to using automated data loggers include errors in data or complete failure to record data due to improper programming and/or severe environmental conditions (e.g., extreme cold). In addition, the user must be familiar with the operation of all software needed to program the instruments and download stored data. This SOP provides step by step instructions to guide users through the process of downloading and archiving raw data following acquisition in the field.

As of December 2009, Onset HOBO® Water Temp Pro v2 data loggers and HOBOware Pro® v2.3.7 software are being used to record soil temperature in SWAN vegetation monitoring plots. Because future software upgrades may not be compatible with older file versions, all raw proprietary software data files will be archived in .csv format prior to analysis.

Data File Naming

Data processing generates multiple files of differing formats and extensions containing the same data, and proper data management will be critical to file organization during downloading, editing and archival phases. For example, soil temperature data from an Onset HOBO® Water Temp Pro v2 sensors are saved in raw data form as a *.hobo file, as a *.csv file for archival, and as a revised *.csv file after quality assurance checks on the data. Saving data files with the proper file naming convention is a critical step in the data management process. Table 12.1 provides the file naming conventions for all files generated from automated data loggers used in monitoring soil temperature. All file names should, at a minimum, contain the 9-character plot ID (park-year-elevation-plot), the date recorded or downloaded, and the data format version (e.g., raw, export, or QA/QC).

Table 12.1. File naming conventions for aquatic monitoring data collected with automated data loggers.

Parameter	Required Software	File Naming Convention	†File Name Example
Soil temperature	Onset BoxCar Pro	"park code_year_elevation_plotID+	LACL200802006 _temp_20090613raw
	Onset HOBOWare Pro	#_3-digit depth+ 'cm' _'temp'_ YYYYMMDD+format"	

†All file names must contain a 9-character plot ID code, temperature designator ('temp'), download date, and data format (raw, export, or QA/QC)

Soil Temperature Data

The objective of monitoring soil temperature is to document soil freeze-thaw dates associated with seasonal transitions, to estimate the timing of snowpack development and snowmelt, and to provide a basis for comparison among sites of different elevation and soil type. Information collected through this methodology is a time-series dataset containing date, time, and soil temperature (°C) data. Instructions below provide a step by step process for programming temperature loggers prior to deployment, recovering data files from temperature loggers and exporting data for archival.

Programming Temperature Loggers Prior to Deployment

Temperature data loggers can be programmed in the office or in the field immediately prior to deployment. Sensor specifications are presented in Table 12.2.

Table 12.2 Specifications for HOBO Water Temp Pro v2 data loggers.

Logger Type	Part Number	Operational Range	Accuracy	Waterproof Depth	Optic Reader Communication / Coupler part #
HOBO Water Temp Pro v2	H22-..1	-20° to 70° C	0.2° C over 0° to 50° C	120 m	Optic USB Base Station or Waterproof Shuttle Coupler2-C

The HOBO Water Temp Pro v2 requires an optical reader to program and download data. Onset products are not compatible with USB technology. There are two types of optical readers that can be used with the Pro v2: 1) the Optic USB Base Station, which requires a computer connection, and 2) the Waterproof Shuttle, which can be used in the field to download the HOBO remotely without a computer connection (Figure 12.1), or can be connected to the computer with a portable cable for programming and downloading. HOBOware Pro software is used to communicate with HOBO water temp Pro v2 and TidBit v2 devices, as outlined in steps 1-8 below.

Figure 12.1. Optical readers for Onset HOBO Water Temp Pro v2 and TidBit v2.

Programming steps:

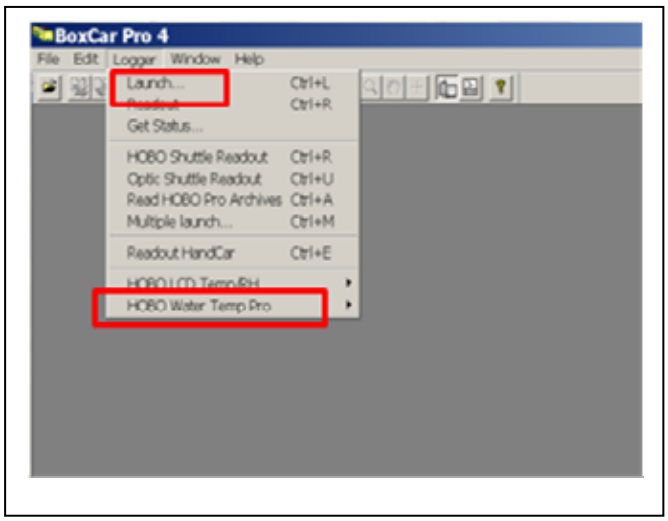
1. Open HOBOware Pro® for Water Temp Pro v2s.

2. Connect the optical reader (Figure 12.1) to the computer using the USB or serial port connections. If using a serial port, ensure that the correct Com Port is active. If you have administrative rights to your computer, you can troubleshoot problems if the correct port is not selected. If you don't have administrative rights, you will need to seek administrative support to determine which com port is in use.

3. Optical readers for the older versions of HOBO devices (Pro v1 and TidBit) require that the face of the logger be held flush to the face of the optical reader. It is not necessary to remove the Pro v1 logger from the protective rubber boot. The TidBit does not use a protective boot.

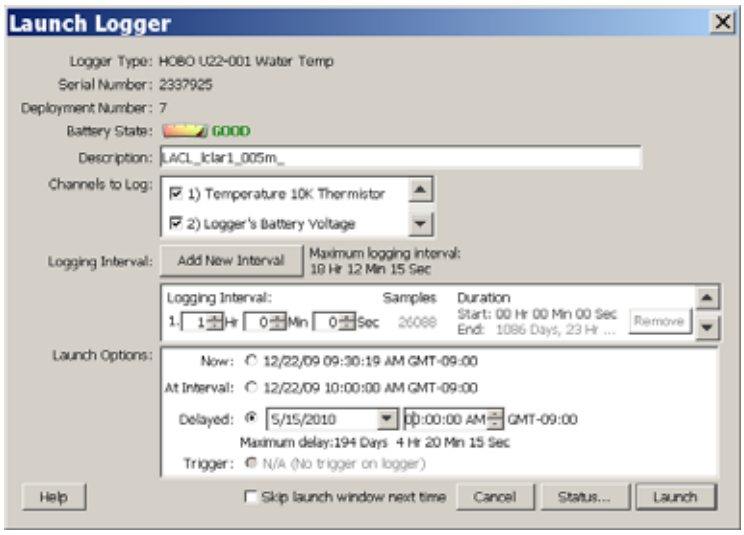
4. The newer HOBO Water Temp Pro v2 loggers fit into a coupler, and must be aligned by matching the arrows on the Pro v2 logger and the coupler. This requires that the Pro v2 loggers be removed from protective boot to fit into the coupler. Match the arrows on the logger and the coupler to ensure proper connection with the optical reader. Press the lever on the coupler to make the connection. A green light will appear if the contact is correct. If no green light appears (on the USB Base Station) or the red Fail light appears (on the Waterproof Shuttle) twist the logger in the coupler slightly and try again.

5. Using HOBOware Pro, select Device / Launch.



6. After the device is launched, a dialogue box will come up with the logger model and serial number. Click OK to select the logger. This will bring up the Launch dialogue box.

7. The dialogue box will show the battery status and the serial number. Type in the desired file name (Table 12.1). Set the logging interval to 1 hr. Be sure to check this, as new loggers are set to a default of 1 min. Select the launch option based on when the logger will be deployed. Generally, a delayed start date and a start time of 00:00 am is programmed.



8. Click Launch when all the programming information is complete. Remove the logger from the coupler. Continue programming loggers until all loggers are programmed. Close the program when finished. Use a permanent marker to mark the depths on newly deployed loggers so that they can be placed at the correct depths. Store the loggers in the rubber boot with cap. The loggers can also be deployed with just a cap that fits over the face to protect it from bio-fouling. These caps are smaller than the ones that come with the protective boot.

Downloading Data from Temperature Loggers

The temperature loggers will most often be downloaded in the field and redeployed. The Water Temp Pro v2 loggers can be downloaded with a Waterproof Shuttle, which is a stand-alone optical reader and can download data and reset the logging schedule remotely, or with an Optic USB Base Station, which requires a computer connection for communication and power. The Waterproof Shuttle can also be connected to the computer and will function like the USB Base Station reader. The steps below present the two methods used to download data from the temperature loggers.

If the loggers are to be downloaded and redeployed in the field, create a folder in My Documents to store the raw data files. Name the parent folder with the 9-character site ID. Name the child folder with the download data (e.g., \lclar01\20100612).

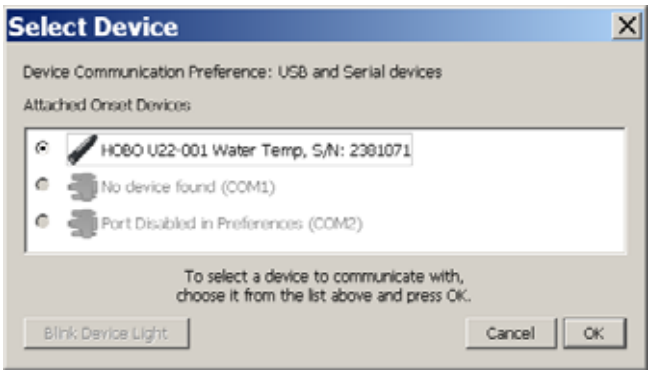
Be sure to have extra temperature loggers packed with the field gear in case a logger is missing or communication can not be established. Also, include the correct couplers for the Water Temp Prov2 (Coupler2-C with blue label).

Optic USB Base Station Reader

1. Connect the Optic USB Base Station reader to the computer via an open USB port and open HOBOware Pro.

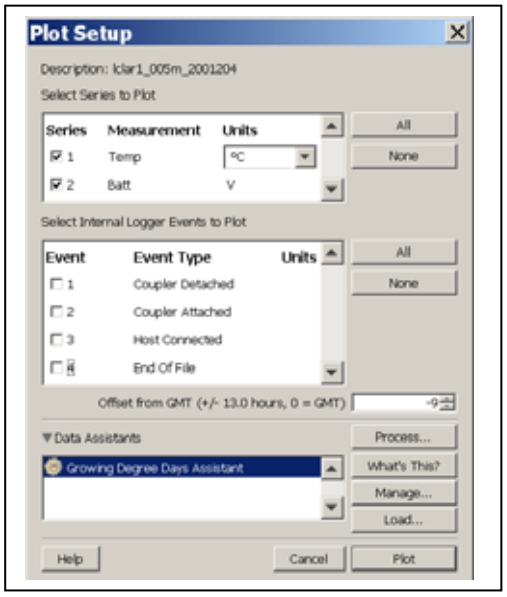
2. If the logger is housed in a protective boot, remove it and clean any residue from the face of the logger. Place it into the coupler – be sure to align the arrows on the logger and the coupler. Press the lever and look for the green light to single a connection.

3. Select Device / Readout. The logger will be identified by its serial number. Click OK to select the logger. Click no when prompted to stop logging. This will allow the logging to continue on the schedule previously programmed.



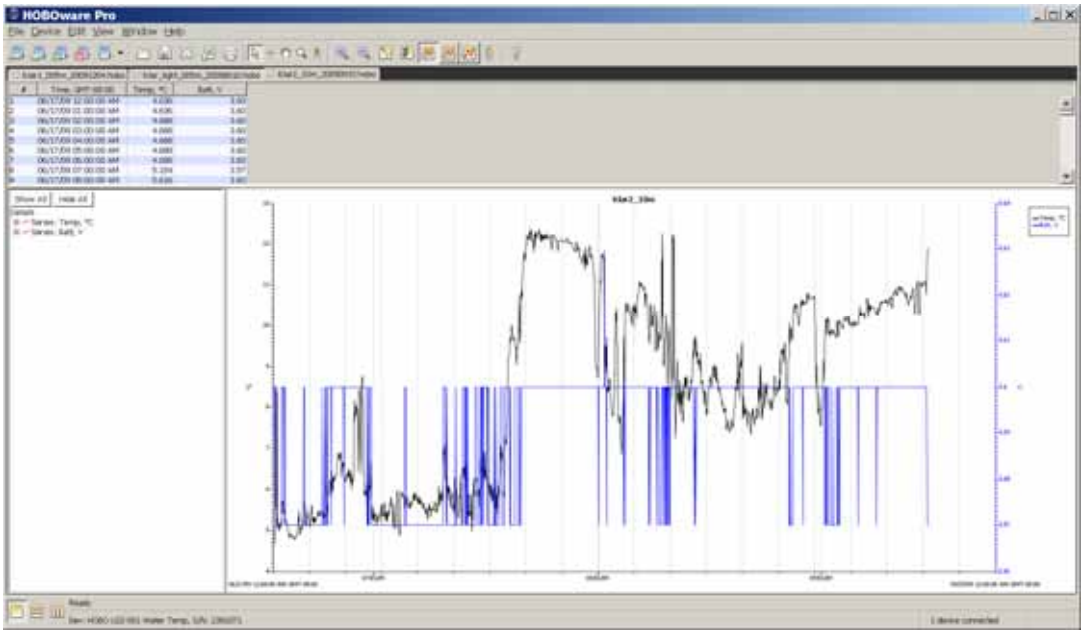
Note: If using BoxCarPro software to download a Pro v1, select Logger / HOBO Water Temp Pro / Readout. If downloading a TidBit v1 select Logger / Readout.

4. If data are downloaded in the field, save the *.hobo (HOBOware Pro) or *.dtf (Boxcar Pro) files to the directory created on the field laptop as noted above (\lclar01\20100612). The file name will default to the description entered when the logger was programmed (see above). Add the download date and the data type to the end of the file name using the YYYMMDD format (e.g., LACL_lclar01_005m_20091204raw). Make sure that there is a depth value included in the plot title and that it corresponds to the correct depth on the temperature array.



5. The Plot Setup window will pop up next. Plot the temperature in Celsius and include the battery voltage as this can help track potential errors in the data. Uncheck the boxes related to the Internal Logger Events. Click Plot in the lower right.

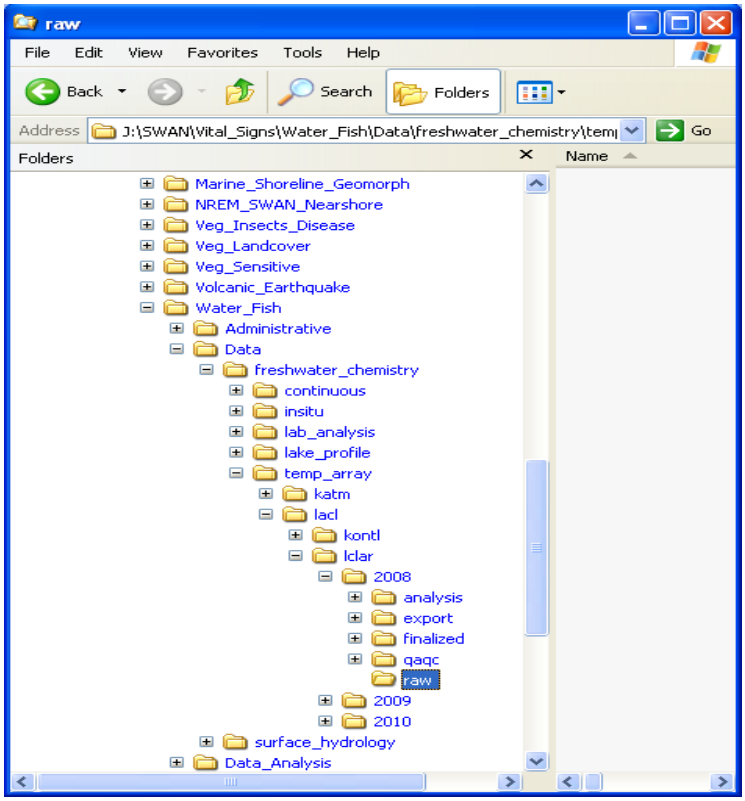
6. The data will be plotted and the tabular data will appear in the upper left part of the screen. Close the file by clicking the X in the tab with the file name.



7. Continue to download the temperature loggers from the array. If communication can not be established, replace the logger with a new logger. Program the new logger following the steps listed above. Note the serial numbers of the old and new loggers and the depth in a field notebook.

8. Try to establish communication with the logger when back in the office. If communication can not be established, send the logger(s) back to Onset for data retrieval.

9. If data are downloaded in the office, save the hobo files to the following directory: J:\SWAN\Vital_Signs\Veg_Landcover\Data\Soil_Temperature



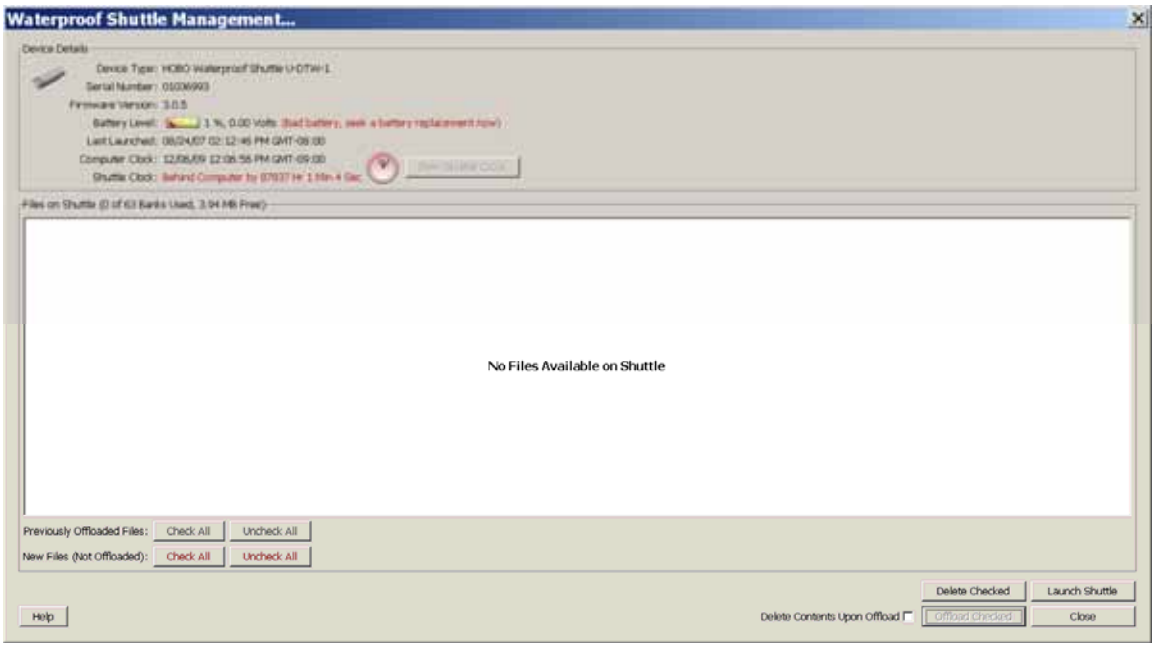
10. Save the file using the following naming convention: plot id + date [YYMMDD] of download + 'raw' (e.g., LACL_2007_02_006_090910_raw)

Optic Waterproof Shuttle Remote Download

When using a USB waterproof shuttle to download files, the temperature logger will continue to log hourly data. Logging can not be stop unless the shuttle is connected to a computer and communicating through HOBOware Pro. If the logger is operating properly, there is no need to stop and restart the logging program.

Check the battery life of the waterproof shuttle before going into the field if you plan to download the HOBO temperature loggers remotely. The shuttle is powered by two AA batteries and will not establish communication with a logger if the battery power is low. Directions for changing the batteries are located on the shuttle.

1. Open HOBOware Pro. Connect the waterproof shuttle to the computer using the portable cable. Select Device \ Manage Shuttle. The battery level is reported in this window. If the batteries need changing, you will get a warning message.



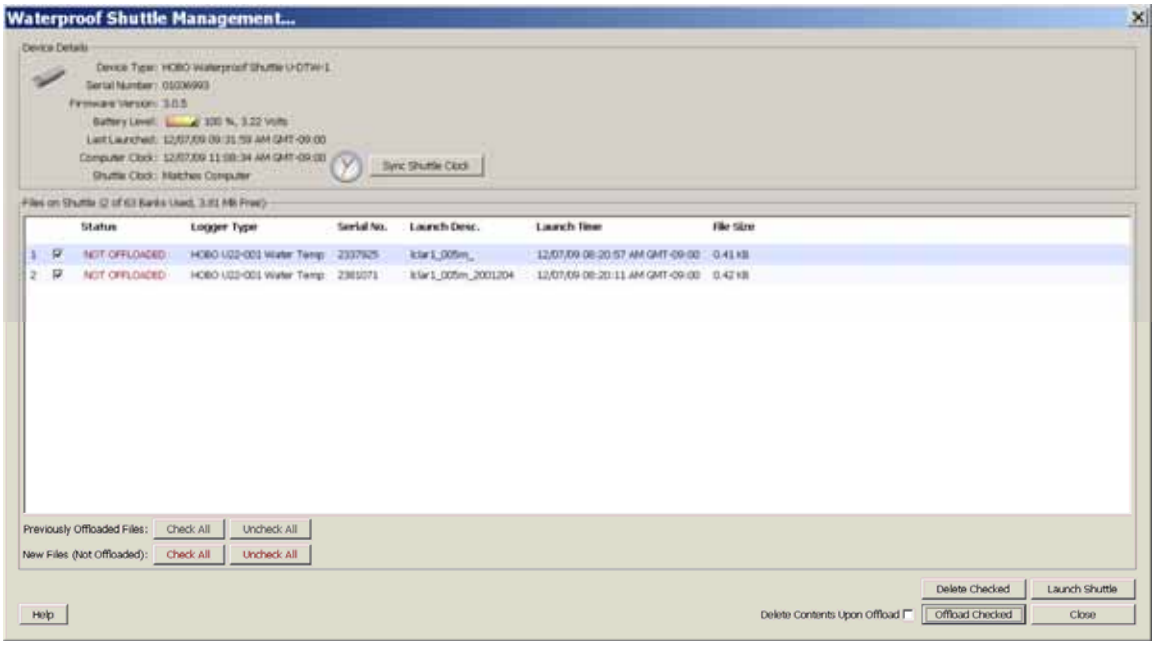
2. After the batteries are changed, the shuttle will need to be launched to set the proper data and time. Reconnect the shuttle to the computer and select Device \ Manage Shuttle. The battery level should now be reported as good. Click Launch Shuttle.

3. Be sure to pack the correct couplers for the Water Temp Prov2 (Coupler2-C with blue label) and Tidbit v2 (Coupler2-D with orange label).

4. Place the logger into the coupler, align the arrows and press the level. A yellow light will blink during the data transfer process. When the download is complete, the green OK light will be displayed until the level is pressed to turn it off.

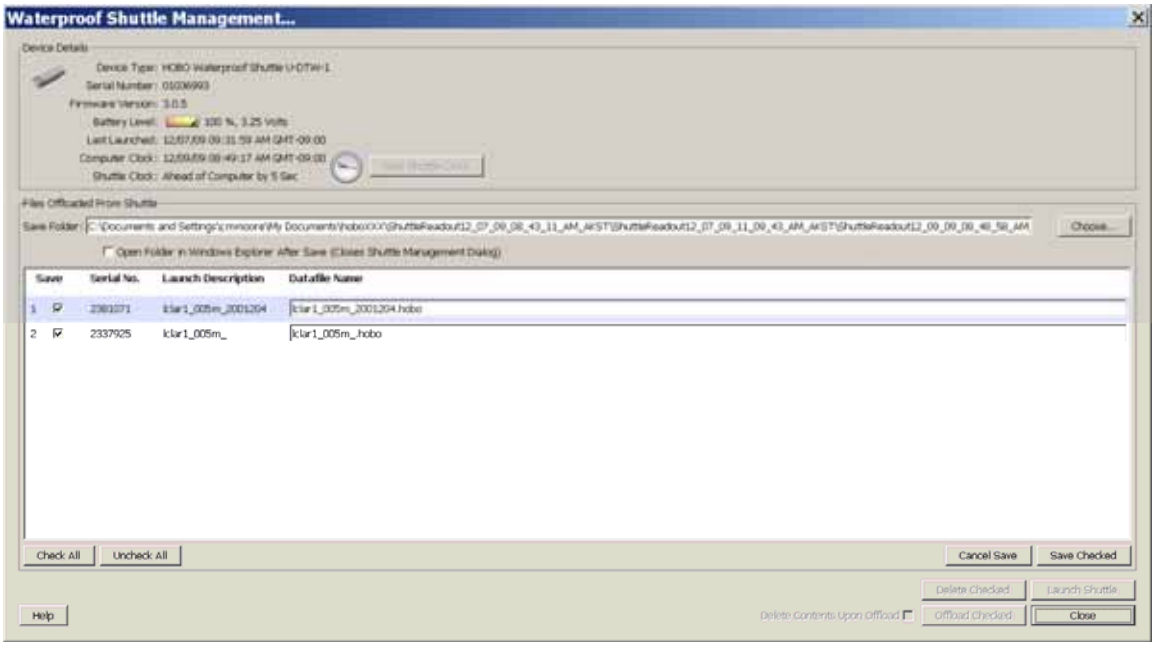
5. If the red Fail light appears, twist the logger slightly and try again. If communication can not be established, replace the logger with a new logger. Program the new logger with the correct site ID. Record the serial numbers of the old and new loggers and the soil depth in the field notebook.

6. Upon returning to base camp or the office, attach the waterproof shuttle to the computer with the remote cable. Open HOBOware Pro and select Device \ Manage Shuttle. When the shuttle is connected, the files that were downloaded in the field will be displayed in the window. The status will read "not offloaded" and the boxes will be checked



7. Click the Offload Checked button in the lower right. Do not check the *delete contents after offloaded* box in case there are problems. There is another option to delete the files once the data have been viewed.

8. The offloaded files will appear in a new screen and you will now have an option to save these files. The directory will default to the last folder in which data were saved, and a new default folder will be created (e.g.,\ShuttleReadout12_07_09_08_43_12_AM_AKST). The folder name indicates that the files were loaded from a shuttle with the current date and time relative to the time zone and standard or day light saving time.

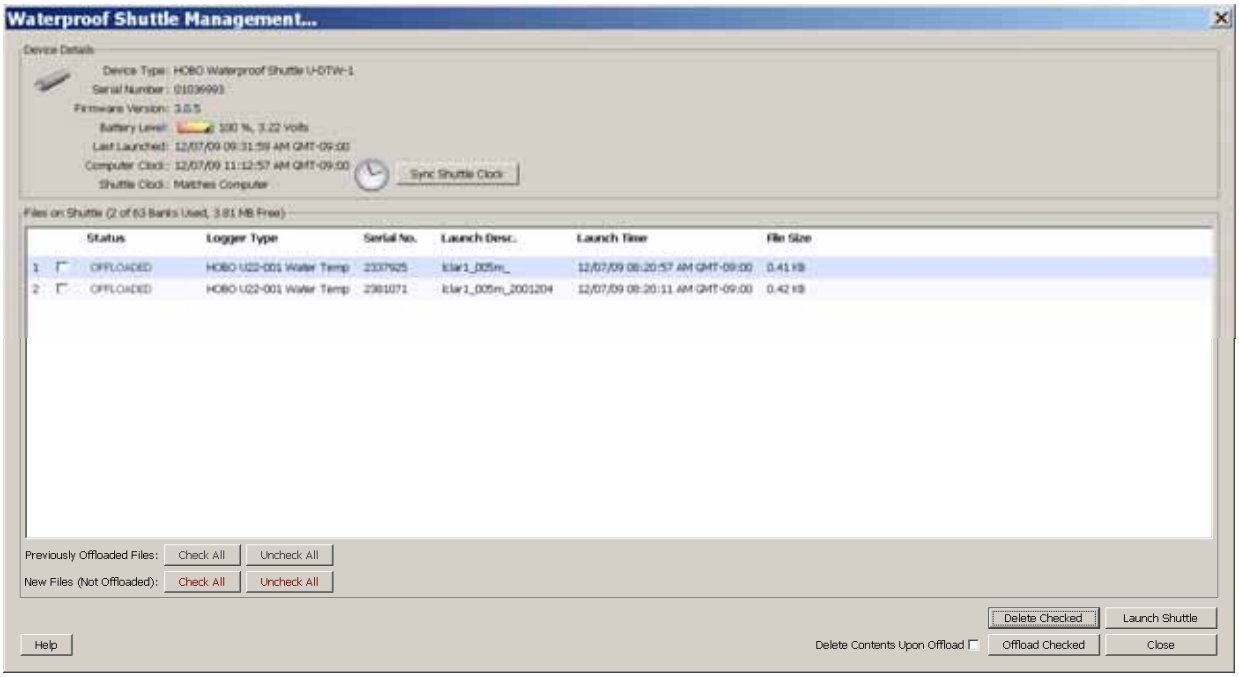


9. If you are operating in the field, browse to the temporary soil temperature folder on the laptop and save the files to that folder until the files can be moved to the J: drive. Note: if the default path is changed in the above step, the selected folder will not have the default shuttle folder name shown above. Click the Save Checked in the lower right.

10. The file name cannot be edited during this process and will have to be edited in Windows Explorer after the download process is completed.

11. Close the shuttle window and open the files that were downloaded to check for valid data. Select File \ Open DataFile and navigate to the folder where the data files were saved. Once the data files have been reviewed, close the files and return to the shuttle manager.

12. If data in the files are missing or otherwise irregular, download the files from the shuttle again. Select Device \ Shuttle Manager. When the window comes up the status will show up as "offloaded". Check the box(es) of the files to be downloaded a second time. A new default shuttle folder with the data and current time will be created. If the data still appear irregular, make a note in the field notebook to replace that logger and send it in to Onset for data retrieval.



13. To delete the files on the shuttle, select Device \ Shuttle Manager. Check the boxes by each offloaded file and then select Delete Checked in the lower right. Select 'yes' to delete the files from the shuttle. Once the files have been deleted, the files previously listed will be cleared.

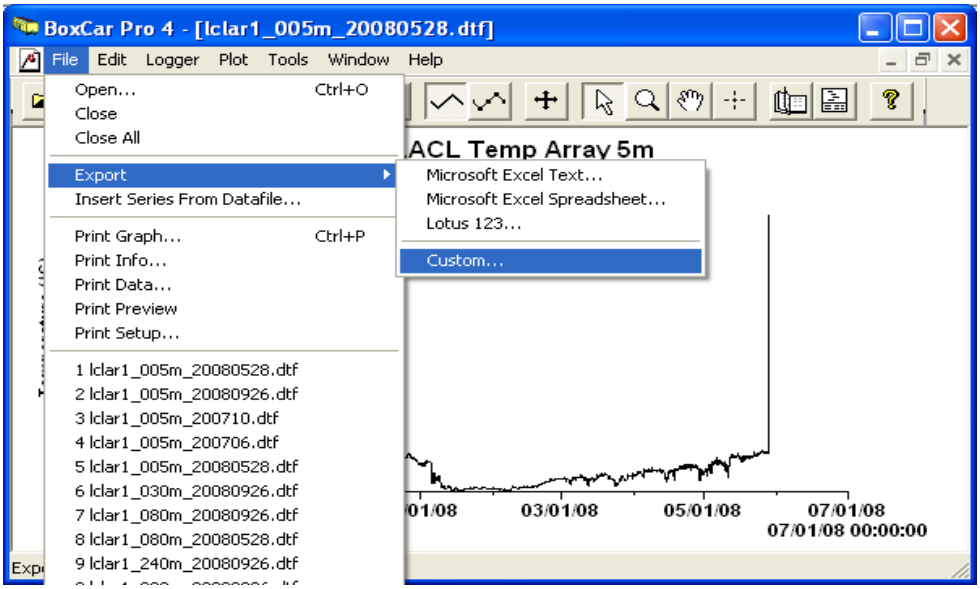
14. Open Windows Explorer and navigate to the folder in which the files were saved. Rename the files using the following naming convention: plot id + date [YYMMDD] of download + 'raw' (e.g., LACL_2007_02_006_090910_raw)

Data Export for Archival

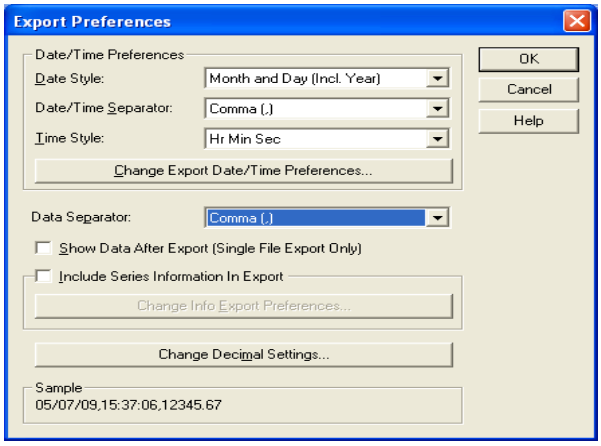
The purpose of this section is to outline the steps needed to convert proprietary software files containing raw data into a universal format for long-term data archival. These steps will ensure that datasets are available for future use, even as software expires or software upgrades prevent opening old data files. All raw proprietary software data should be exported and saved in .csv format. If .csv format is not an export option for a particular software, export the raw data in .txt format and then convert the .txt file to .csv format in MS Excel.

Steps if using BoxCar® Pro

1. Open raw data file and select File / Export / Custom.



2. In Export Custom box, select Preferences and set Date / Time Separator and Data Separator to "Comma." Select OK, then select the Export button.



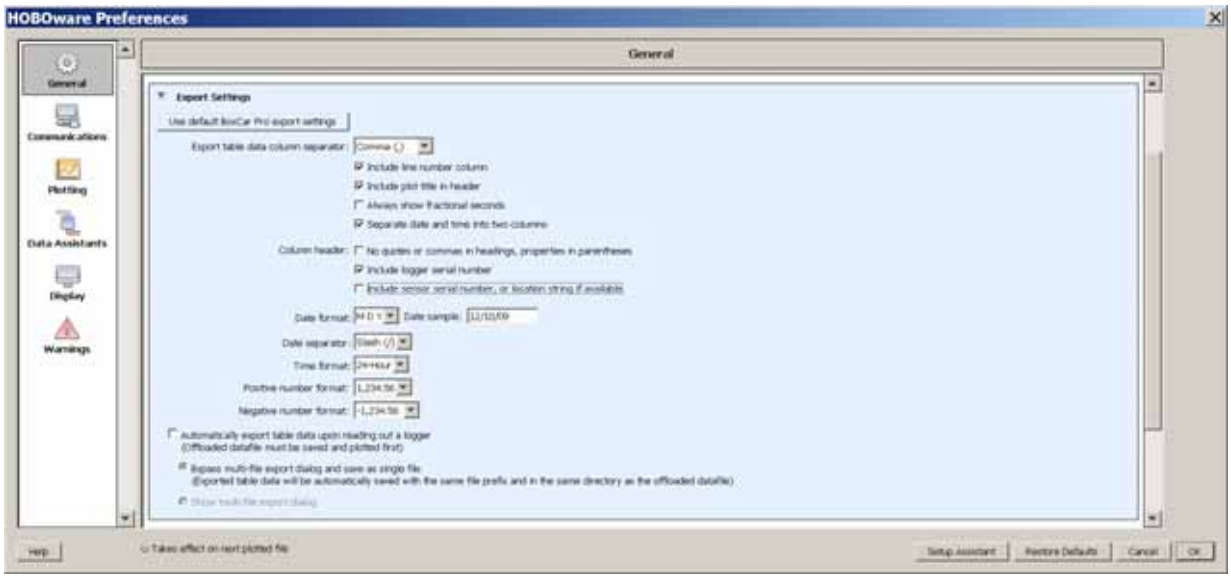
3. Save exported file as a .txt file in the following directory: J:\SWAN\Vital_Signs\Veg_Landcover\Data\Soil_Temperature. File naming convention is the same as for the raw data file.

Steps if using HOBOware® Pro

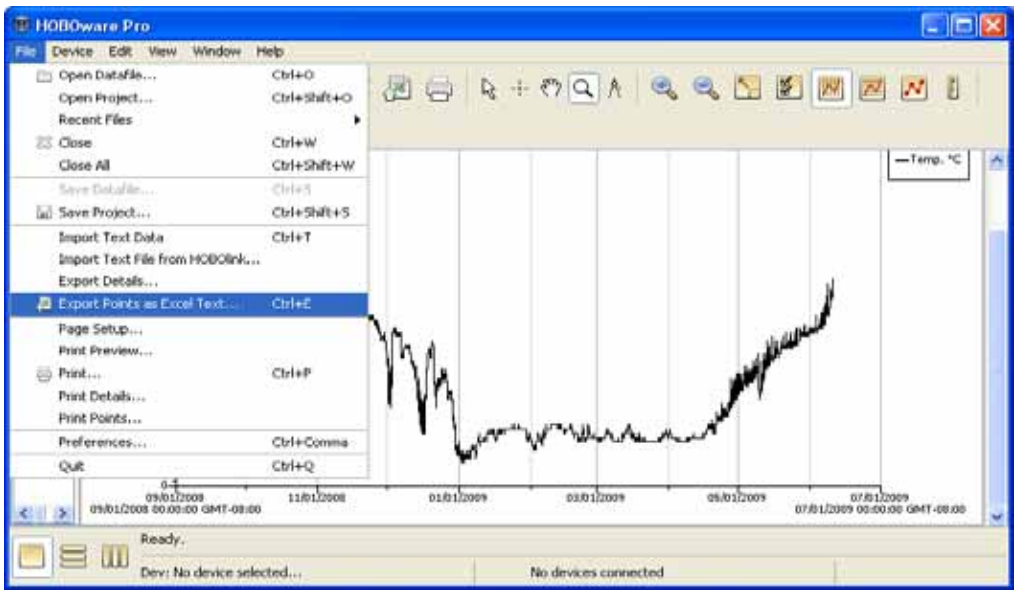
1. If the software has been newly installed or has been recently upgraded, open HOBOware Pro and verify that your export settings are set like those shown below. Select File / Preference. Select General from the left side, then expand Export Settings and set the following:

   Column separator – comma
   Check the following boxes:
   -separate data and time into two columns;
   -include logger serial number.
   Date format – M D Y
   Date separator – slash
   Time format – 24 hr

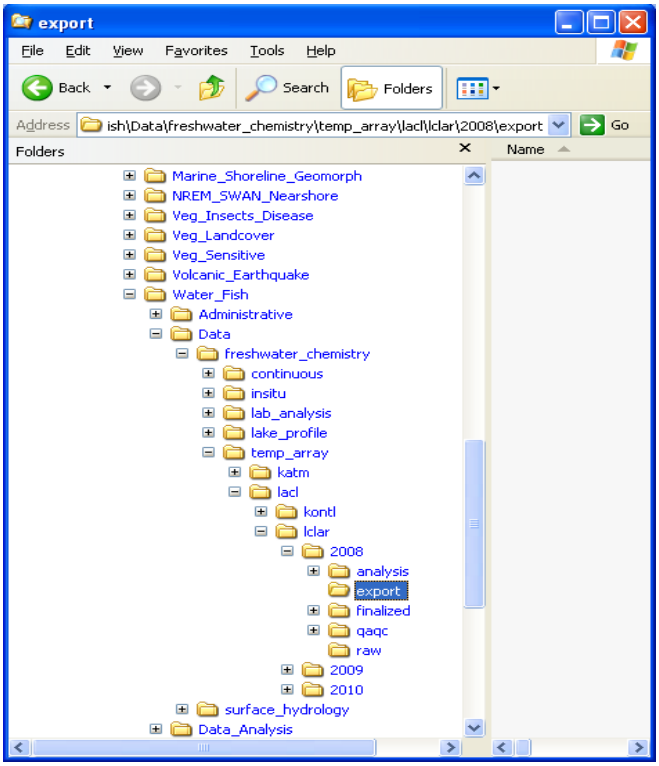
Leave the remaining defaults as set. Click OK at the bottom right and close the Export Settings, close the Preferences window.



2. Open raw data file and select File / Export Points as Excel Text/ Export to a single file. Select Export to a single file, then click the Export button.



3. Save exported file as a .csv file in the following directory: J:\SWAN\Vital_Signs\Veg_Landcover\Data\Soil_Temperature. File naming convention is the same as for the raw data file.



4. Continue to export the files following the above steps until all HOBO files have been exported to *.csv files. Close the program.

Using AQUARIUS Time Series to Process Time Series Data

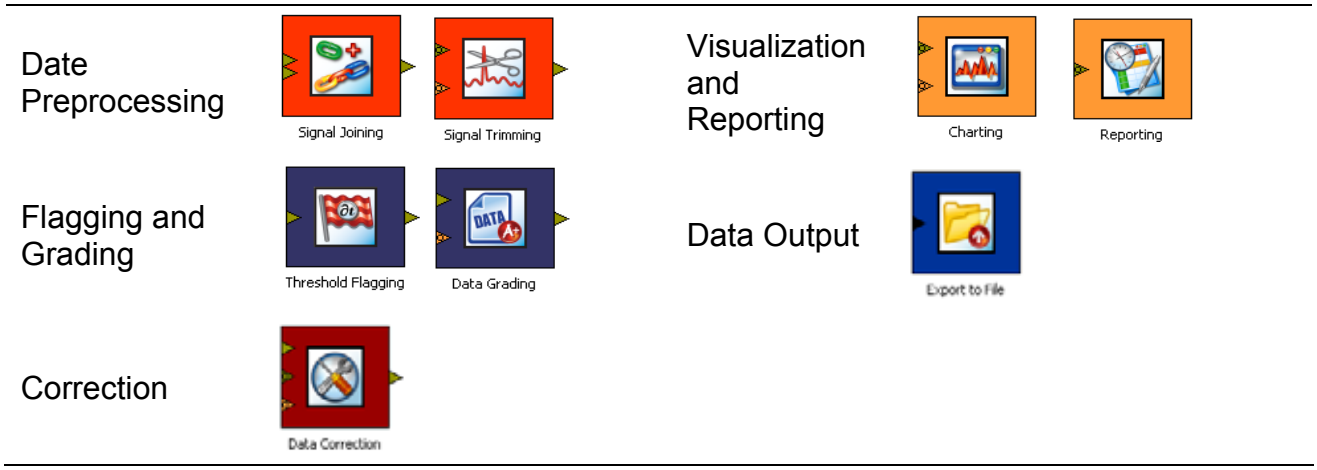
Introduction to Aquarius Time-Series Software

AQUARIUS is a software platform designed to simplify the management and analysis of time-series data. The software uses a visual environment - the Aquarius Whiteboard™ - a simplified workflow management system to process and analyze large time-series datasets. Data are processed by dragging a series of toolboxes onto the whiteboard workspace, which are then connected (wired) to each other in a variety of ways to provide a powerful yet easy to use work environment. Although examples shown are for freshwater monitoring data, continuous soil temperature data can be processed using the same methods.

Toolboxes are categorized by topic in the toolbox pane. Toolboxes are equipped with input ports located on the left side of the toolbox and output ports located on the right side of the tool box. The user should be familiar with the toolboxes listed in Figure 12.2 prior to processing SWAN time series data. Additional information on use of the software can be found in the user manual or training videos, which can be accessed online at http://www.aquaticinformatics.com/main/ or through the help menu.

Figure 12.2 Primary toolboxes used to process SWAN time series water quality data.

Toolbox Category	Frequently Used Toolboxes	Toolbox Category	Frequently Used Toolboxes
Data Input	Import from File	Math and Statistics	Descriptive Statistics Math



Another feature of the software is the way in which data processing is tracked. The software tracks all changes to the raw dataset, creates a corrected data file and stores this information in a comma delimited *.txt file that can be exported for metadata tracking purposes. This feature standardizes the way in which changes to processed data are tracked. Meta data files provide important documentation on these datasets and are required as part of the SWAN data management protocol.

This section of the SOP describes how to use AQUARIUS Time-Series to process SWAN soil temperature data collected from temperature loggers. The steps for each data type are presented separately. Prior to processing data files in AQUARIUS, we will first discuss preparation of the raw data file in comma separated value (.csv) format.

Preparing the Comma Separated Value (.csv) Files

The .csv files that were exported in the above procedures may need to be modified prior to importing into AQUARIUS. The water quality data (HOBO and YSI) files can be imported without any modifications to the .csv file. Because of the metadata header information associated with the level logger files, it is easier to modify the .csv files prior to importing them into AQUARIUS.

Processing Temperature Data

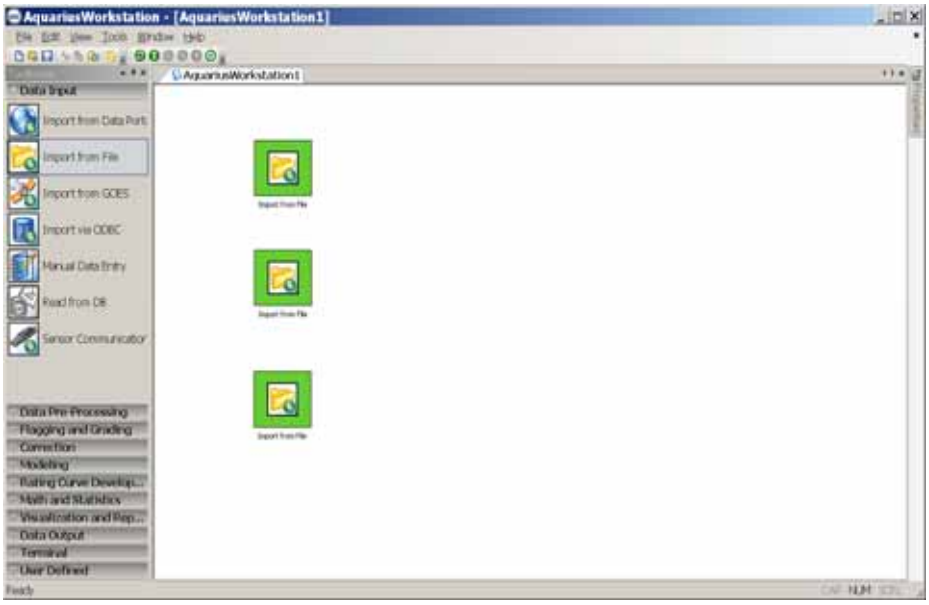
SWAN currently has twelve soil temperature loggers (HOBO Pro V2) deployed in Lake Clark (n = 2) and Katmai (n = 10). Additional deployments in both parks are expected in the coming years. Each temperature logger will have one file per year. The steps below will show how to process data for the current year (new and existing loggers) and how to append data into an existing soil temperature data set.

To simplify the file management, create a working AQUARIUS folder to manage the Aquarius files (e.g., aquarius_LACL_2009) and copy all .csv files for the AQUARIUS session into the folder. Once the final products have been completed, the files can be moved to a permanent location and the temporary folder can be deleted.

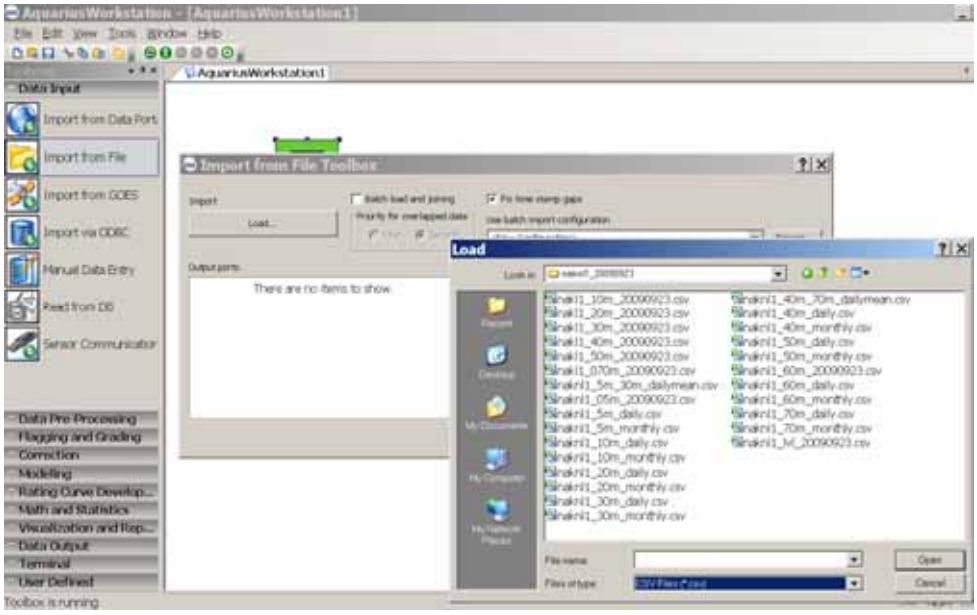
Importing Comma Separated Value (.csv) files

This process will load temperature data collected from loggers deployed year-round.

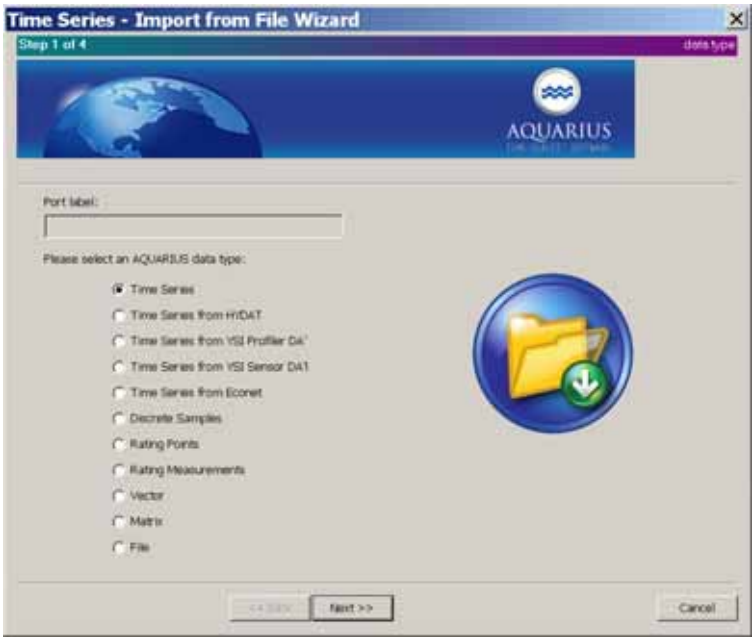
1. Open AQUARIUS and drag Import from File Toolboxes into the whiteboard.



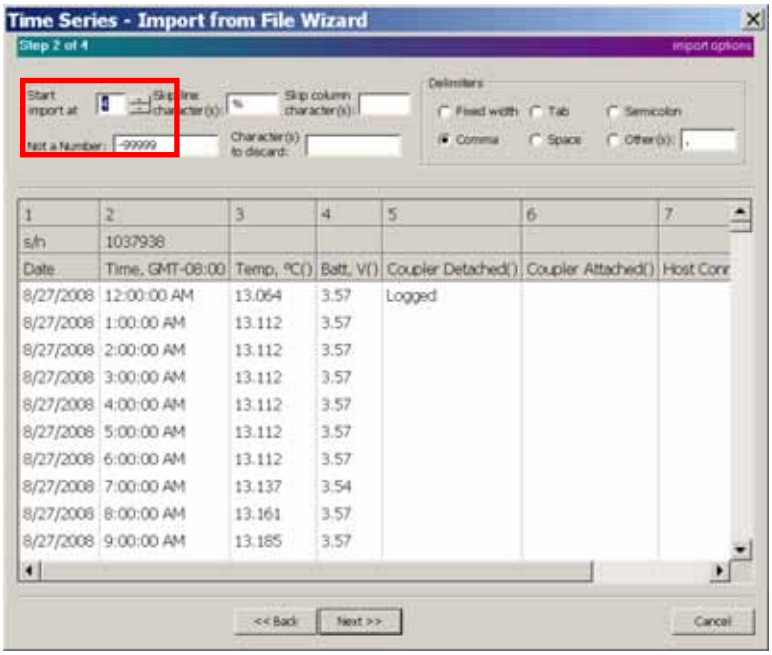
2. Double click the first toolbox to begin loading data. Click load and navigate to the working Aquarius folder. Set file type to .csv to remove other files from view.



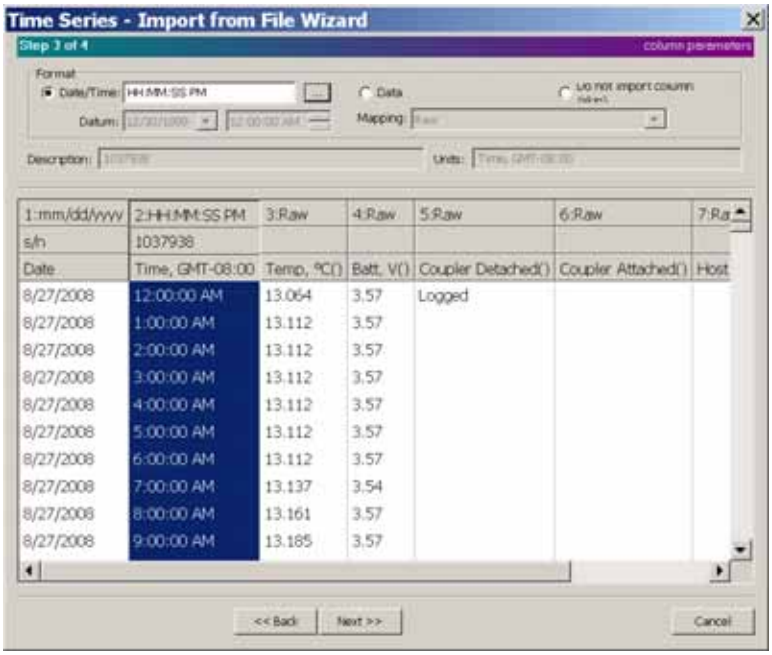
3. Select the first file to import (e.g., naknl01_005m_20090923). In the first step of the import process, the default is set to Time Series. The HOBO data files are all time series data. Click next.



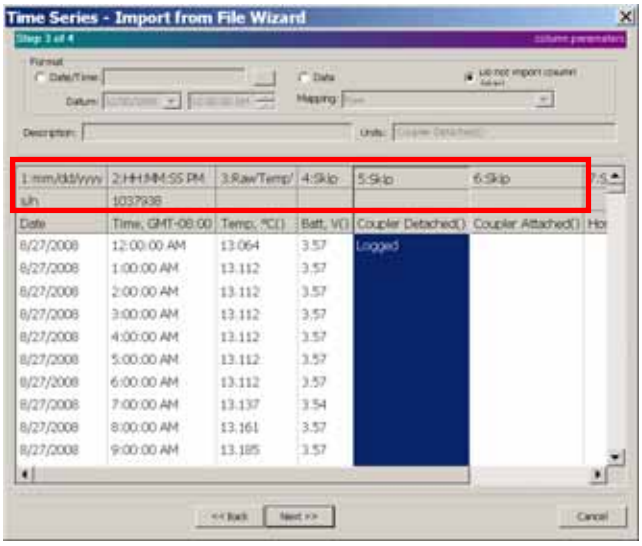
4. In step 2, the user will set the *Start import* feature. This feature sets the pointer on the first row of data to import. In the Start import box, click the up arrow to include the header columns. Click next.



5. In step 3, the user will determine which columns to import and set the format for the date and time. *Be sure to process all the columns before pressing the next button.* The first column is the date. Click the Format Date / Time radio button and type in mm/dd/yyyy. Select the time column and Click the Format Date / Time radio button and type in HH:MM:SS PM. If the time is formatted to 24 hr, enter HH:MM:SS. AQUARIUS is case-sensitive for these commands. The date is in lower case and the time is in upper case.



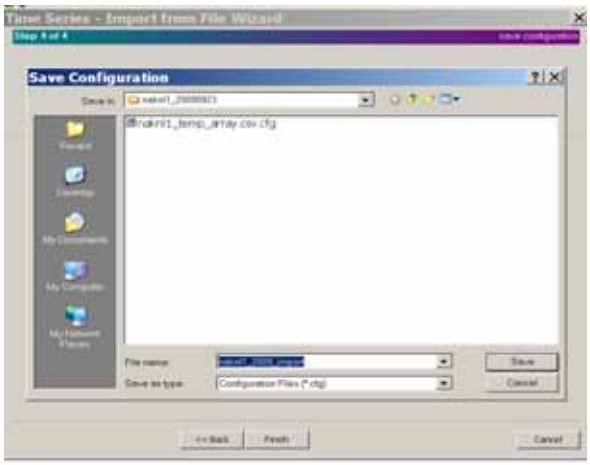
6. Select the temperature column. Notice that the Data radio button is select. Fill in the description (temperature) and units (C). Select the battery column and click the Do not Import radio button. Notice that the format and description sections become grayed out. Select any additional columns that may be part of the .csv file (coupler detached, etc.) and click the Do not Import radio button. Notice that the columns selected for import have headers, while those that weren't selected say Skip. Click next.

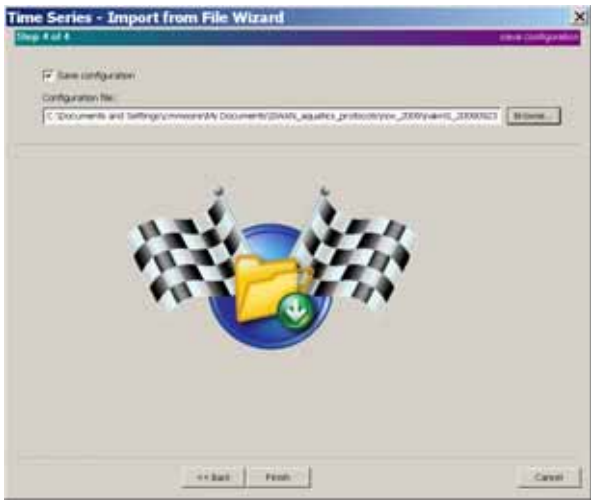


7. Step four is the final step and allows the user to save the configuration file. This is a small script that can be used to import additional .csv files with the *exact same layout*. If the .csv files differ at all, an error message will be displayed when additional file are imported. Click the save configuration box.

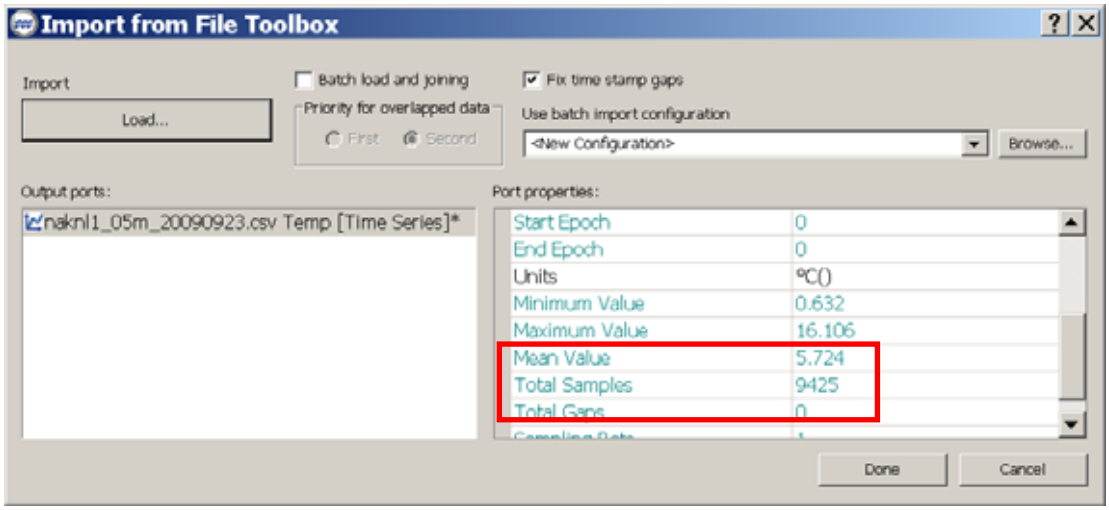
8. The .cfg file will be saved in the current working folder. Select browse and rename the configuration file as the name of the plot _ temperature_year (yyyy) _ import (e.g., LACL_2008_02_006_temperature_2009_import). Click save to close the save configuration

window. The final screen of the import wizard will show the path of the saved configuration file. Click finish to complete the import process.



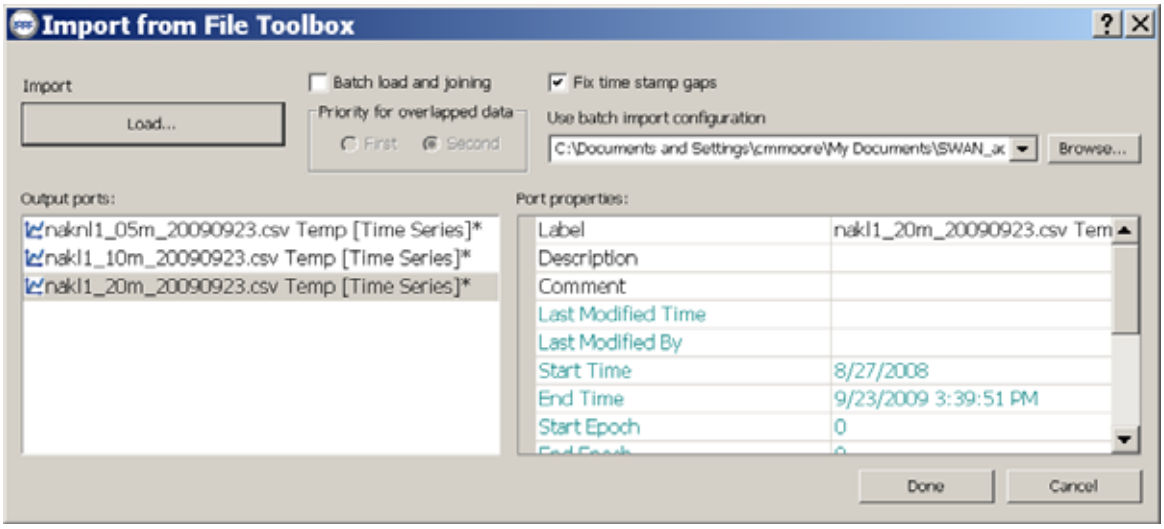


9. When the file has been loaded a new window will appear. The left side displays the name of the file that was imported and the right side provides information about the file. Scroll through the right side and view the number of records that were imported. Each file should include several thousand records. If the file did not import correctly – checking this value is the first clue.

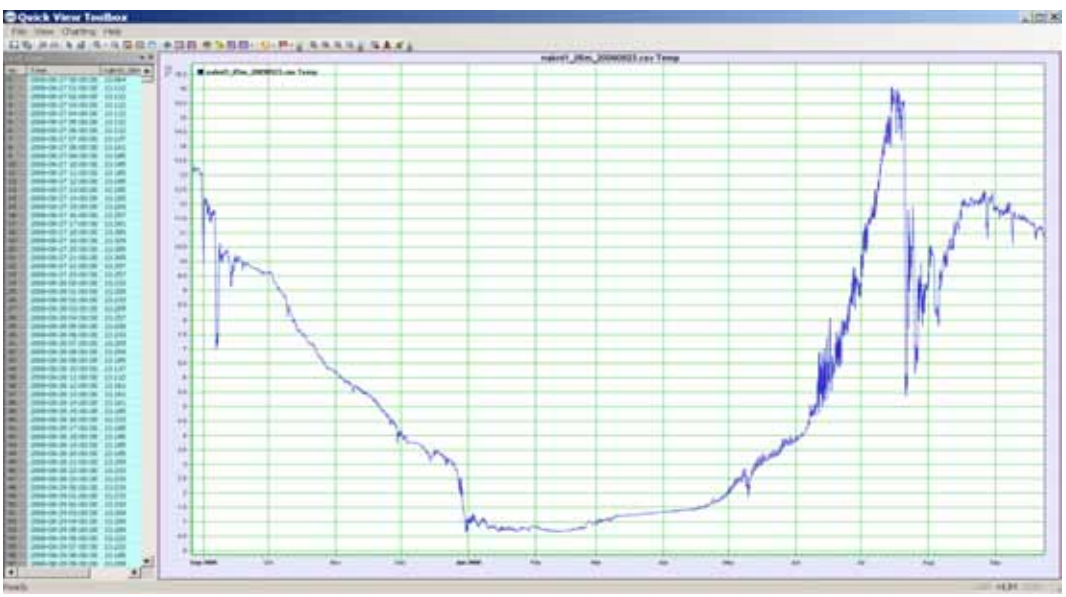


10. Continue importing the temperature files in sequence by depth, if applicable (e.g., if more than one logger was used to record temperature at different soil depths). The configuration file can now be used to import the remaining file. Select browse and navigate to the folder, select the .cfg file and click save.

11. Using the example given for lake temperature arrays, click the load button to import the 10 m depth next. The file will load automatically and appear in the left screen. Check the total samples as above. Select load and import the 20 m depth. There are now three files loaded into the Import File toolbox. They should be displayed in the left box.



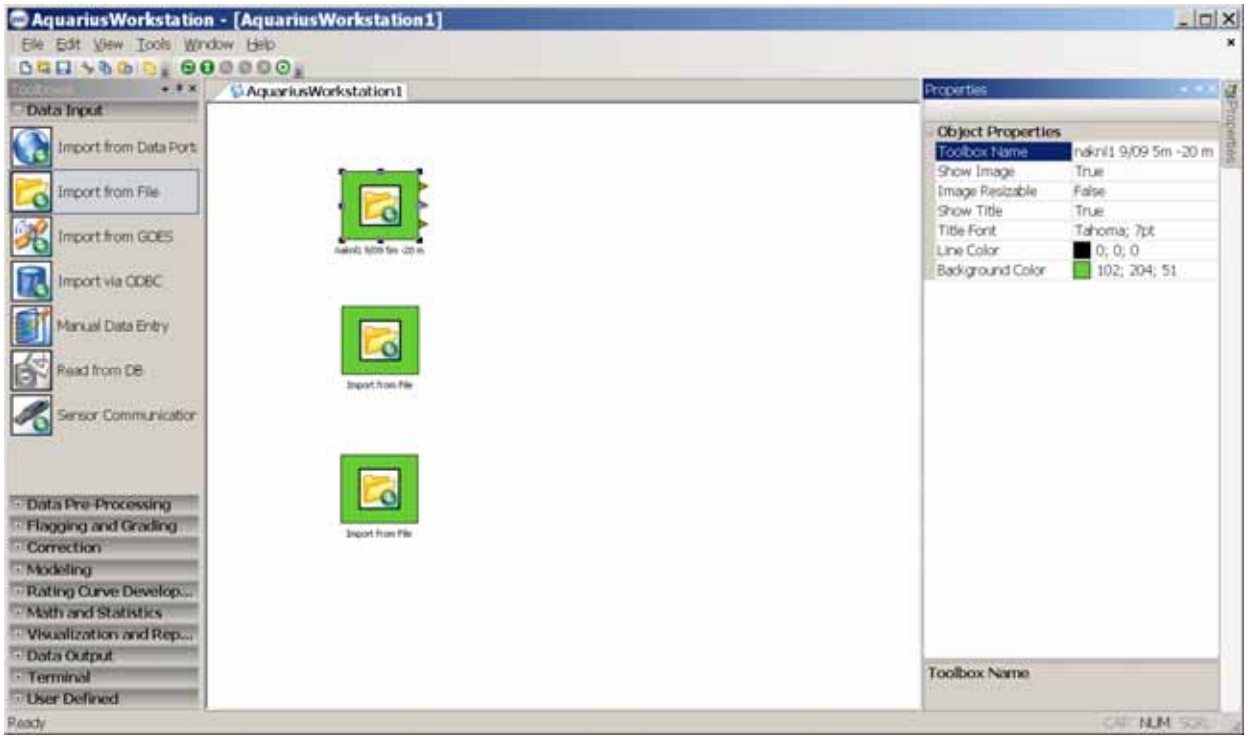
12. Click done and notice that the green box now has three active output ports on the right side. Each port corresponds to a depth data set. Select any arrow and right click to perform a quick view. The data will be displayed graphically. The tabular data appears to the left. Click the X to close the quick view image. Do not minimize the view.



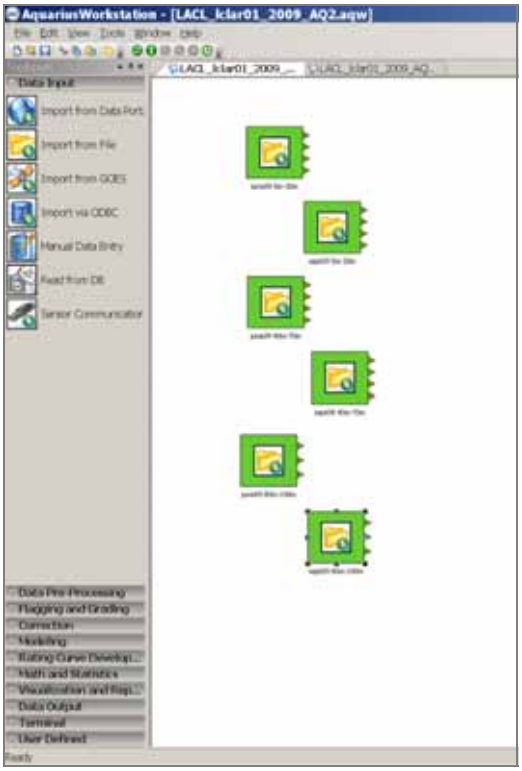
Note 1: When screen views are minimize in AQUARIUS, the program becomes inactive and it can appear that it is frozen. Check for minimized screens in the left corner if the whiteboard appears inactive.

Note 2: To help with toolbox management in complex whiteboards it is helpful to rename the toolboxes as data are imported and functions are carried out. These toolboxes can be copied and pasted into other whiteboards for additional analysis.

13. Right click on the toolbox with the loaded data and select the Properties page from the pick list. The properties box will appear. Type in the plot ID + the month and year of the offload date (mm/yy) (e.g., LACL-2007-02-006 09/09).



14. Repeat steps 1-13 to load in the remaining temperature array files for the remaining depths, if applicable. Load three to four files into each toolbox. If you are loading two files for a given year, the white board will have six Import from File toolboxes.



15. Save this whiteboard file using the following naming convention plot ID + year of download + AQ (e.g., LACL_2007-02-006_2009_AQ)

Note: If recording temperature data for multiple soil depths at a site, another helpful tip is to keep the depths in order in the toolboxes (i.e., load the depths sequentially from the surface to the bottom). If the incorrect depth is loaded into a tooxbox or the depths are out of order, files can be deleted or reordered to maintain consistency.

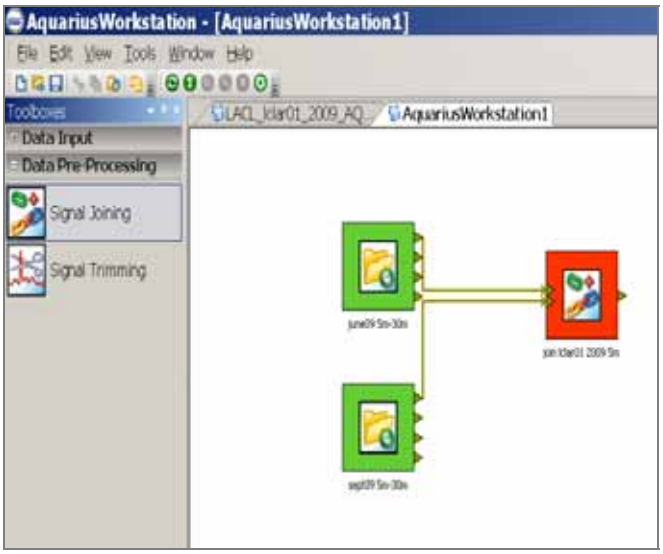
16. Double click on the toolbox to bring up the import file window. Select the file that is out of sequence. To delete the file right click and select delete. To reorder the files, select the file and move it to the proper location to reorder the depths.

Signal Joining

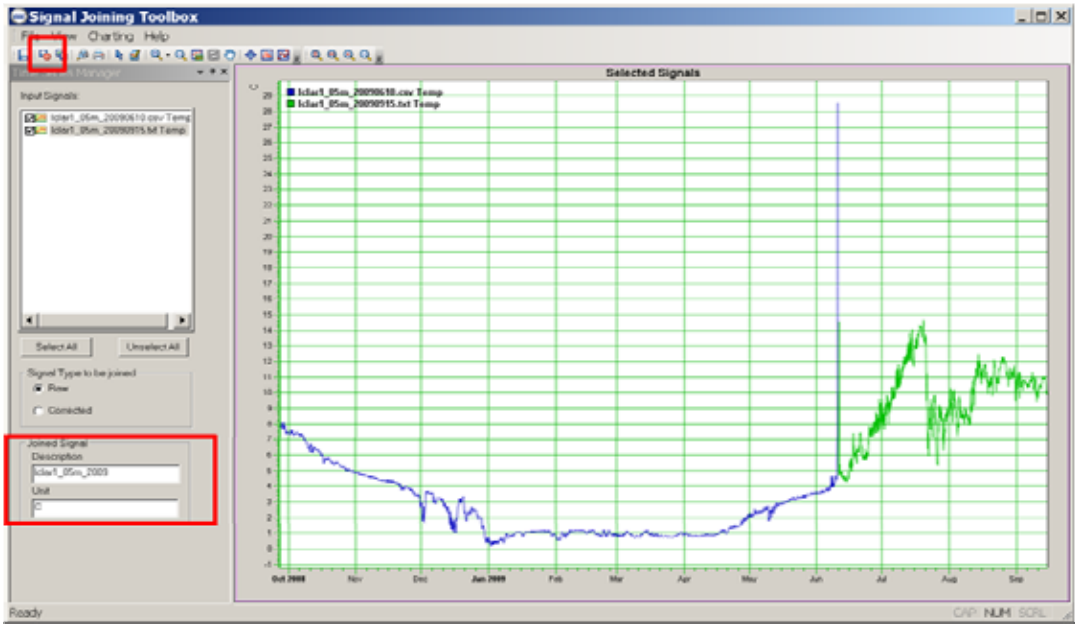
The next step is to join data signals for depths with more than one file per year (i.e. for arrays where multiple data downloads occurred within one year). ***If there is only one depth file for the year, proceed to the Data Corrections section.***

1. Select the Data Preprocessing tab and drag a Signal Joining toolbox into the whiteboard. The default toolbox has two input data ports available indicating that two files can be joined. If there are more files that need to be joined, right click the toolbox and change the value of the Input Ports Time Series to equal the number of datasets to be joined.

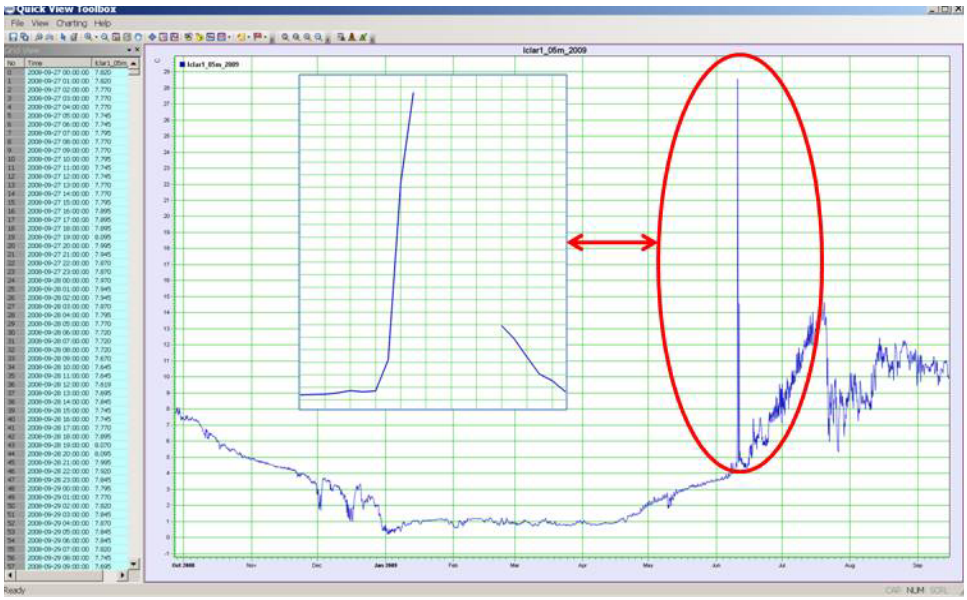
2. Using the example of the lake temperature arrays, wire the two 5 m datasets to the input port on the Signal Joining toolbox. Be sure that the data files are wire in the proper time sequence. The earliest data should always be wired to the top input port and additional datasets added sequentially. Rename the toolbox (right click and select properties pane) with the toolbox action + 5-digit waterbody code + ID + year + depth (e.g., join lclar01 2009 5m).



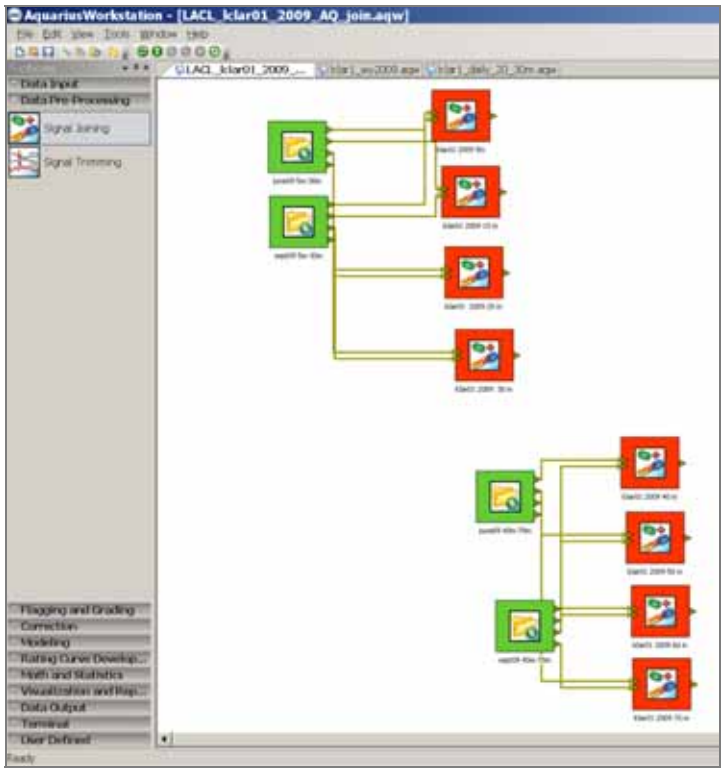
3. Double click on the Signal joining toolbox. Each dataset will appear in a different color. Update the description of the dataset in the Signal Join Description field with the water body code and site ID + depth + 2009 (e.g., lclar01_005m_2009). Click the Save Data to Output Port and Exit icon.



4. Once the join function has been run, the output port will become active. Right click on the output port. The entire dataset will be one color indicating that the datasets are now joined in one file. Notice that there is still a gap in the time series data. This will be addressed with the Correction toolbox.



5. Join files for all depths following steps 1-3. Each depth will require its own Join toolbox. Rename the toolboxes and save the AQUARIUS file.

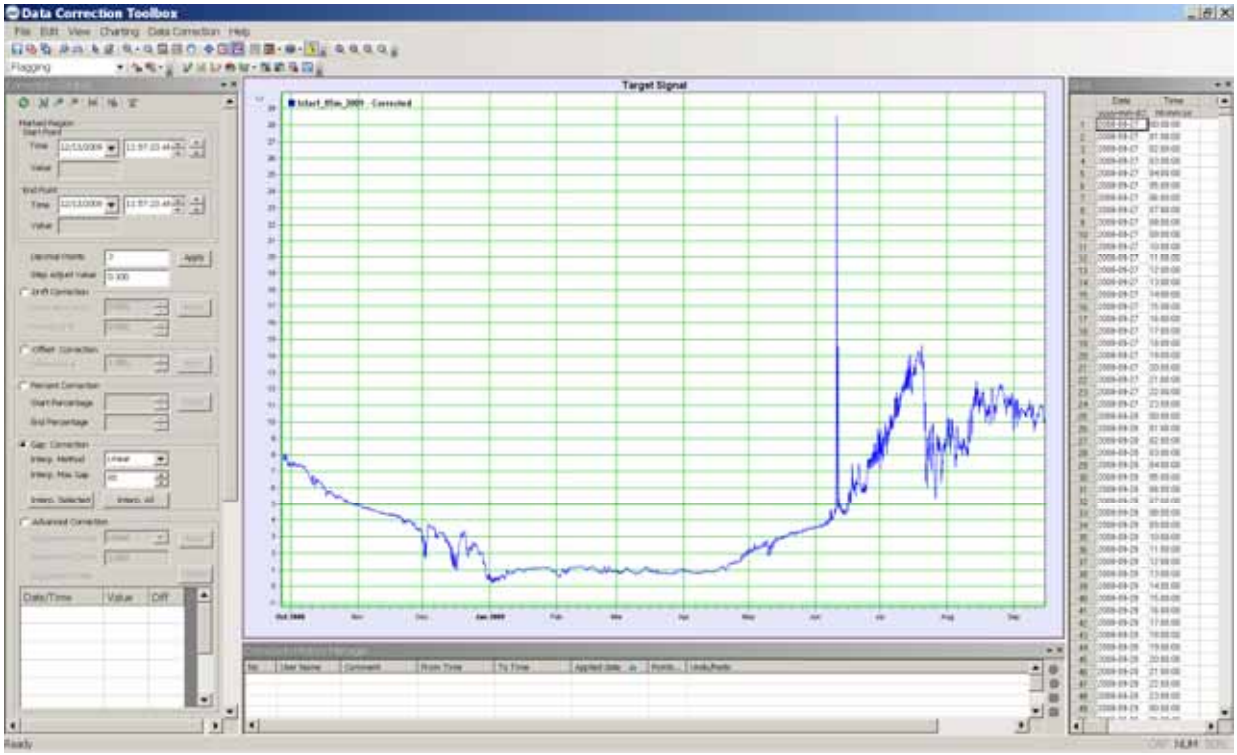


Data Correction

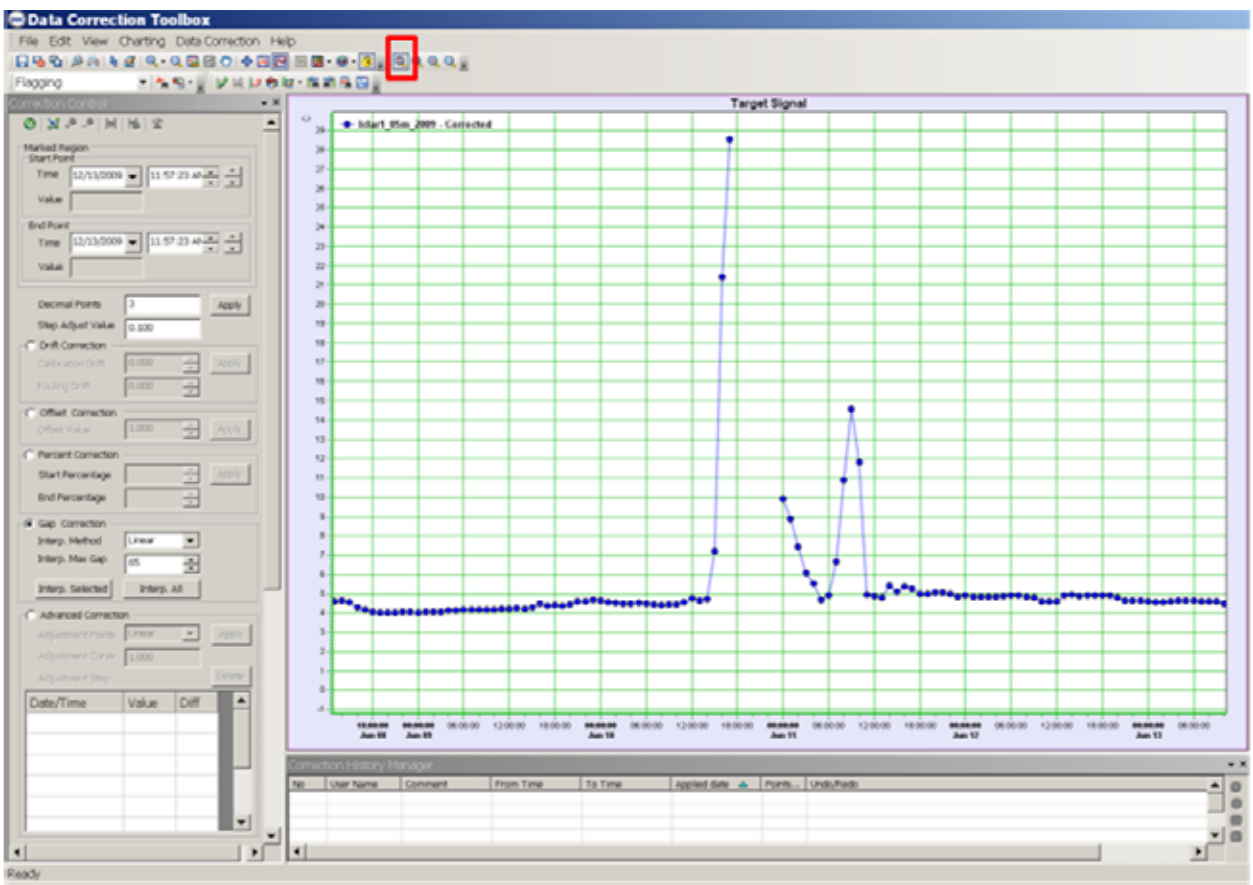
Now that the datasets have been joined, the data will need to be corrected. Corrections include smoothing data and correcting gaps created during periods when the temperature array is serviced and pulled out of the water. Generally, data gaps will be corrected using a cubic spline correction. This fills the data gap using a cubic interpolation by assessing data before and after the gap. Each correction is recorded in the Correction History Manager. The corrections can be undone if necessary. If there is only one file for the year and the temperature array was not pulled up to service, there will be no corrections applied to the dataset. Proceed to the Calculating Daily Summaries section.

1. Open the Correction Tab from the Toolbox pane and drag a Correction toolbox into the whiteboard for each depth. Wire the Signal Join toolbox to the Correction toolbox.

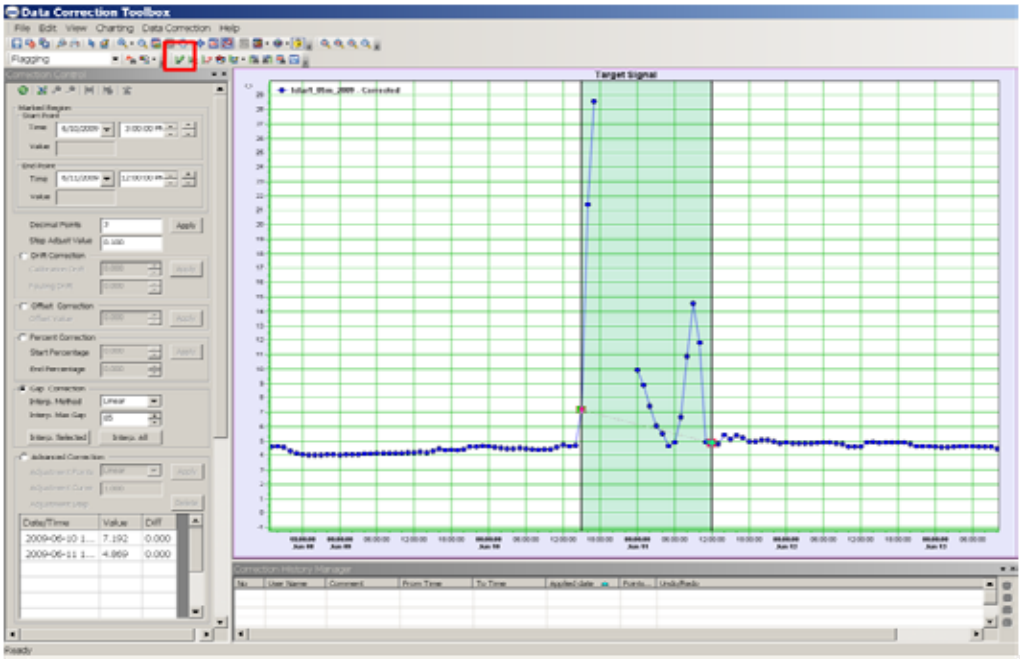
2. Double click the Correction toolbox and review the data. The correction window features two areas. The Correction Control pane to the left shows the correction features that a user can apply to the dataset. The Correction History Manager records all changes to the raw data and can be exported as a metadata .txt file.



3. Known data corrections will include periods where the temperature array was downloaded creating gaps and erroneous temperatures in the dataset. Start the correction process by correcting the most obvious spikes in the data. Using the vertical zoom icon, zoom into the spike data values.

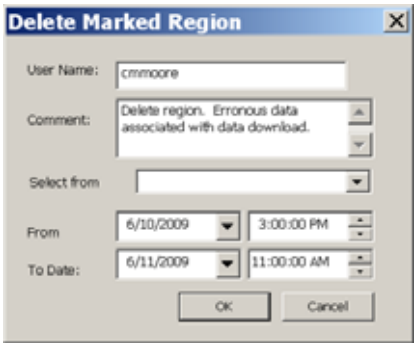


4. This area of the dataset needs to be smoothed to remove air temperature values and connected to remove the data gap. Use the Mark Region icon to select the data to be corrected and connected.

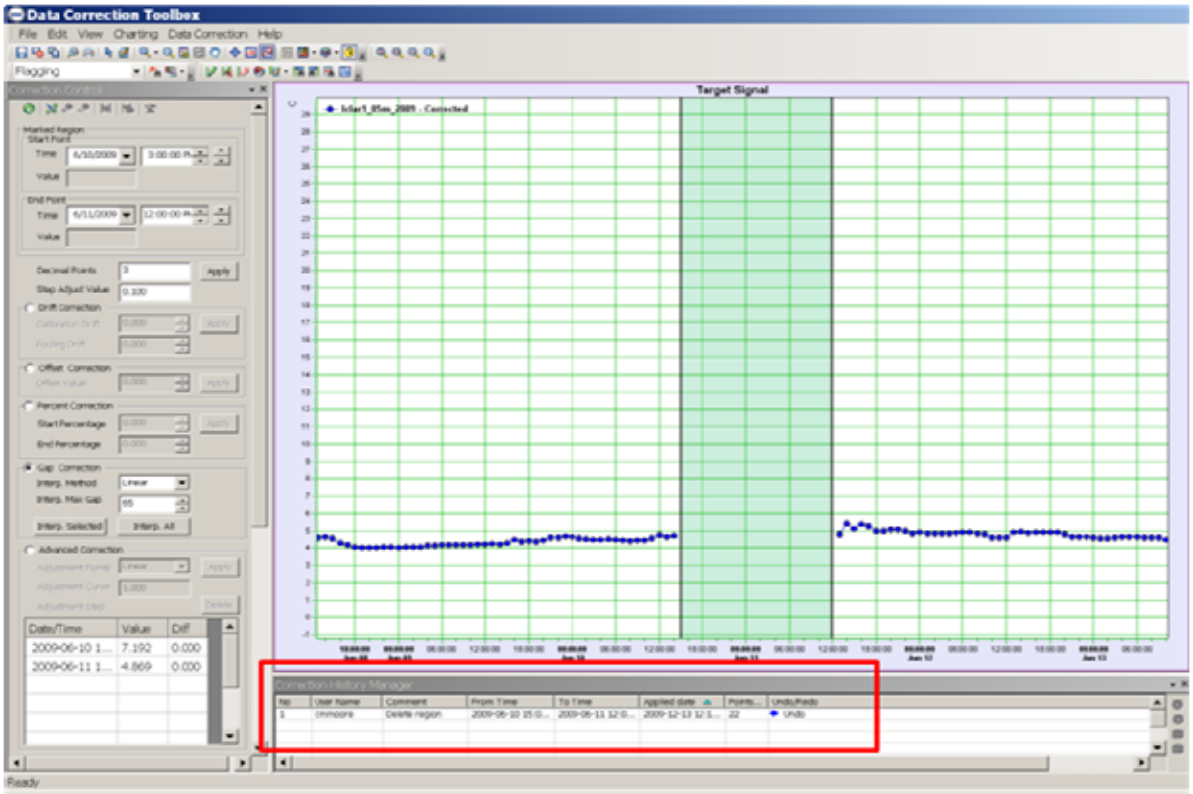


5. Use the delete region icon to remove the selected data points. A window will pop up showing the information that is related to the delete data task. The comment field will have Delete region already entered. Type in an additional comment stating that the erroneous data is associated with the data download. Keep these statements brief.

Note: In the new version (2.6) of the software there will be an Add to List feature that allows the user to add the comment to a pick list. Add the comment to the pick list to keep comments standard and reduce typing. This comment will be available for future deletions related to data download periods.



6. Notice that there is now information in the Correction History Manager.

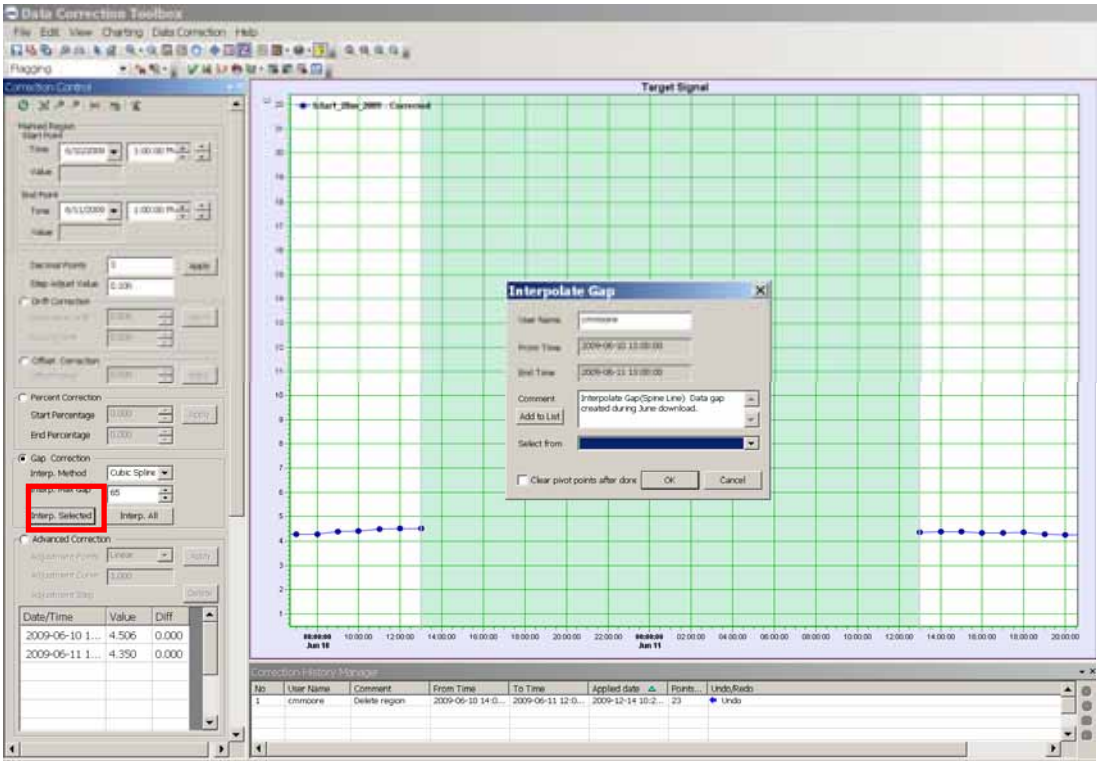


7. If the data points need to be restored, click undo in the Correction History Manager.

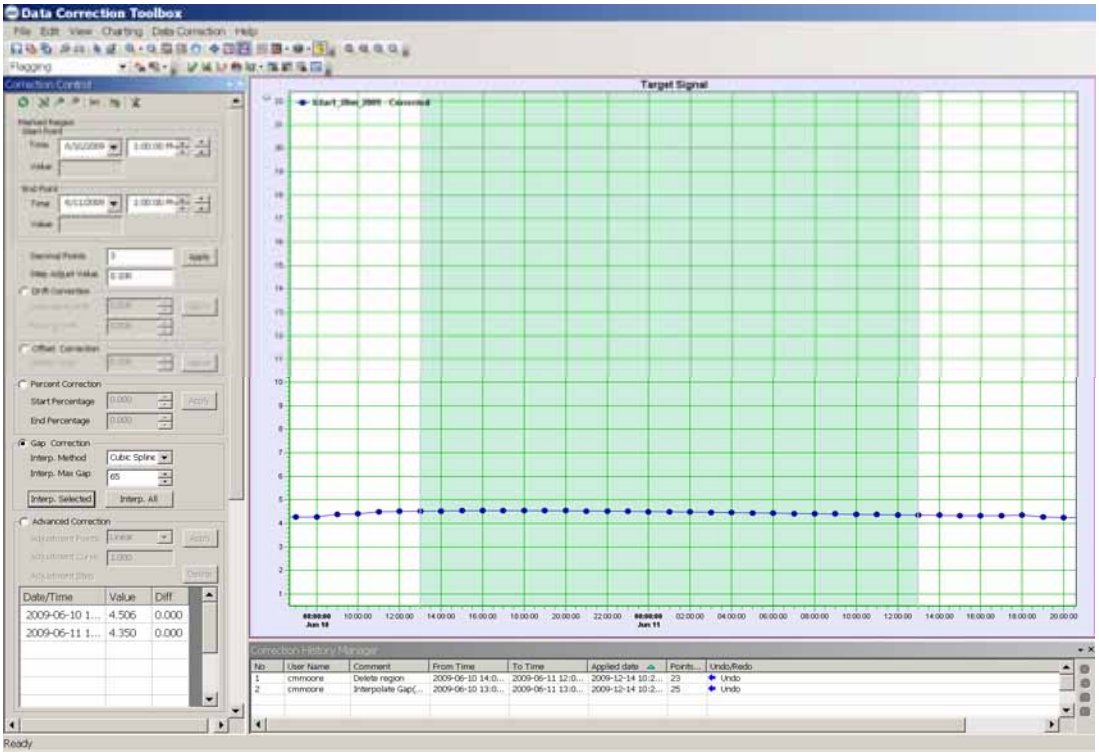
8. Now that the erroneous data points have been removed, apply a cubic spline correction to the gap. Use the Mark Region Icon to include the entire gap. The data points to the left and right of the gap must be included in the mark region selection. In the Correction Control Pane, select the Gap Correction Radio Button and Cubic Spline from the Interp. Method pull down menu. Then click the Interp. Selected button. This will apply the correction to this data gap only.

9. Another pop up window will appear showing the data gap to be corrected and the type of gap correction. The comment field will show that a cubic spline was applied to this data gap. Add a comment stating that this correction fills a gap created when during the temperature array download.

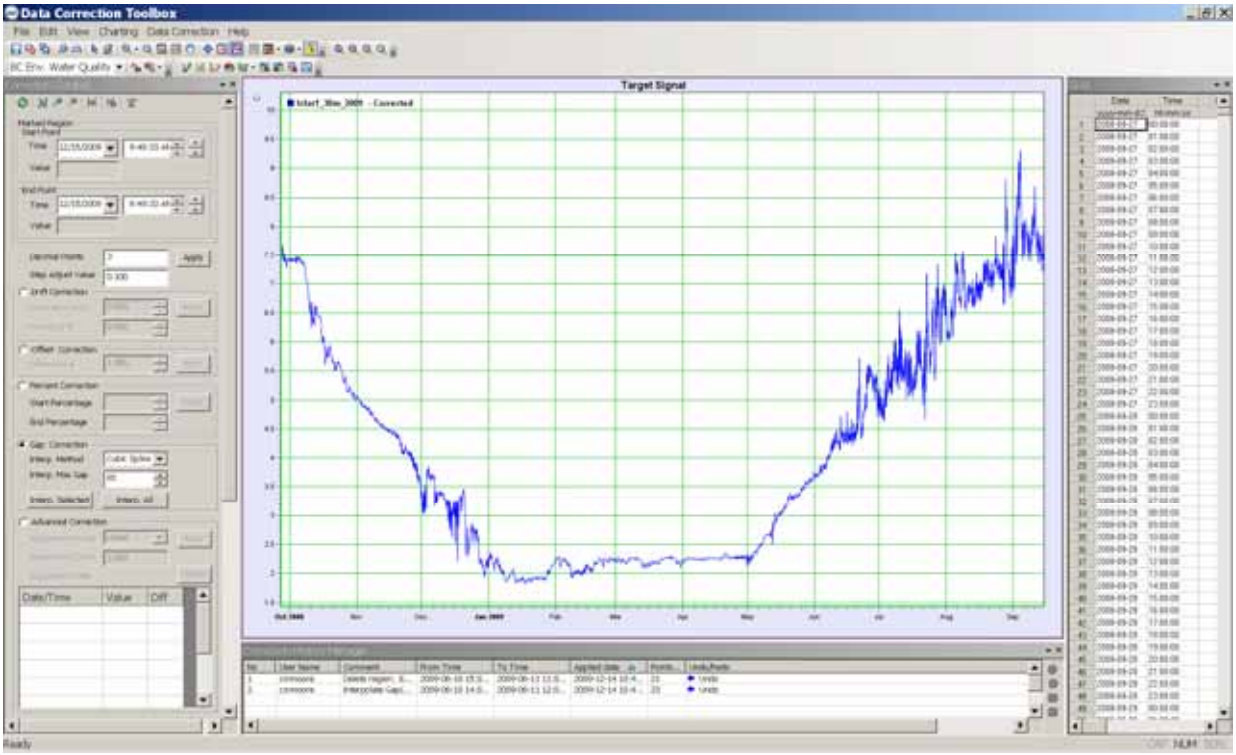
10. The added comment can be added to a pick list to keep comments standard and reduce typing. If this is the first run through, select the Add to List button and click OK. This comment will be available for future cubic spline corrections.



11. The data gap will be corrected and a new line of information will be added to the Correction History Manager. The new data points should blend into the graphic display of the dataset.



12. Select the Reset Axis icon to show the full dataset. The large data spike that was obvious is now removed. Select the Save Data to Output Port and Exit icon.



13. When the toolbox is double clicked, a pop up window appears asking if you want to load the corrected data. Selecting yes will display the corrected data; selecting no will display the raw data. When the output port is selected, both the raw and corrected files will be displayed.

14. Right click on the Correction toolbox to bring up the properties pane. Rename the correction toolbox with the toolbox action + water body code and site ID + depth + 2009 (e.g., correct lclar01 005m 2009).

15. Generally, there are two data files for each depth for each year. If the temperature array has been serviced during the summer, there may be additional time periods to clean up. Consult the field notebook to identify other time periods in which erroneous data may have been recorded.

16. Complete corrections for all depths following steps 1-15. Save the whiteboard.

Threshold Flagging – under development

Calculating Daily Summaries

The data sets have now been joined and corrected for all depths. The next step is to summarize the hourly data values into daily mean values for each depth.

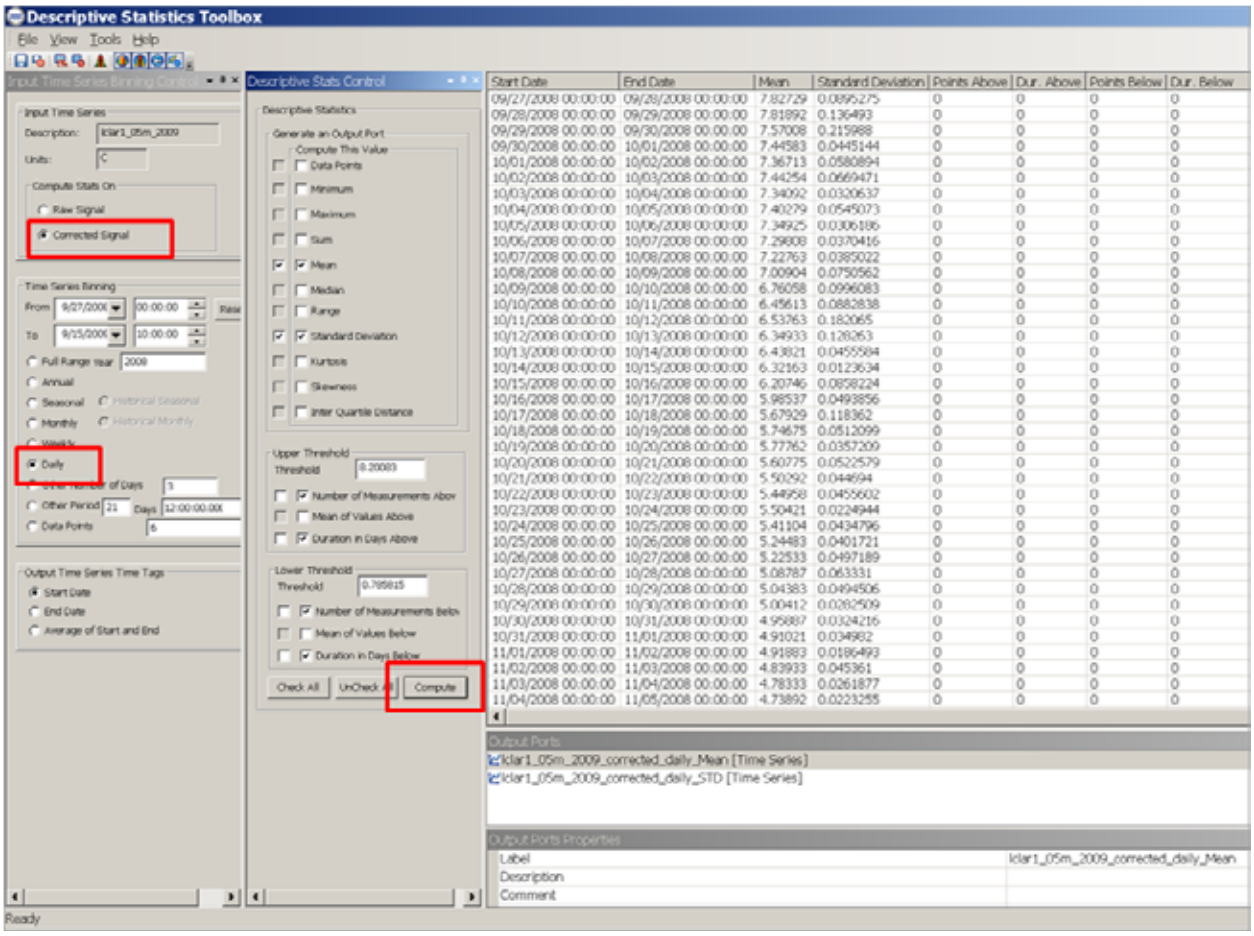
1. Select the Math and Statistics Tab from the Toolbox pane. Drag a Descriptive Statistics toolbox into the whiteboard for each depth and wire them to the Corrections toolboxes.

2. Double click the Descriptive Statistics toolbox. The Input Time Series pane allows the user to set the parameters that will be used to summarize the data. Select the Corrected Data radio button. This will apply the analysis to the corrected data. Allow the summary to be performed on the entire dataset. Select the daily radio button.

3. In the Descriptive Statistics pane, check both boxes for the Mean and Standard Deviation values. The right check computes the value and the left check will allow the values to be saved to an output port. Click the Compute button.

4. A set of daily values will be generated and displayed in the Descriptive Statistics toolbox. Select the Save Data to Output Port and Exit icon. Rename the Descriptive Statistics toolbox with the toolbox action + water body code and site ID + depth + 2009 (e.g., daily lclar01 005m 2009).

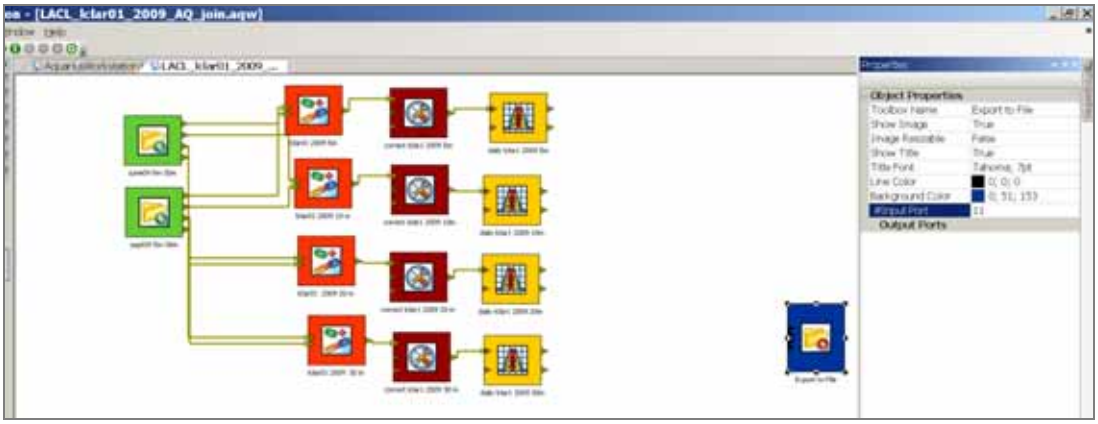
5. Complete steps 1-4 for each depth. Save the whiteboard.



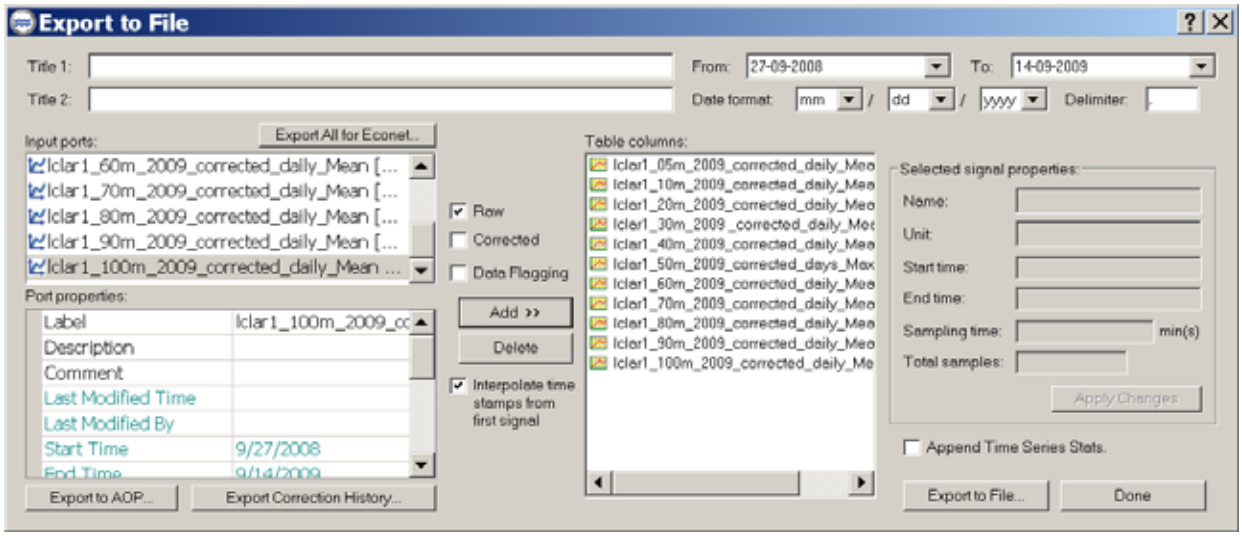
Data Export – under development

When the daily means and standard deviations have been completed for each depth, the files are ready to be exported. Two files will be exported to the .csv format. One file will include the full range of daily depths and the other file will include the 5 m daily average and standard deviation.

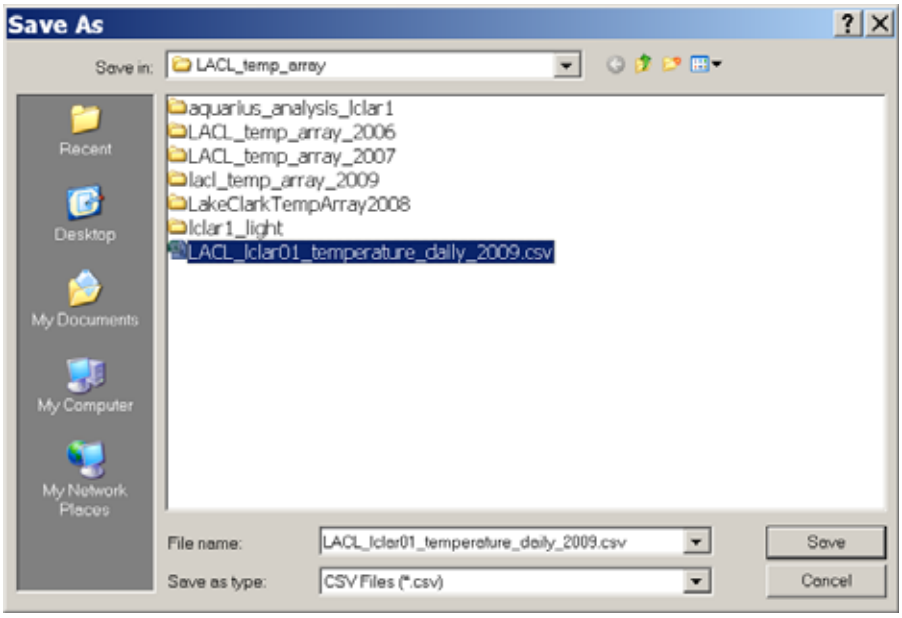
1. Select the Data Output tab in the Toolbox pane and drag an Export to File toolbox into the whiteboard. Right click the toolbox to open the Properties Pane. Change the number of input ports to the number of files that are to be exported. If the depths range from 5 m to 100 m, eleven ports will be needed.



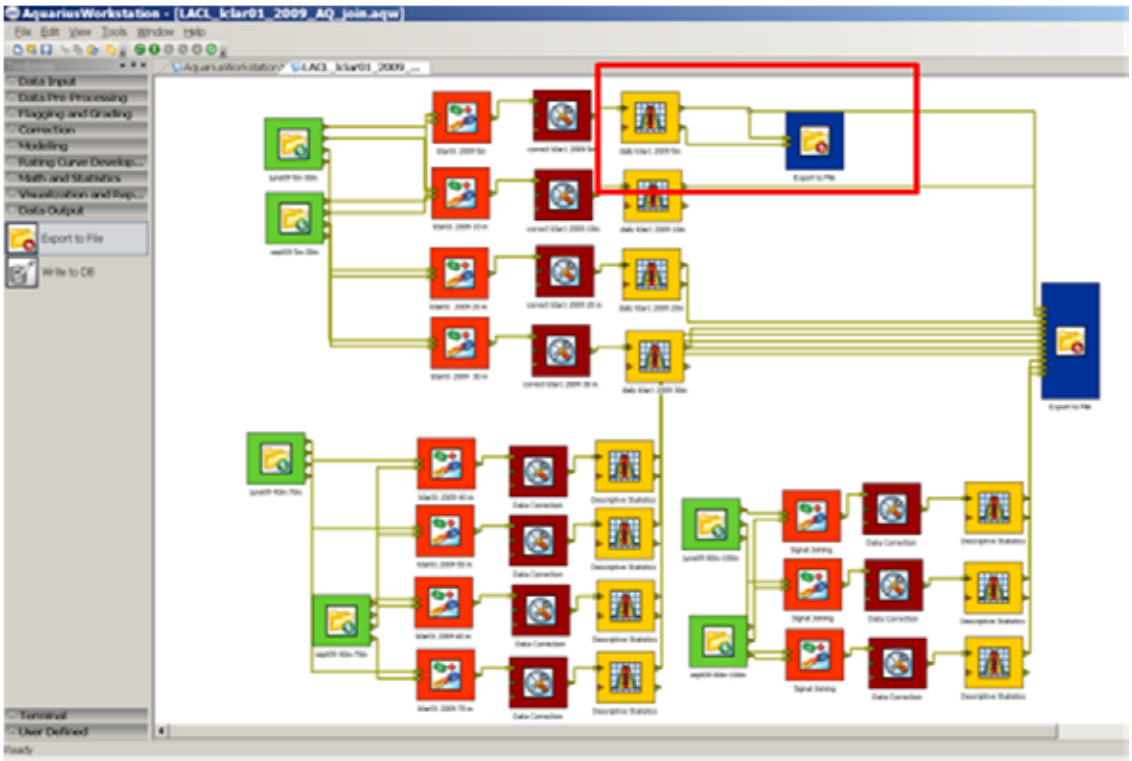
2. Double click the Export File toolbox. All the files connected to an input port will be listed in the Input ports pane. Check the corrected box from the list of options between Input ports pane and the Table columns pane. Highlight each file starting with the 5 m depth and click add. The file will display in the Table columns pane.



3. When all the files have been added, click export to file. Browse to the working folder and save the file using the following naming convention: 4-letter park code + year of plot establishment (YYYY) + 2-digit elevation band + site ID + temperature + daily + year (YYYY) (e.g., LACL_2007_02_006_temperature_daily_2009).



4. Drag another Export to File toolbox into the whiteboard. Open the Properties pane and change the input port to 2. For multiple depth measurements, wire the next set of daily depth mean and standard deviation output ports to the Export to File input ports.



5. Double click the toolbox. Select corrected and add the two files to the Table Columns pane. Click Export to file and save the file using the following naming convention: 4-letter park code + 5-digit water body code + site ID + temperature_depth + daily + year (YYYY) (e.g., LACL_2007_02_006_temperature_50cm_daily_2009). Save and close the white board. Close Aquarius.

Processing Surface Temperature Data

There will be only one file for the surface temperature data with a date range of 4 to 5 months. No signal joining or correction will be necessary.

1. Open a new whiteboard and drag in an Import from File toolbox. Load the data using the configuration file (cfg) used to load the temperature data.

2. Right click on the output port for a quick view of the data to verify there are no erroneous data points.

3. Drag in a Descriptive Statistics toolbox, wire it to the Import from File toolbox and run the daily min, max, mean and SD summaries. Save the results to the output port.

4. Drag in an Export to File, right click the toolbox, open the properties pane and change the number of input ports from 1 to 4.

5. Wire the toolboxes and export the daily summaries following the steps 2 and 3 in the previous section.

Vegetation Monitoring Protocol for the Southwest Alaska Network (SWAN)

Standard Operating Procedure (SOP) # 13

Data Analysis and Reporting

Version 1.0 (December 2008)

Revision History Log:

Version No.	Revision Date	Author	Changes Made	Reason for Change

This SOP outlines a general approach for summarizing data and analyzing for long-term trends in species composition. Consultation with a statistician is advised.

I. Summary statistics

1. Analyze by elevation band and vegetation class within and across parks.
2. Develop summary statistics for species composition within strata and year (Appendix F). Variables may include, but are not limited to, cover by growth form; cover by species (for abundant species only); species occurrence (all species); seedling and sapling density; and size-class distribution.
3. Report summary statistics for a given stratum for all years sampled. Quantify interannual variation within and among plots (e.g., Fig. 13.1; Appendix F).

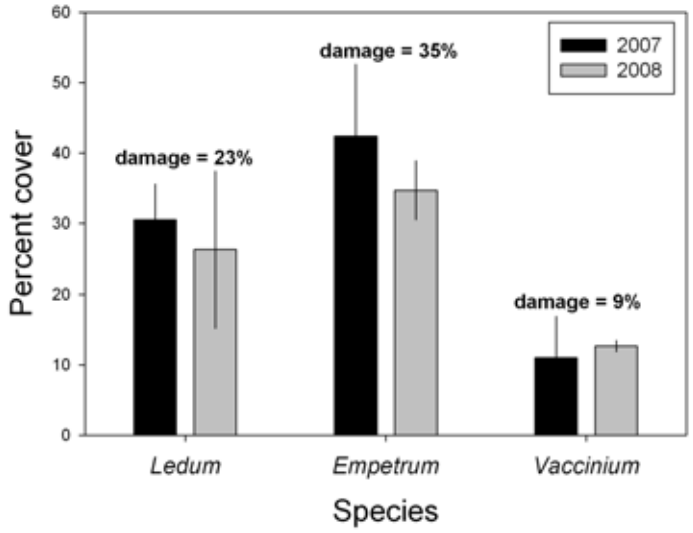


Figure 13.1. Interannual variability in species cover associated with frost damage in 2007 (Miller et al. 2009; Appendix 5). Mean cover (± 1 S.E.) was estimated by point-intercept in late June of both years. Percent damage shown for each species refers to the proportion of the population that sustained frost damage.

Interannual variability in plot attributes can likewise be displayed across sites and years, as shown in Woodward et al. (2009).

II. Change or trend detection – Bayesian hierarchical models

Bayesian hierarchical models (random effects models) will be used to analyze for long-term trends in plot variables within each park × elevation band × vegetation class combination (Appendix G). We will use an MS Excel add-in (BugsXLA) and freeware program WinBUGS to fit these models from within an MS Excel environment.

III. Graphical analysis – ordination

Nonparametric ordination (e.g., nonmetric multidimensional scaling [NMS]) and cluster analysis can be used to locate plots in multivariate space and are useful in data exploration. Species values are standardized to give uncommon and common species equal weight, and rare species are removed. Ordination plots are tested for dissimiliarity between sampling dates: vectors between two points in time provide a descriptive, graphical depiction of change (Fig. 13.2).

Tests for convergence or divergence among groups of sites use a simple rank correlation between date and between-group dissimilarity. Tests for progressive change in species composition (dissimilarity in species composition across sampling dates) can use the correlation or rank correlation between time and dissimilarity with a baseline condition (Philippi et al. 1998). Nonparametric test statistics include Spearman's rank correlation, Kendall's tau, and the Mantel test of association between two distance matrices (Philippi et al. 1998). COMDYN (http://www.mbr-pwrc.usgs.gov/software.html#a) or similar software can be used to estimate species richness and turnover (colonization/extinction) rates in targeted vegetation types, and provides a more quantitative estimation of change. Change can be quantified by examining summary statistics for variables of interest (Table 13.1).

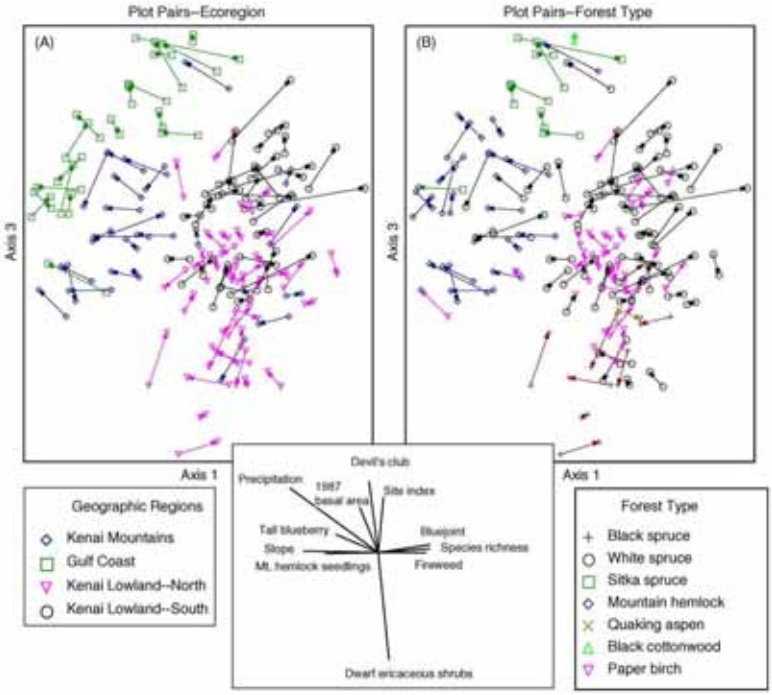


Figure 13.2. Nonmetric multidimensional scaling diagrams of vegetation plots sampled in (a) four ecoregions and (b) seven forest types in 1987 and 2000 (Boucher and Mead 2006). The direction and magnitude of change in species composition for each plot is indicated by a directional vector.

Vectors in the inset show the direction and strength of the correlation of species and environmental variables with the ordination axes.

Table 13.1. Cover (mean ± SE) for species included in the above ordination (Boucher and Mead 2006). Number of plots is indicated in parentheses for each species. Mean cover of fireweed and bluejoint increased by 95% and 163%, respectively, between 1987 and 2000 in the Southern Kenai Lowland. Mean cover of hemlock trees and saplings approximately doubled over the sampling interval.

Plant species[a]	Kenai Mountains (24)		Gulf Coast (19)		Northern Kenai Lowland (38)		Southern Kenai Lowland (33)	
	1987	2000	1987	2000	1987	2000	1987	2000
Hemlock, tree	21.0 ± 5.3 (16)	39.1 ± 7.6 (16)	28.6 ± 7.2 (12)	35.7 ± 9.2 (12)	0.1 ± 0.1 (1)	0.2 ± 0.2 (1)	–	–
Hemlock, seedling	6.7 ± 1.7 (16)	3.5 ± 1.1 (17)	4.1 ± 1.4 (11)	2.1 ± 0.7 (11)	<0.1 ± <0.1 (1)	<0.1 ± <0.1 (1)	–	–
Hemlock, sapling	6.9 ± 2.3 (9)	13.0 ± 4.2 (8)	8.4 ± 3.7 (5)	2.0 ± 1.4 (2)	–	–	–	–
Tall blueberry	1.8 ± 0.7 (15)	1.7 ± 0.9 (12)	11.0 ± 3.5 (17)	15.2 ± 3.8 (16)	0.3 ± 0.2 (7)	0.2 ± 0.1 (7)	1.0 ± 0.3 (12)	0.6 ± 0.2 (11)
Rusty menziesia	9.5 ± 1.9 (18)	8.3 ± 1.7 (18)	7.5 ± 1.8 (15)	7.2 ± 1.8 (15)	8.5 ± 2.6 (15)	10.2 ± 3.1 (15)	9.1 ± 2.9 (13)	5.1 ± 2.0 (13)
Sitka burnett	0.4 ± 0.2 (7)	0.3 ± 0.1 (7)	0.1 ± 0.1 (2)	0.1 ± 0.1 (1)	0.9 ± 0.4 (9)	0.4 ± <0.2 (8)	3.3 ± 0.8 (21)	2.3 ± 0.4 (22)
Twin flower	2.4 ± 0.6 (19)	1.2 ± 0.5 (17)	0.3 ± 0.2 (6)	0.1 ± 0.1 (4)	5.9 ± 0.8 (37)	4.3 ± 0.8 (34)	5.1 ± 0.7 (30)	4.9 ± 1.0 (29)
Fireweed	0.6 ± 0.2 (12)	0.6 ± 0.2 (11)	0.1 ± 0.1 (2)	0.1 ± 0.1 (2)	2.0 ± 0.3 (36)	2.2 ± 0.6 (35)	2.2 ± 0.4 (30)	4.3 ± 0.8 (32)
Bluejoint	1.1 ± 0.6 (15)	0.8 ± 0.3 (11)	0.9 ± 0.3 (9)	0.3 ± 0.1 (8)	3.7 ± 1.3 (27)	4.6 ± 1.3 (26)	5.2 ± 0.7 (31)	13.7 ± 2.1 (33)

[a] Hemlock = mountain hemlock.

IV. Reporting

Annual reports will summarize the previous year's work and will be organized as follows:

1. Introduction: Brief description of monitoring objectives and sampling design
2. Methods: Reference protocol and describe any changes that were implemented
3. Results: Site descriptions, data summaries; major findings
4. Discussion: Interpretation of results; ecological significance
5. Literature cited

Five-year reports will use the same format, but will address longer-term trends in community composition and structure through the analysis of multi-year data sets. All reports will follow NPS Natural Resource Publication guidelines, using the pre-formatted MS Word template available on the NRPM website (http://www.nature.nps.gov/publications/NRPM/). See Miller et al. (2009) for an example of an annual technical report (NRTR format).

Literature cited

Boucher, T.V., and B.R. Mead. 2006. Vegetation change and forest regeneration on the Kenai Peninsula, Alaska following a spruce beetle outbreak, 1987-2000. Forest Ecology and Management 227:233-246.

Miller, A.E., W.L. Thompson, and C. Moore. 2009. Vegetation composition and structure: baseline monitoring in the Southwest Alaska Network, 2008 annual summary report. Natural Resource Technical Report NPS/SWAN/NRTR-2009/213. (http://science.nature.nps.gov/im/units/swan/index.cfm?theme=reports_pub). Accessed 18 September 2009.

Phillipi, T.E., P.M. Dixon, and B.E. Taylor. 1998. Detecting trends in species composition. Ecological Applications 8:300-308.

Appendix B: Field Data Forms

Site evaluation checklist – SWAN Vegetation Monitoring – Version 1.0 (SOP #2)

Date: _____ **Park:**_____ **Plot ID:**_____
Recorders: _____ **Travel time to site:**_____

Description of best route to site:_____
_____
_____

Description of access constraints (1):_____
_____
_____

Permanent Rejection Criteria

Yes	No	Description
☐	☐	1. Site is dangerous or prohibitively difficult to access
☐	☐	2. Travel time to site from nearest access point is >2 h
☐	☐	3. Site is dangerous or prohibitively difficult to work on
☐	☐	4. Site occurs on private property
☐	☐	5. Site could be damaged by establishment of a monitoring plot
☐	☐	6. Site is located within 100 m of a previously selected GRTS point

Temporary Rejection Criteria

Yes	No	Description
☐	☐	7. Not a targeted vegetation association
☐	☐	8. Slope angle ≥25 degrees
☐	☐	9. Not representative of surrounding vegetation (inclusion)
☐	☐	10. No suitable plot location within 100 m

Photos

View	Photo id	Description – dominant species
North		
South		
East		
West		
Ground cover (close-up)		
Ground cover (close-up)		
Veg. structure (close-up)		
Veg. structure (close-up)		

Viereck Level IV-V Class: _____
Notes:_____
_____
_____
_____
_____
_____

Plot data sheet – SWAN Vegetation Monitoring – Version 1.0 (SOP #3)

Date:	**Park:**	**Plot ID:**	**Crew:**	
Time:	**GPS:**	**Elevation (m):**	**Plot slope (º):**	**Plot aspect (º):**
Plot year (establ.):		**Declination (º):**		
General location – notes:				

All lat/long = NAD 83
Elevation recorded from GPS at SW corner (Transect 1 = 0 m) of plot; slope & aspect are for plot mean

Transect 1 = 0 m	Transect 1 = 30 m	Transect 2 = 0 m	Transect 2 = 30 m	Transect 3 = 0 m	Transect 3 = 30 m
Lat:	**Lat:**	**Lat:**	**Lat:**	**Lat:**	**Lat:**
Long:	**Long:**	**Long:**	**Long:**	**Long:**	**Long:**

Dominant species

Tree:	Shrub/dwarf shrub:	Graminoid:	Herbaceous:	Viereck Class IV	Viereck Class V

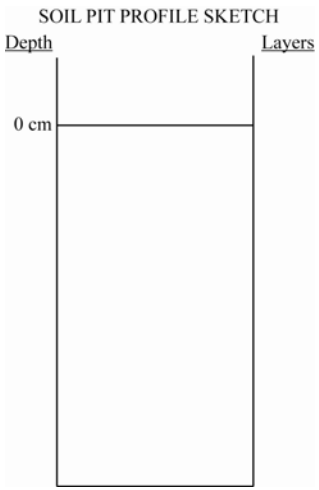
Parent Material (if known): Bedrock or residuum Alluvium Till Colluvium Loess Lacustrine sediment Other (describe): **Evidence of humans:** building; airstrip; campsite; social trail; developed trail; garbage; people nearby; equipment; artifacts; other	**Drainage:** Rapid – runoff / hillslope Rapid - coarse, permeable substrate Impeded – low permeability Saturated soil (H_2O table) Scattered standing H_2O Aquatic **Slope position:** ridgetop, saddle, upper 1/3, middle 1/3, lower 1/3 (toe), valley bottom **Notes:**	**Slope type:** concave; convex; planar; undulating **Micro-relief type:** Bedrock outcrops Mass movement (erosion) Mass movement (deposition) Turf hummocks Earth hummocks Moss hummocks Depressions Animal burrows Planar surface **USDA-NRCS landform:**_____
Evidence of fire:	**Evidence of wind:**	**Wind exposure class:**

Soils/surface characteristics data sheet – SWAN - Vegetation Monitoring Program - Version 1.0 (SOP # 9)

Date: _____ **Park:**_____ **Plot ID:**_____
Recorder: _____ **Reader:**_____

Describe soil profile at least 2 m outside of SW corner of plot. Temperature logger, if installed, should be located approximately 1 m west of plot monument.

Soil profile:		**Observation depth**							
	Descriptor	**Top (cm)**	**Bottom (cm)**	**Decomposition**	**pH**	**Texture**	**Moisture**	**Root density**	**Sample collected?**
Litter layer					-	-	-	-	-
Living mat					-	-	-	-	-
Rock fragments					-	-	-	-	-
Organic mat						-	-	-	-
Mineral									



Depth to hard surface (active layer or rock):			
Plot corner	**Transect location**	**Depth (cm)**	**Descriptor**
SW	**T1-0**		
NW	**T1-30**		
SE	**T3-0**		
NE	**T3-30**		

Notes:_____
_____
_____

Soil Temperature Sensor:					
Make & model	**Serial no.**	**Depth (cm)**	**Time installed**	**Latitude**	**Longitude**
Location description (distance/azimuth from SW corner/plot monument:					

Point-intercept data sheet – SWAN Vegetation Monitoring – Version 1.0 (SOP #5)
30 m transect (south - north) – page 1

Date: _____ **Park:**_____ **Plot ID:**_____
Transect No: _____ **Recorder:** _____**Reader:**_____

Record species code, cover type code or collection # for each hit. (FD) = frost damage; (SD) = standing dead tree/shrub

Point	>4m	1-4 m	50 – 100 cm	<50 cm
0.5 m				
1.0 m				
1.5 m				
2.0 m				
2.5 m				
3.0 m				
3.5 m				
4.0 m				
4.5 m				
5.0 m				
5.5 m				
6.0 m				
6.5 m				
7.0 m				
7.5 m				
8.0 m				
8.5 m				
9.0 m				
9.5 m				
10.0 m				
10.5 m				
11.0 m				
11.5 m				
12.0 m				
12.5 m				
13.0 m				
13.5 m				
14.0 m				
14.5 m				
15.0 m				

Cover type codes: moss (M); lichen (LI); litter (LT); gravel (G); rock (RK); bare soil (BG); down wood (DW); standing dead (dead tree/shrub) (SD); dead branches on live tree/shrub (SDL); current-year frost damage (FD); scat (SC); standing water (W).

Point-intercept data sheet – SWAN Vegetation Monitoring – Version 1.0 (SOP #5)
30 m transect (south - north) – page 2

Date: _____Plot ID:_____ Transect No: _____
Recorder: _____ Reader:_____

Record species code, cover type code or collection # for each hit. (FD) = frost damage; (SD) = standing dead tree/shrub

Point	>4m	1-4 m	50 – 100 cm	<50 cm
15.5 m				
16.0 m				
16.5 m				
17.0 m				
17.5 m				
18.0 m				
18.5 m				
19.0 m				
19.5 m				
20.0 m				
20.5 m				
21.0 m				
21.5 m				
22.0 m				
22.5 m				
23.0 m				
23.5 m				
24.0 m				
24.5 m				
25.0 m				
25.5 m				
26.0 m				
26.5 m				
27.0 m				
27.5 m				
28.0 m				
28.5 m				
29.0 m				
29.5 m				

Cover type codes: moss (M); lichen (LI); litter (LT); gravel (G); rock (RK); bare soil (BG); down wood (DW); standing dead (dead tree/shrub) (SD); dead branches on live tree/shrub (SDL); current-year frost damage (FD); scat (SC); standing water (W).

Quadrat data sheet – SWAN Vegetation Monitoring – Version 1.0 (SOP #6) – page 1

Date: ___________________________ Park:________________ Plot ID:________________________
Transect No: ____________ Recorder: _____________________Reader:____________________________

Vascular species: Record frequency by species using USDA species codes or collection number (if unknown).

Species Code or Collection No.	Quad 1 0m	Quad 2 7 m	Quad 3 14 m	Quad 4 21 m	Quad 5 28 m

Frequency: 1 = 0.25 m^2; 2 = 1 m^2; 3 = 4 m^2; blank = absent
Growth form: T = tree; S = shrub; DS = dwarf shrub; F = forb; FN = fern; G = graminoid; L = lycophyte; H = horsetail; NV= nonvascular

See (http://plants.usda.gov/) for vascular species list and associated growth form data. NA = not applicable.

Quadrat data sheet – SWAN Vegetation Monitoring – Version 1.0 (SOP #6) – page 1

Date: ______________________ **Park:**______________ **Plot ID:**_____________________
Transect No: ___________ **Recorder:** ____________________**Reader:**_________________________

Non-vascular species: Record frequency by species using USDA species codes or collection number (if unknown).

Species Code or Collection No.	Quad 1 0m	Quad 2 7 m	Quad 3 14 m	Quad 4 21 m	Quad 5 28 m

Frequency: 1 = 0.25 m^2; 2 = 1 m^2; 3 = 4 m^2; blank = absent
Growth form: T = tree; S = shrub; DS = dwarf shrub; F = forb; FN = fern; G = graminoid; L = lycophyte; H = horsetail; NV= nonvascular

See (http://plants.usda.gov/) for vascular species list and associated growth form data. NA = not applicable.

Point-intercept data sheet – SWAN Vegetation Monitoring – Version 1.0 (SOP #5)
30 m transect (south - north) – page 1

Date: _____ **Park:**_____ **Plot ID:**_____
Transect No: _____ **Recorder:** _____**Reader:**_____

Record species code, cover type code or collection # for each hit. **(FD) = frost damage; (SD) = standing dead tree/shrub**

Point	>4m	1-4 m	50 – 100 cm	<50 cm
0.5 m				
1.0 m				
1.5 m				
2.0 m				
2.5 m				
3.0 m				
3.5 m				
4.0 m				
4.5 m				
5.0 m				
5.5 m				
6.0 m				
6.5 m				
7.0 m				
7.5 m				
8.0 m				
8.5 m				
9.0 m				
9.5 m				
10.0 m				
10.5 m				
11.0 m				
11.5 m				
12.0 m				
12.5 m				
13.0 m				
13.5 m				
14.0 m				
14.5 m				
15.0 m				

Cover type codes: moss (M); lichen (LI); litter (LT); gravel (G); rock (RK); bare soil (BG); down wood (DW); standing dead (dead tree/shrub) (SD); dead branches on live tree/shrub (SDL); current-year frost damage (FD); scat (SC); standing water (W).

Point-intercept data sheet – SWAN Vegetation Monitoring – Version 1.0 (SOP #5)
30 m transect (south - north) – page 2

Date: _____Plot ID:_____ Transect No: _____
Recorder: _____ Reader:_____

Record species code, cover type code or collection # for each hit. (FD) = frost damage; (SD) = standing dead tree/shrub

Point	>4m	1-4 m	50 – 100 cm	<50 cm
15.5 m				
16.0 m				
16.5 m				
17.0 m				
17.5 m				
18.0 m				
18.5 m				
19.0 m				
19.5 m				
20.0 m				
20.5 m				
21.0 m				
21.5 m				
22.0 m				
22.5 m				
23.0 m				
23.5 m				
24.0 m				
24.5 m				
25.0 m				
25.5 m				
26.0 m				
26.5 m				
27.0 m				
27.5 m				
28.0 m				
28.5 m				
29.0 m				
29.5 m				

Cover type codes: moss (M); lichen (LI); litter (LT); gravel (G); rock (RK); bare soil (BG); down wood (DW); standing dead (dead tree/shrub) (SD); dead branches on live tree/shrub (SDL); current-year frost damage (FD); scat (SC); standing water (W).

Quadrat data sheet – SWAN Vegetation Monitoring – Version 1.0 (SOP #6) – page 1

Date: ___________________________ **Park:**________________ **Plot ID:**________________________
Transect No: ____________ **Recorder:** _____________________ **Reader:**____________________________

Vascular species: Record frequency by species using USDA species codes or collection number (if unknown).

Species Code or Collection No.	Quad 1 0m	Quad 2 7 m	Quad 3 14 m	Quad 4 21 m	Quad 5 28 m

Frequency: 1 = 0.25 m^2; 2 = 1 m^2; 3 = 4 m^2; blank = absent
Growth form: T = tree; S = shrub; DS = dwarf shrub; F = forb; FN = fern; G = graminoid; L = lycophyte; H = horsetail; NV= nonvascular

See (http://plants.usda.gov/) for vascular species list and associated growth form data. NA = not applicable.

Quadrat data sheet – SWAN Vegetation Monitoring – Version 1.0 (SOP #6) – page 1

Date: ___________________________ **Park:**________________ **Plot ID:**________________________
Transect No: ____________ **Recorder:** _____________________**Reader:**____________________________

Non-vascular species: Record frequency by species using USDA species codes or collection number (if unknown).

Species Code or Collection No.	Quad 1 0m	Quad 2 7 m	Quad 3 14 m	Quad 4 21 m	Quad 5 28 m

Frequency: 1 = 0.25 m^2; 2 = 1 m^2; 3 = 4 m^2; blank = absent
Growth form: T = tree; S = shrub; DS = dwarf shrub; F = forb; FN = fern; G = graminoid; L = lycophyte; H = horsetail; NV= nonvascular

See (http://plants.usda.gov/) for vascular species list and associated growth form data. NA = not applicable.

Point-intercept data sheet – SWAN Vegetation Monitoring – Version 1.0 (SOP #5)
30 m transect (south - north) – page 1

Date: _____ Park:_____ Plot ID:_____
Transect No: _____ Recorder: _____Reader:_____

Record species code, cover type code or collection # for each hit. (FD) = frost damage; (SD) = standing dead tree/shrub

Point	>4m	1-4 m	50 – 100 cm	<50 cm
0.5 m				
1.0 m				
1.5 m				
2.0 m				
2.5 m				
3.0 m				
3.5 m				
4.0 m				
4.5 m				
5.0 m				
5.5 m				
6.0 m				
6.5 m				
7.0 m				
7.5 m				
8.0 m				
8.5 m				
9.0 m				
9.5 m				
10.0 m				
10.5 m				
11.0 m				
11.5 m				
12.0 m				
12.5 m				
13.0 m				
13.5 m				
14.0 m				
14.5 m				
15.0 m				

Cover type codes: moss (M); lichen (LI); litter (LT); gravel (G); rock (RK); bare soil (BG); down wood (DW); standing dead (dead tree/shrub) (SD); dead branches on live tree/shrub (SDL); current-year frost damage (FD); scat (SC); standing water (W).

Point-intercept data sheet – SWAN Vegetation Monitoring – Version 1.0 (SOP #5)
30 m transect (south - north) – page 2

Date: _____Plot ID:_____ Transect No: _____
Recorder: _____ Reader:_____

Record species code, cover type code or collection # for each hit. (FD) = frost damage; (SD) = standing dead tree/shrub

Point	>4m	1-4 m	50 – 100 cm	<50 cm
15.5 m				
16.0 m				
16.5 m				
17.0 m				
17.5 m				
18.0 m				
18.5 m				
19.0 m				
19.5 m				
20.0 m				
20.5 m				
21.0 m				
21.5 m				
22.0 m				
22.5 m				
23.0 m				
23.5 m				
24.0 m				
24.5 m				
25.0 m				
25.5 m				
26.0 m				
26.5 m				
27.0 m				
27.5 m				
28.0 m				
28.5 m				
29.0 m				
29.5 m				

Cover type codes: moss (M); lichen (LI); litter (LT); gravel (G); rock (RK); bare soil (BG); down wood (DW); standing dead (dead tree/shrub) (SD); dead branches on live tree/shrub (SDL); current-year frost damage (FD); scat (SC); standing water (W).

Quadrat data sheet – SWAN Vegetation Monitoring – Version 1.0 (SOP #6) – page 1

Date: __________________________ Park:________________ Plot ID:_______________________
Transect No: ____________ Recorder: _____________________Reader:____________________________

Vascular species: Record frequency by species using USDA species codes or collection number (if unknown).

Species Code or Collection No.	Quad 1 0m	Quad 2 7 m	Quad 3 14 m	Quad 4 21 m	Quad 5 28 m

Frequency: 1 = 0.25 m^2; 2 = 1 m^2; 3 = 4 m^2; blank = absent
Growth form: T = tree; S = shrub; DS = dwarf shrub; F = forb; FN = fern; G = graminoid; L = lycophyte; H = horsetail; NV= nonvascular

See (http://plants.usda.gov/) for vascular species list and associated growth form data. NA = not applicable.

Quadrat data sheet – SWAN Vegetation Monitoring – Version 1.0 (SOP #6) – page 1

Date: ___________________________ **Park:**________________ **Plot ID:**________________________
Transect No: ____________ **Recorder:** _____________________**Reader:**____________________________

Non-vascular species: Record frequency by species using USDA species codes or collection number (if unknown).

Species Code or Collection No.	Quad 1 0m	Quad 2 7 m	Quad 3 14 m	Quad 4 21 m	Quad 5 28 m

Frequency: 1 = 0.25 m^2; 2 = 1 m^2; 3 = 4 m^2; blank = absent
Growth form: T = tree; S = shrub; DS = dwarf shrub; F = forb; FN = fern; G = graminoid; L = lycophyte; H = horsetail; NV= nonvascular

See Appendix F for vascular species list and associated growth form data. NA = not applicable.

Quadrat data sheet – SWAN Vegetation Monitoring – Version 1.0 (SOP #6)

Date: _____ **Park:**_____ **Plot ID:**_____
Recorder: _____ **Reader:**_____

Record percent cover and tree seedling counts in 4m^2 quad for each living and non-living parameter:

Transect 1

	Bedrock-Boulder	*Cobble*	*Gravel*	*Bare Soil*	*Crypto Crust*	*Litter*	*Dead Stand*	*Down wood*	*Lichen*	*Moss*	*Graminoid*	*Forb*	*Dwarf shrub*	*Shrub*	*Tree*	*# seedlings*
Q1 – 0 m																
Q2 – 7 m																
Q3 – 14 m																
Q4 – 21 m																
Q5 – 28 m																

Transect 2

	Bedrock-Boulder	*Cobble*	*Gravel*	*Bare Soil*	*Crypto Crust*	*Litter*	*Dead Stand*	*Down wood*	*Lichen*	*Moss*	*Graminoid*	*Forb*	*Dwarf shrub*	*Shrub*	*Tree*	*# seedlings*
Q1 – 0 m																
Q2 – 7 m																
Q3 – 14 m																
Q4 – 21 m																
Q5 – 28 m																

Transect 3

	Bedrock-Boulder	*Cobble*	*Gravel*	*Bare Soil*	*Crypto Crust*	*Litter*	*Dead Stand*	*Down wood*	*Lichen*	*Moss*	*Graminoid*	*Forb*	*Dwarf shrub*	*Shrub*	*Tree*	*# seedlings*
Q1 – 0 m																
Q2 – 7 m																
Q3 – 14 m																
Q4 – 21 m																
Q5 – 28 m																

Note tree species (seedlings), where applicable:

Transect 1:_____
Transect 2:_____
Transect 3:_____

Additional notes:

_____
_____
_____

Tree and sapling data sheet – SWAN Vegetation Monitoring Program – Version 1.0 (SOP #7) – page 1

Date: _____Park:_____Plot ID:_____
Recorder: _____ Reader:_____

TREES (>12.0 cm DBH)

Tree#	Species	Cond (L/D)	½ Plot (E/W)	Transect No. & Dist N/S (m)	Dist E/W (m)	X (m)	Y (m)	DBH (cm)	Height (m)	Crown class	Crown length	Comments
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												
31												
32												
33												
34												
35												
36												
37												
38												

Record the transect number and N/S distance from the transect tape closet to the tree. Record the distance and direction (E/W) from the N/S point on the transect tape. Calculate X and Y values (m) for tree location in plot.

Crown classes: open grown (1); dominant (2); co-dominant (3); intermediate (4); overtopped (5); dead standing tree (6).

Tree and sapling data sheet – SWAN Vegetation Monitoring Program – Version 1.0 (SOP #7) – page 2

Date: _____ **Park:** _____ **Plot ID:** _____
Recorder: _____ **Reader:** _____

TREES (>12.0 cm DBH)

Tree#	Species	Cond (L/D)	½ Plot (E/W)	Transect No. & Dist N/S (m)	Dist E/W (m)	X (m)	Y (m)	DBH (cm)	Height (m)	Crown class	Crown length	Comments
39												
40												
41												
42												
43												
44												
45												
46												
47												
48												
49												
50												
51												
52												
53												
54												
55												
56												
57												
58												
59												
60												
61												
62												
63												
64												
65												
66												
67												
68												
69												
70												

Record transect number and N/S distance from transect tape closet to the tree. Record distance and direction (E/W) from the N/S point on the transect tape. Calculate X and Y values (m) for tree location in plot. Use densiometer in 4 cardinal directions to estimate mean canopy cover; calculate %.
Crown classes: open grown (1); dominant (2); co-dominant (3); intermediate (4); overtopped (5); dead standing tree (6).

Canopy cover:	North	South	East	West	Average cover
Plot center					
T1-0					
T1-30					
T3-0					
T3-30					

Tree and sapling data sheet – SWAN Vegetation Monitoring Program – Version 1.0 (SOP #7) – page 3

Date: ________________________ **Park:**________________ **Plot ID:**__________________________

Recorder: ______________________________ **Reader:**______________________________

SAPLINGS (>0 cm DBH, <12.0 cm DBH)

½ Plot (E/W)	Species	Cond (L/D)	DBH (cm)	Crown class		½ Plot (E/W)	Species	Cond (L/D)	DBH (cm)	Crown class

Estimate DBH to nearest 0.1 cm using calipers. Estimate mean crown class and mean height for all saplings in ½ plot.

Crown classes: open grown (1); dominant (2); co-dominant (3); intermediate (4); overtopped (5); dead standing tree (6).

Tree core & fuels data sheet – SWAN Vegetation Monitoring – Version 1.0
(SOPs #8 & 10)

Date: _____ Park:_____ Plot ID:_____
Reader:_____Recorder: _____

Tree cores: **Core trees within a 10 m-wide buffer outside of 30 m × 30 m plot. Core 2 largest trees per ½ plot.**

Tag #	Species	Cond (L/D)	DBH (cm)	Tree height (m)	Core height (cm ARC)	Location description

Location description: record the transect number and N/S + E/W distance from the transect tape closet to the tree; alternatively, record distance and azimuth from closest corner stake.

Ladder fuels**: Reference cored trees above. Measure radius and branch heights to nearest 0.1 m**

Tag #	Crown radius (m)	Ht to dead ladder fuel (m)	Ht to live ladder fuel (m)	Ht to main crown (m)	Notes

Notes:_____

***Down woody material*: Record coarse woody debris (CWD – 1000 h) by size and decay class along 30 m transects. Tally fine woody debris (FWD – 1 h; 10 h; 100 h) intersected by each transect. Minimum length of CWD = 1.0 m**

	1000 h fuels (>3" or 7.62 cm)					100 h	10 h	1 h
Transect	**Species**	**Decay class**	**Transect diameter (cm)**	**Length (m)**	**Max/min diameter (cm)**	**No. pieces**	**No. pieces**	**No. pieces**

FMH fuels definitions: 1000 hr (>3" or 7.62 cm); 100 hr (1"-3" or 2.54-7.62 cm); 10 hr (0.25"-1" or 0.64-2.54 cm); 1 hr (<0.25" or <0.64 cm).

Quadrat data sheet – SWAN Vegetation Monitoring – Version 1.0 (SOP #6) – page 2

Date: ___________________________ Park:________________ Plot ID:________________________
Transect No: ____________ Recorder: _____________________Reader:_____________________________

Vascular or Nonvascular (circle one): use USDA species code or collection code (if unknown).

Species Code or Collection No.	Quad 1 0m	Quad 2 7 m	Quad 3 14 m	Quad 4 21 m	Quad 5 28 m

Quadrat data sheet – SWAN Vegetation Monitoring – Version 1.0 (SOP #6) – page 2

Date: __________________________ Park:________________ Plot ID:________________________
Transect No: ____________ Recorder: _____________________Reader:____________________________

Vascular or Nonvascular (circle one): use USDA species code or collection code (if unknown).

Species Code or Collection No.	Quad 1 0m	Quad 2 7 m	Quad 3 14 m	Quad 4 21 m	Quad 5 28 m

Appendix C: Using S-DRAW to Generate GRTS Samples

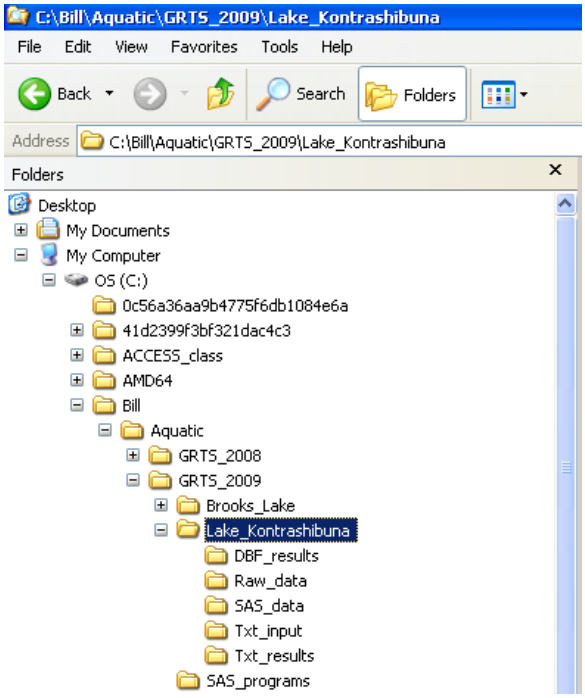
Author: Bill Thompson, SWAN Quantitative Ecologist
Date: 24 April 2009

Purpose: This document describes the step-by-step approach for using S-DRAW 1.0 (http://www.west-inc.com/programs/S-Draw1b.zip) and SAS 9.2 Windows XP Professional x64 edition (www.sas.com) to select generalized random tessellation stratified (GRTS) samples. Examples provided are for generating GRTS samples for freshwater monitoring, but the methods are identical to those used to generate GRTS samples from an access layer for vegetation monitoring. SAS is a commercial software package used to manipulate the raw data file of all grid points into input and file formats that can be read by S-DRAW, and to manipulate the files outputted by S-DRAW into .dbf files that can be easily read by ArcGIS 9.2. S-DRAW is a freeware program used for choosing GRTS samples; see the S-DRAW 1.0 User's Guide (SDRAW_users_guide.pdf) in http://www.west-inc.com/programs/S-Draw1b.zip for details.

Step 1: Generate a file or files containing UTM x-y coordinates for a grid of points overlaid on the lake of interest. The spacing of the points will be dictated by the size of the lake and by the perceived minimum distance required to minimize dependency of measurements among water quality samples. For instance, grid points on Lake Clark are spaced 1 km apart, whereas they are spaced 0.25 km apart on Lake Kontrashibuna. If a lake is divided into different subareas, a file of grid point locations should be created for each subarea.

SAS v. 9.2 Windows XP Professional x64 edition will import various file formats, such as DBF, CSV, TXT, WKn, JMP, SPSS, Stata, Paradox, MS Excel 4, 5 or 95, etc. The only file formats that are not supported by the x64 edition *Import/Export wizards* are the ones that use the MS Jet data provider (MS Excel 97, MS Access 97 and higher; see http://support.sas.com/kb/17/075.html for details). These file formats still can be imported into and exported from the 64-bit version of SAS, but they require a separate procedure (see **Step 4**).

Step 2: Create a folder structure on the C-drive or other relevant drive that will house the various data files used or generated from this process, such as the following.



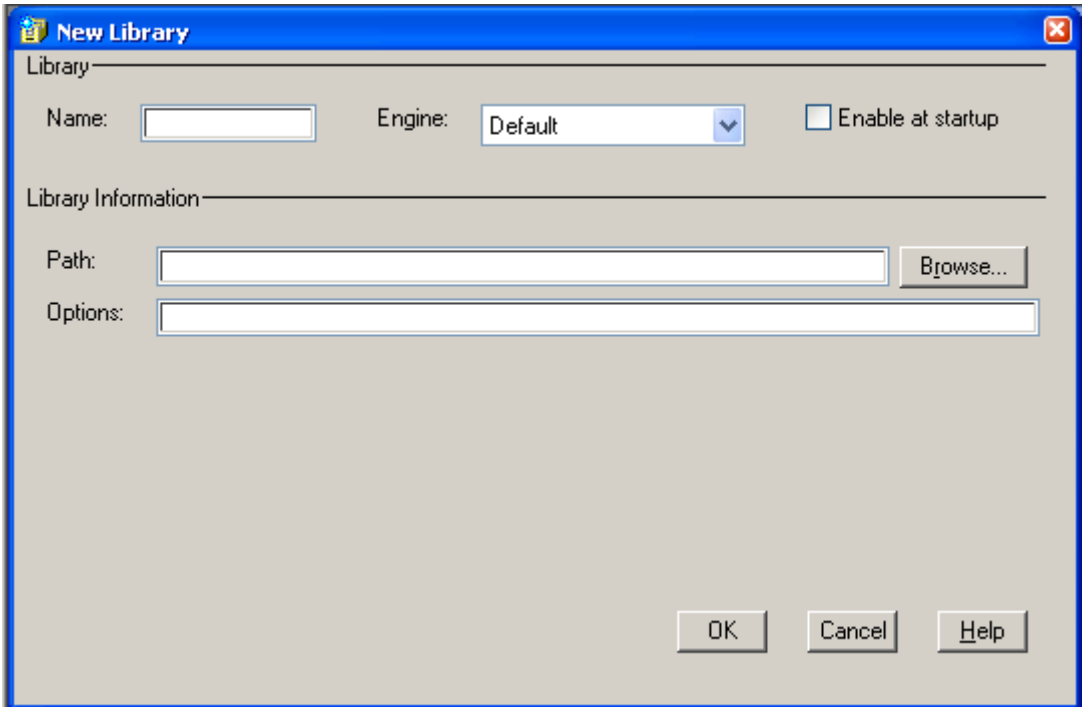
The key folders above are

DBF_results: .dbf file(s) with the coordinates of the GRTS sample points
Raw_data: file(s) of grid points created in **Step 1**.
SAS_data: SAS data files (.sas7bdat)
Txt_input: text file in S-DRAW input format
Txt_results: text file(s) outputted by S-DRAW that contain(s) the GRTS selected points.

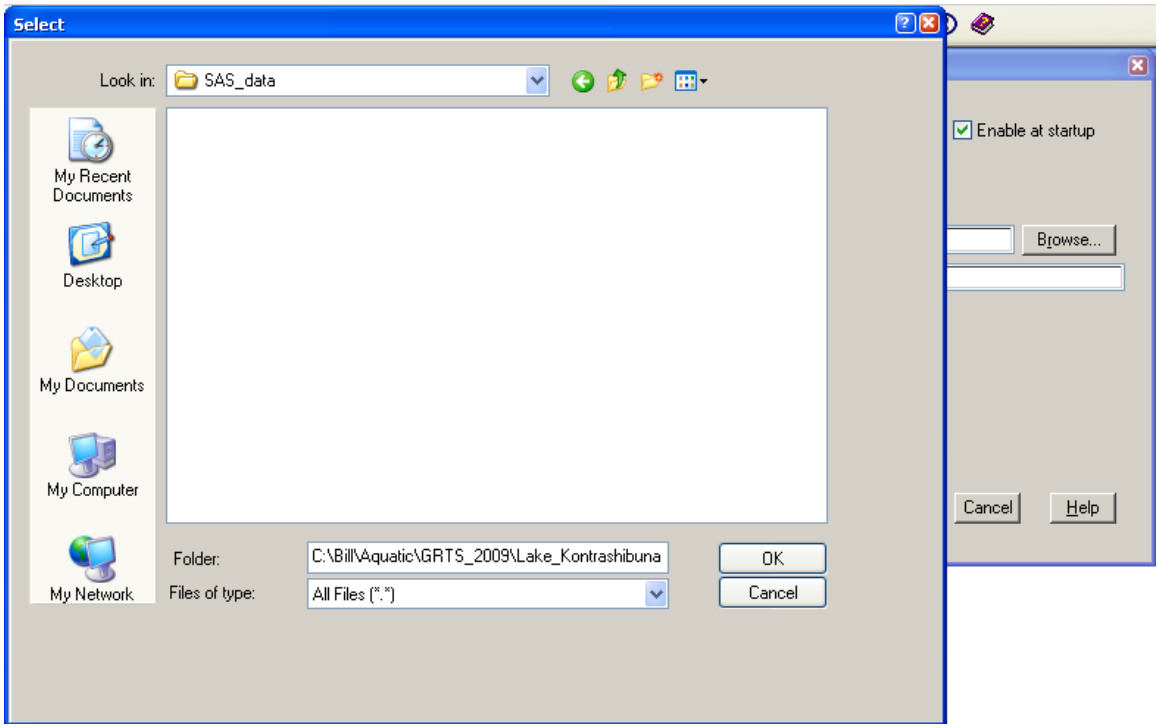
The user can name these folders whatever he/she wishes, but should create them for each lake sampled (e.g., Brooks Lake, Lake Kontrashibuna) and, if desired, by the year the GRTS sample is chosen.

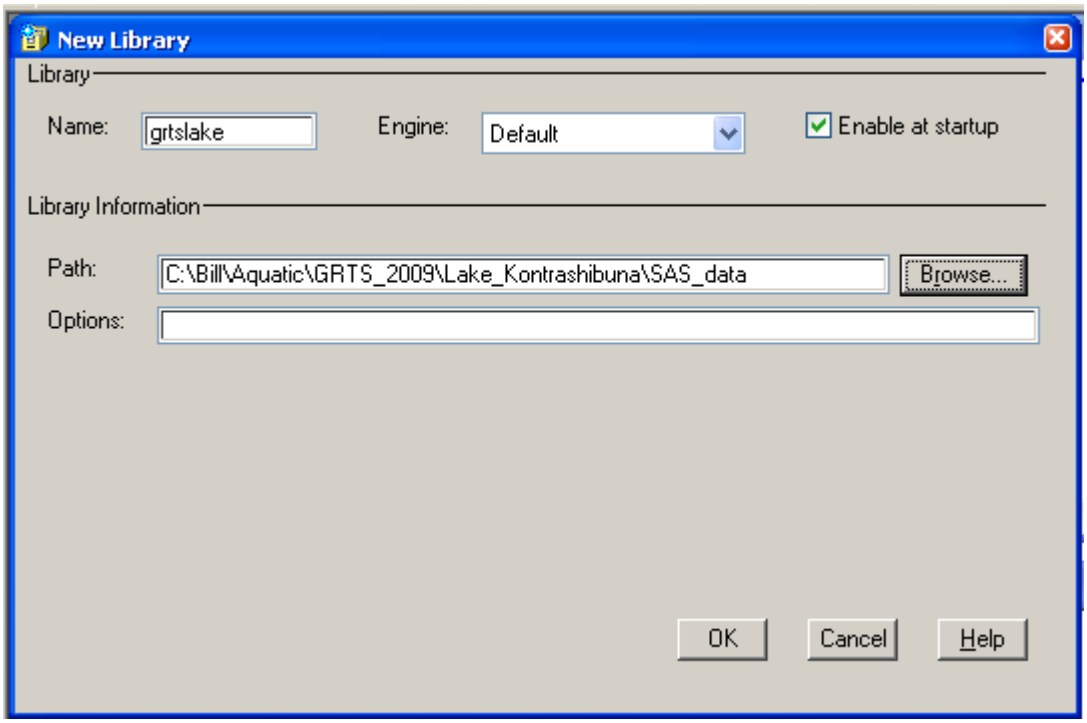
Step 3: Create a SAS library to house the SAS files generated in the next steps.

3a: Double-click on the SAS icon to start the program. Click on the *Add New Library* button in the top tool bar and the following pop-up window appears.



3b: Enter a name for the SAS library ("grtslake" in this example), click on the box to the left of *Enable at startup*, click on the *Browse...* button, navigate to the place on the C-drive or relevant drive where the SAS_data subfolder is located, select it, and click *OK*. SAS library names are limited to a maximum of 8 characters.



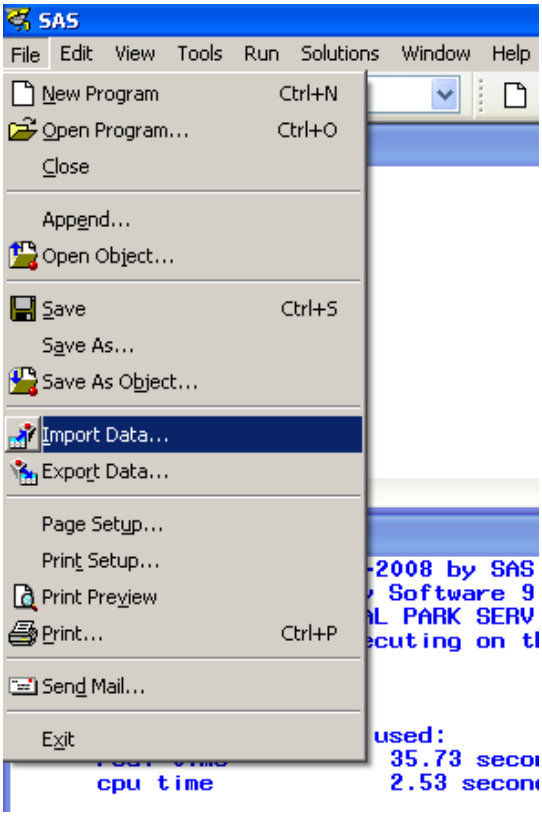


Step 4: Import the file(s) created in **Step 1** into SAS to convert it/them to the input format and file format required by S-DRAW.

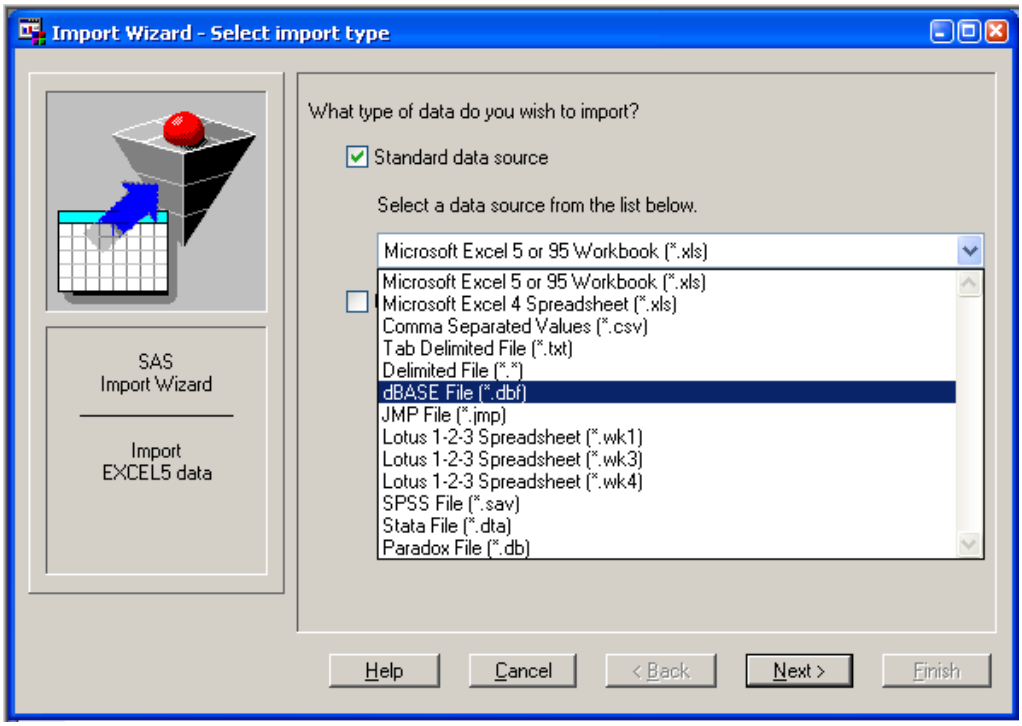
(Note: Later versions of MS Excel and MS Access can be saved in an earlier file format, e.g., an Excel 97 file can be saved as an Excel 95 file. The SAS *Import Wizard* then can be used to import the MS Excel 95 file as described in **Step 4a1** and the user can proceed to **Step 4b.**)

4a1: For file formats except MS Excel 97 and later or MS Access 97 and later, use the *Import Wizard* in SAS to import the file(s) created in **Step 1**, convert it/them to SAS file format(s), and assign it/them to a SAS library.

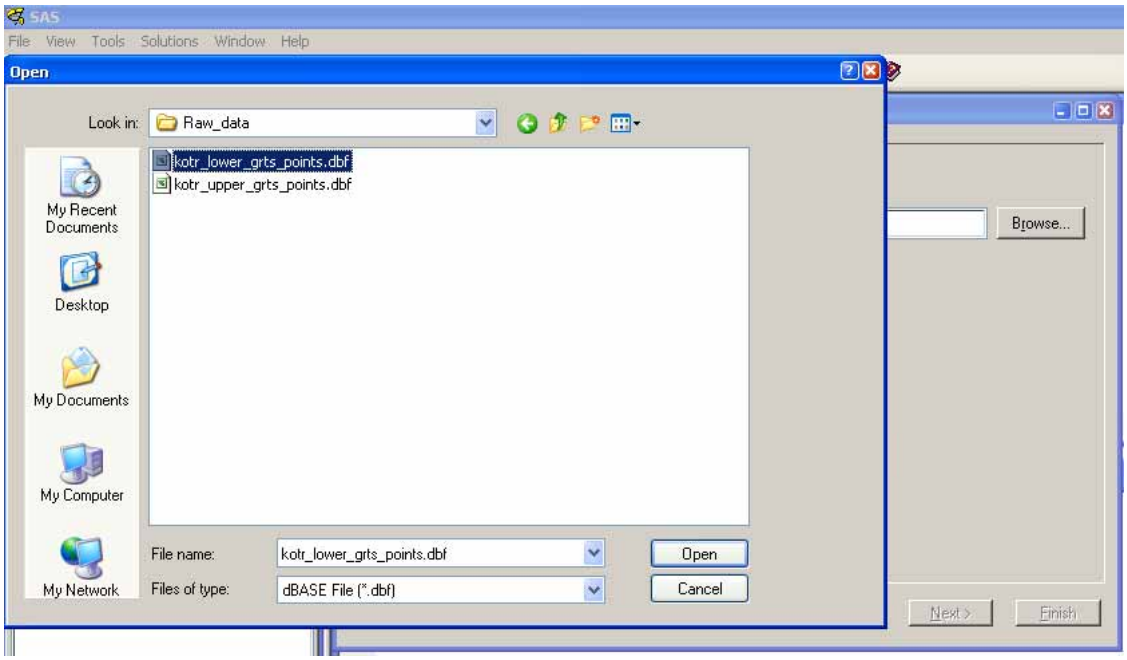
4a1-i: Double-click on the SAS icon to start the program if it is not already running. Select *Import Data...* from the *File* drop-down menu.

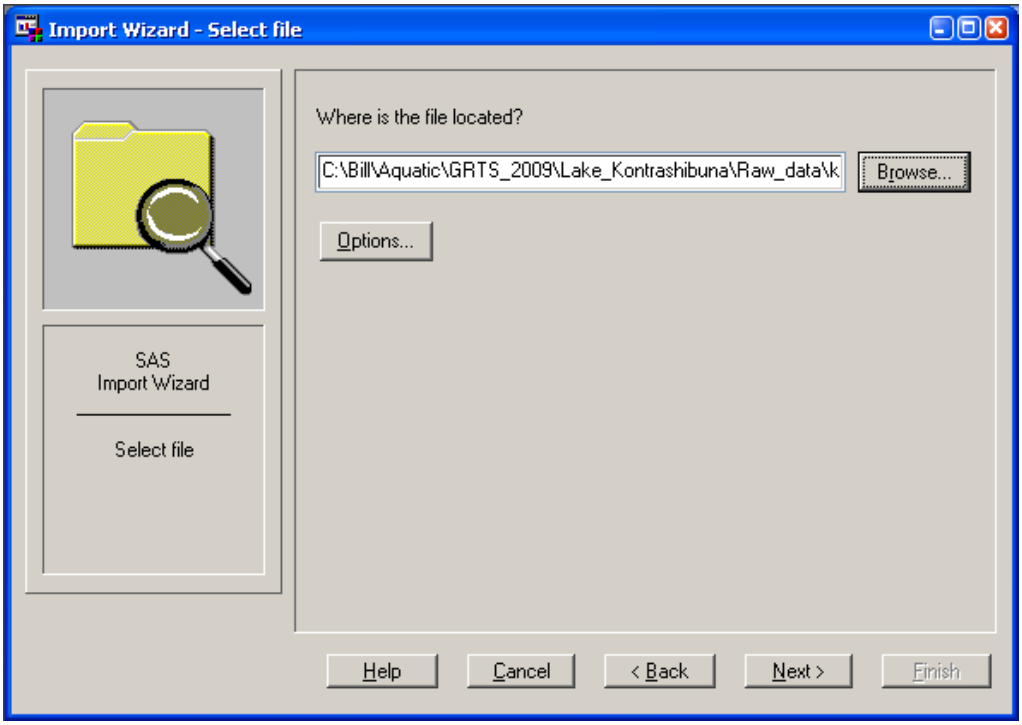


4a1-ii: Select the relevant file format from the drop-down list in the middle of the pop-up window and click on the *Next>* button. In this example, we will be importing .dbf files.

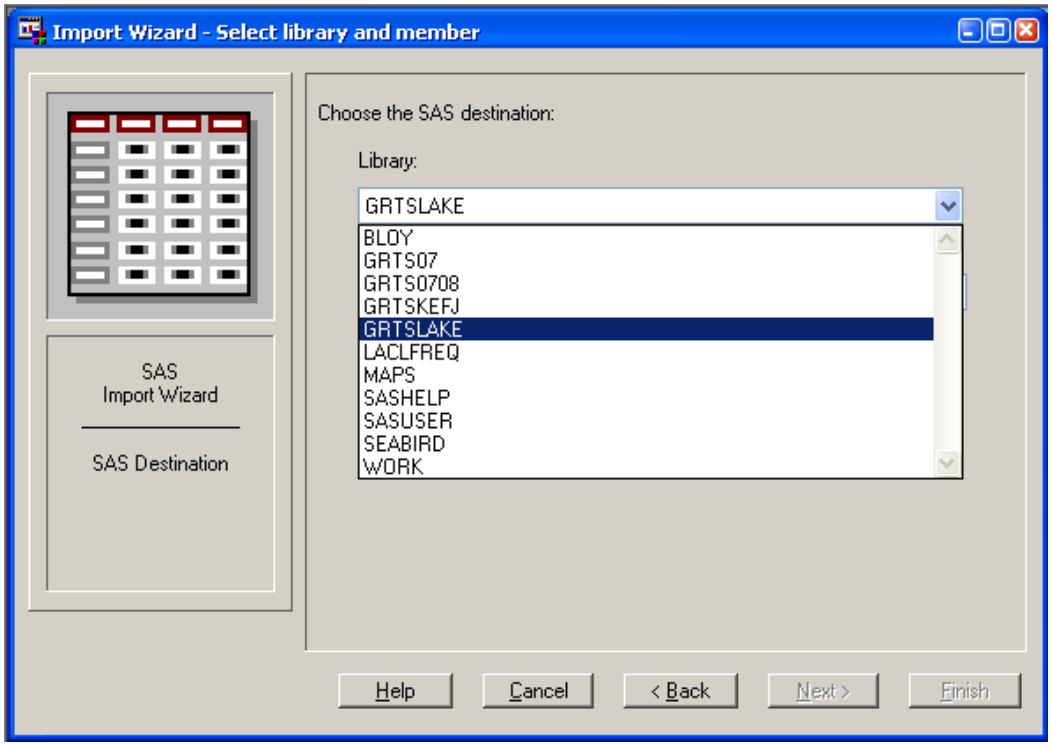


4a1-iii: The next pop-up window asks you to browse to the drive location containing the file you would like to import. Click on the *Browse...* button, navigate to the file's location on the drive, select the file, and click on the *Next>* button.

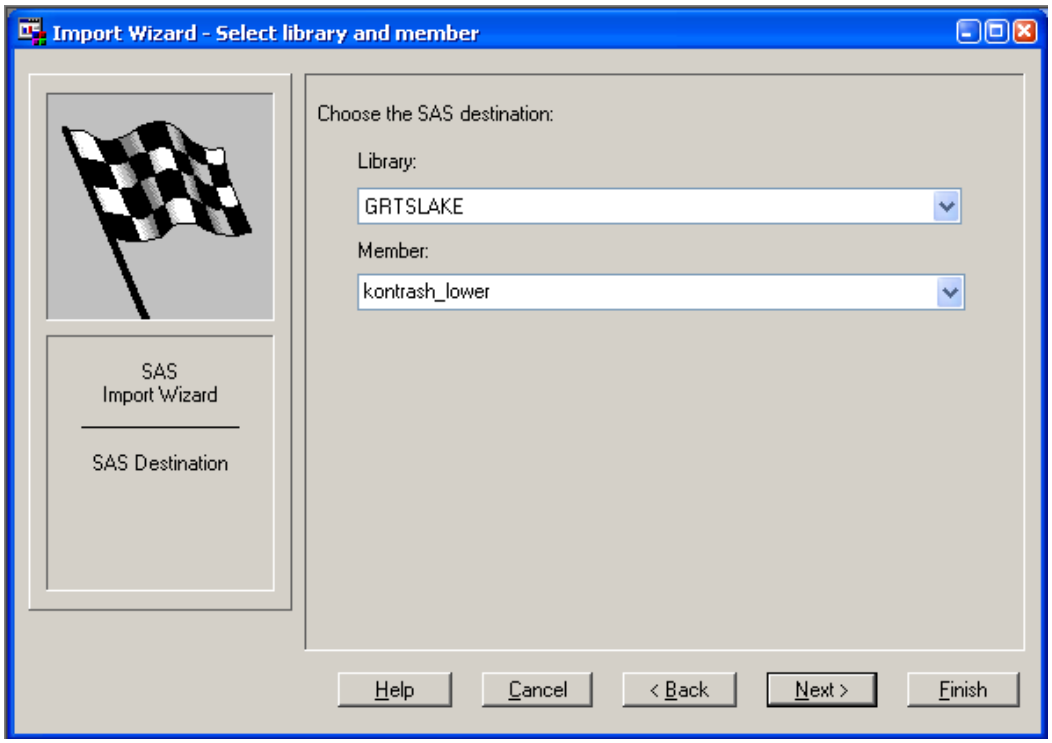




4a1-iv: The next pop-up window allows the user to name the imported file and select a SAS library in which to store this file in SAS file format. Select the SAS library created in **Step 3** by clicking on the down arrow button next to the *Library:* box and clicking on the library name. (Note: the list of libraries to choose from will vary depending on how many have been previously created.)



4a1-v: Click in the box under *Member:*, enter a name for the imported file (e.g., "Kontrash_lower" in the example below), and click on the *Finish*> button.



4a1-vi: Repeat the previous steps in **4a1.** for importing additional files.

4a2: For file formats MS Excel 97 and later or MS Access 97 and later, use SAS PC files server to import them.

Perform the following steps to install the PC files server.

4a2-i: Download the PC files server program from the following location to your choice of directory on your PC/laptop that is going to run this application.

ftp://ftp.sas.com/techsup/download/blind/zqjpcfileserver.zip

4a2-ii: Unzip the zqjpcfileserver.zip file on your pc, it will unzip to the pcfilesrv__9210__prt__xx__sp0__1 subdirectory where you stored the zip file.

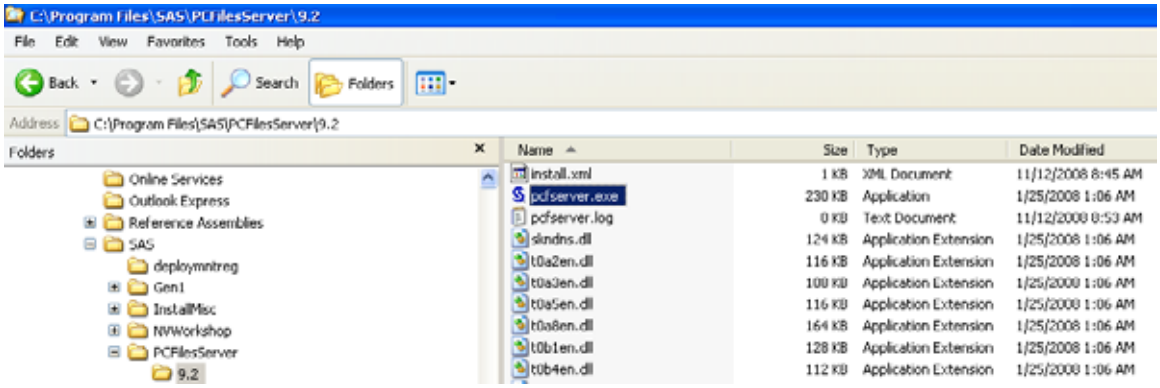
4a2-iii: In the unzipped directory pcfilesrv__9210__prt__xx__sp0__1, double click on the setup.exe. This will start the install.

4a2-iv: The setup.exe will install the PC files server in the C:\Program Files\SAS\PCFilesServer directory.

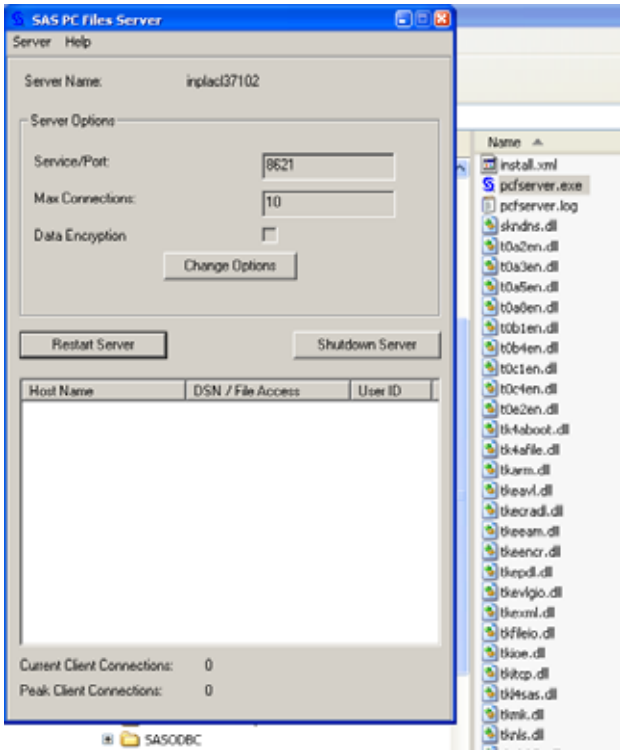
4a2-v: Start the PC files server in one of two ways.

a. Select START=>Programs=>SAS=>PC files server

b. Go to the C:\Program Files\SAS\PCFilesServer\9.2 directory and double click on the PCFILESERVER.EXE program.



4a2-vi: After starting up the .exe, the PC files server window will pop up. This window contains the server name (e.g., 'inplacl37102' for the laptop above) and Port Number (i.e., 8621) that will be needed in the SAS code in Step 7. DO NOT CLOSE the PC files server window during the import/export procedure – it has to be running for the code in **Step 4a2-vii** to work.



4a2-vii: To use the PC files server to import an MS Excel file, copy the following SAS code into the SAS Editor window, modify as needed, and click on the Run button in the top toolbar:

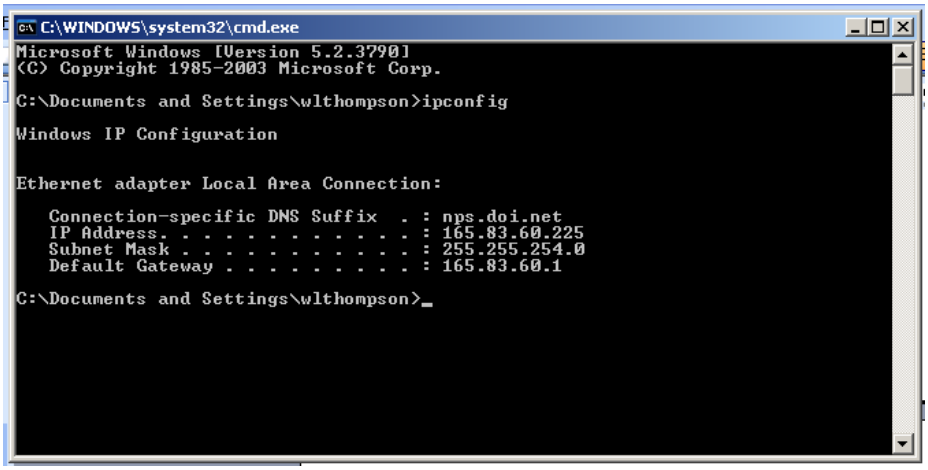
```
proc import dbms=excelcs
out=yoursasdata
datafile="yourdirectory\yourfile.xls" replace;
port=8621;
server="yourpcname";
sheet="yoursheet";
run;
quit;
```

The “out=” statement specifies the SAS library name (if relevant) and SAS data file name. The “datafile=” statement indicates the name of the MS Excel file that is being imported and its location on the drive. The “sheet=” statement specifies the name of the particular sheet that is to be imported from the MS Excel spreadsheet.

Here is example SAS code, where the sheet "freq_toSAS" in the MS Excel file "LACL_GRTS_2007_2008_CoverFreq_SAS_080923.xls" is converted to a SAS data file "freqdata" and saved to the SAS library "laclfreq":

```
proc import dbms=excelcs
 out=laclfreq.freqdata
 datafile="C:\Bill\LACL_GRTS_2007_2008_CoverFreq_SAS_080923.xls" replace;
 server="inplacl37102";
 port=8621;
 sheet="freq_toSAS";
 run;
 quit;
```

(Note: The names above should be in double quotes; SAS will return an error in the log window if they're placed within single quotes. Also, if the server name is longer than 31 characters, you will receive a “Failed to connect to the Server” error message in the SAS log window. If this occurs, you will need to replace the server name with your computer’s IP address. You can find the IP address by typing in “cmd” (without quotes) in the START=>RUN window and clicking OK. This will bring up a DOS window. Type in “ipconfig” (without quotes) after the DOS prompt and hit return. The IP address should be listed in a DOS window similar to the one below. Close down the DOS window by clicking on the “x” in the upper right corner.)



Use the following SAS code to import an MS Access file.

```
proc import dbms=accesscs
  out=yoursasdata
  datatable=youraccesstable;
  database="yourdirectory\yourfile.mdb";
  server="yourpcname";
  port=8621;
  run;
  quit;
```

4b: Convert the SAS file(s) created in **Step 4a1** or **4a2** to generate input formats that can be read by S-DRAW and save them to the SAS library created in **Step 3**. This example uses the "UTM_x-coordinate UTM_y-coordinate Sample_Point_ID" style input format in S-DRAW but other input formats are available depending on how the sample is chosen; see the S-DRAW User’s Guide (SDRAW_users_guide.pdf) in http://www.west-inc.com/programs/S-Draw1b.zip for details.

4b1: Click on the SAS Explorer icon on the top tool bar to view the file(s) created in **Step 4a1** or **4a2** to ensure data are correct and to check the column variable names, which will be used in SAS code below.

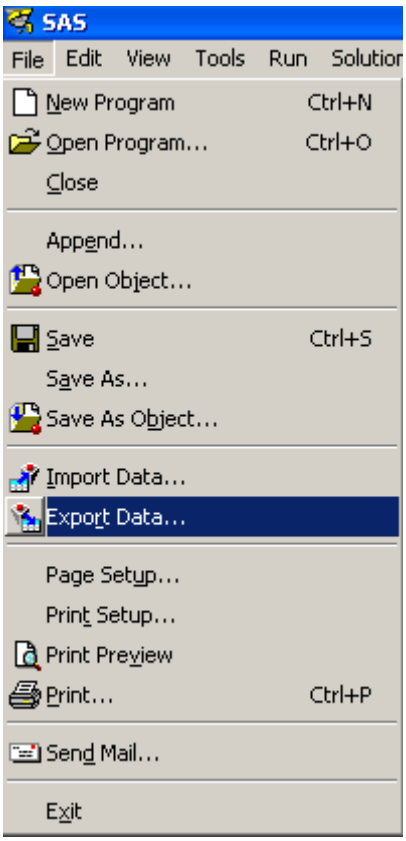
4b2: Copy and paste the following lines of SAS code into the SAS Editor window, modify as needed, and click on the Run button in the top toolbar. The only modifications will be to the top lines of code beginning with "%let"; see the instructions after the asterisk on each line. (Note: text between an asterisk and a semi-colon is treated as a comment by SAS and hence will be ignored.)

```
%let inpfile=grtslake.kontrash_lower;  * to the right of the equal sign,
                                         specify the name of SAS library
                                         (before the period) and the name of
                                         SAS file containing grid points
                                         (after the period);
%let id=uniqueid;                      * to the right of the equal sign,
                                         specify the variable name containing
                                         the unique id of each grid point.
                                         If there is not a variable for this,
                                         specify "_N_" (without quotes);
%let utm_x=xcoord_utm;                 * to the right of the equal sign,
                                         specify the variable name containing
                                         the UTM x-coordinate of each grid
                                         point;
%let utm_y=ycoord_utm;                 * to the right of the equal sign,
                                         specify the variable name containing
                                         the UTM y-coordinate of each grid
                                         point;
%let outfile=grtslake.kontr_low_SDRAW; * to the right of the equal sign,
                                         specify the name of SAS library
                                         (before the period) and the name of
                                         SAS file of grid points in the input
                                         format of S-DRAW (after the period);

***** DO NOT CHANGE ANYTHING BEYOND THIS POINT ***
***** UNLESS YOU KNOW WHAT YOU ARE DOING.      ***;

data &outfile;
  set &inpfile;
  id=&id;
  keep &utm_x &utm_y id;
run;
```

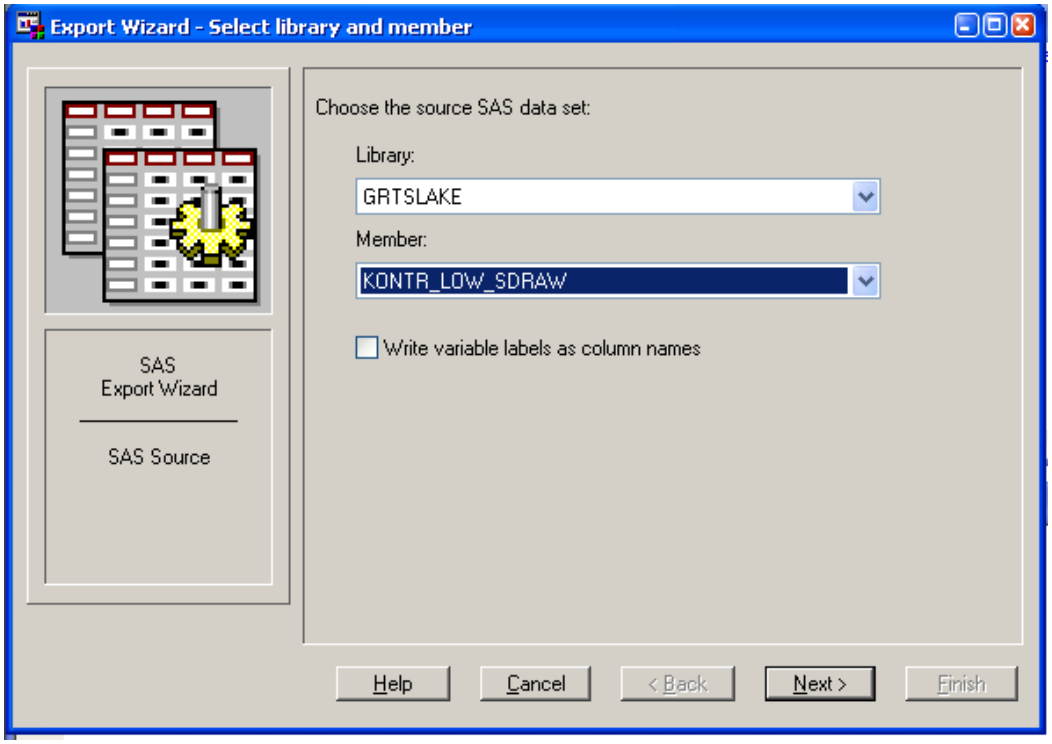
The above code should be rerun for each file of grid points, with file names modified accordingly.

Step 5: Export the SAS file(s) created in **Step 4** as space-delimited text files so they can be read into S-DRAW.

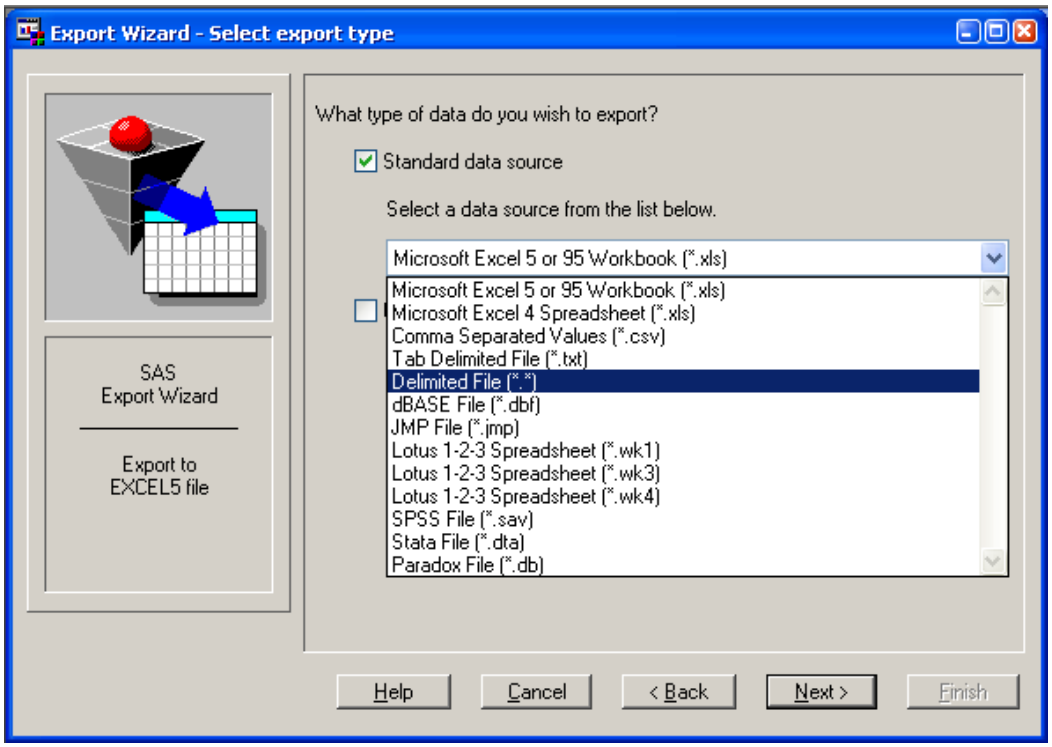
5a: Select *Export Data...* from the *File* drop-down menu.



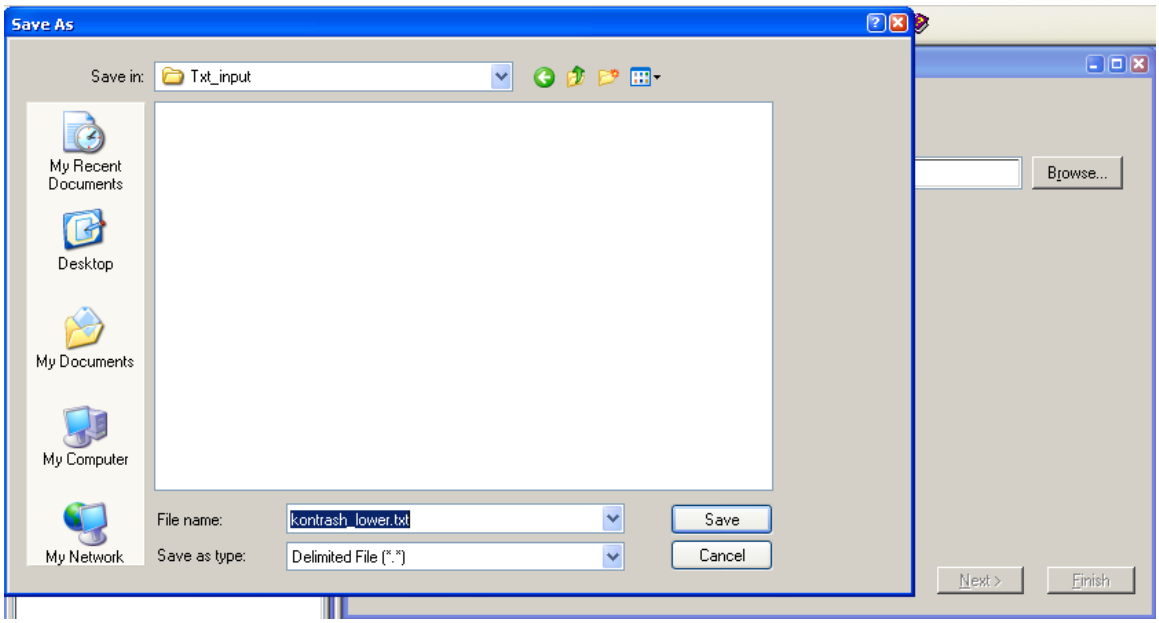
5b: Use the drop-down arrow buttons next to the *Library:* box to select the SAS library (**Step 3**) and next to the *Member:* box to select the SAS file produced in **Step 4**. Click on the *Next>* button.



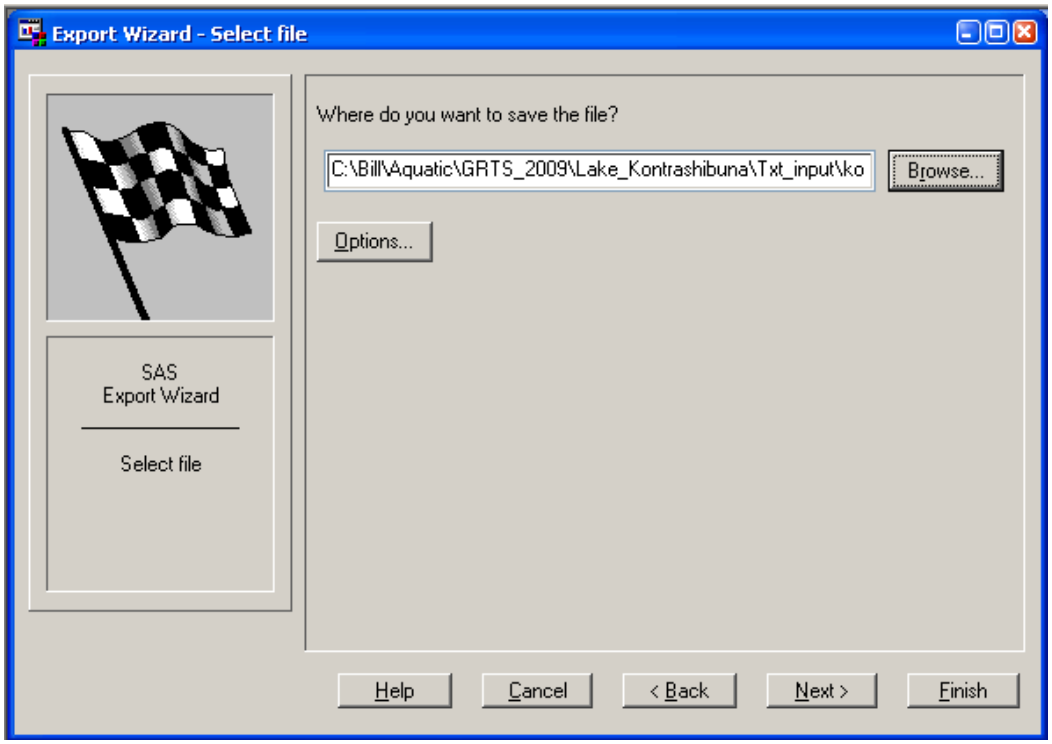
5c: Select *Delimited File (*.*)* from the drop-down menu. Click on the *Next>* button.



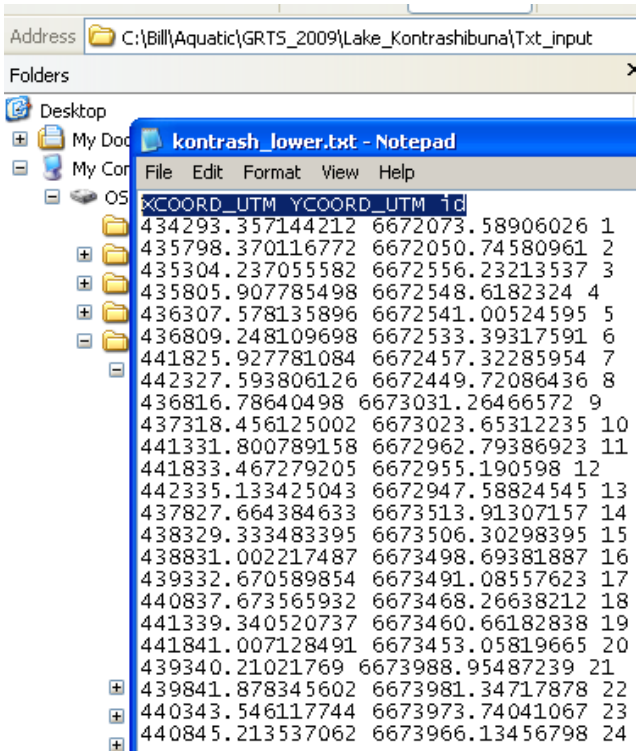
5d: Click on the *Browse...* button, navigate to the Txt_input folder (**Step 2**) on the drive, type in the name of the text file (kontrash_lower.txt in this example) in the *File Name:* box, and click on the *Save* button.



5e: Click on the *Finish* button to export the file.



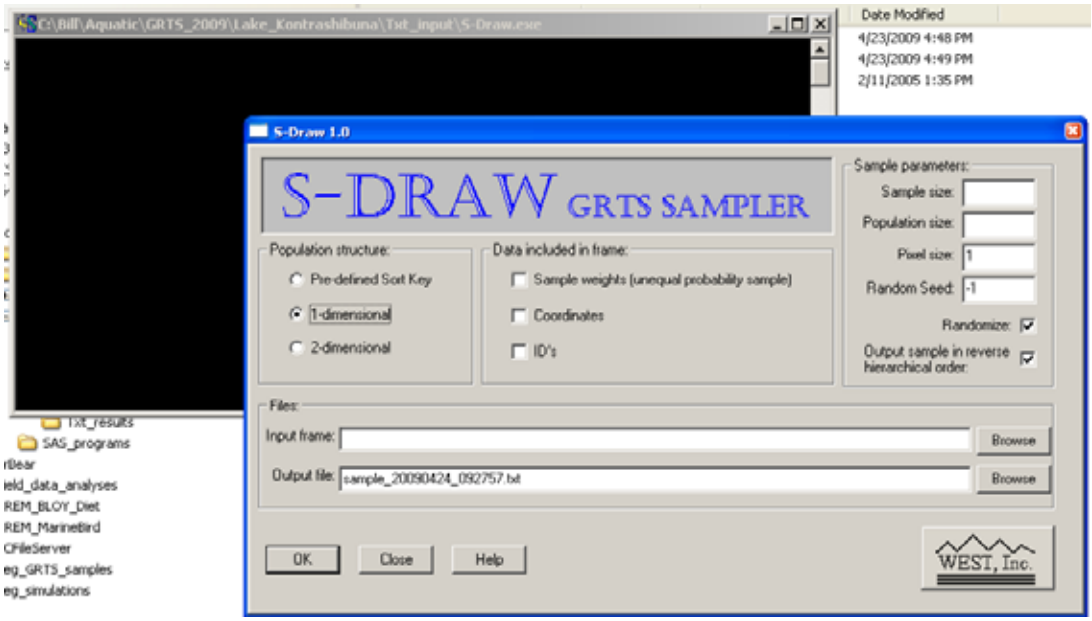
5f: The .txt file produced above will need to have the header information (variable names) removed from the file before it can be read into S-DRAW. Use Windows Explorer or other means to navigate to the Txt_input folder on the drive. Use Notepad or other word processor to open the .txt file, highlight the variable names in the header, delete them, and save the file in its original .txt format.



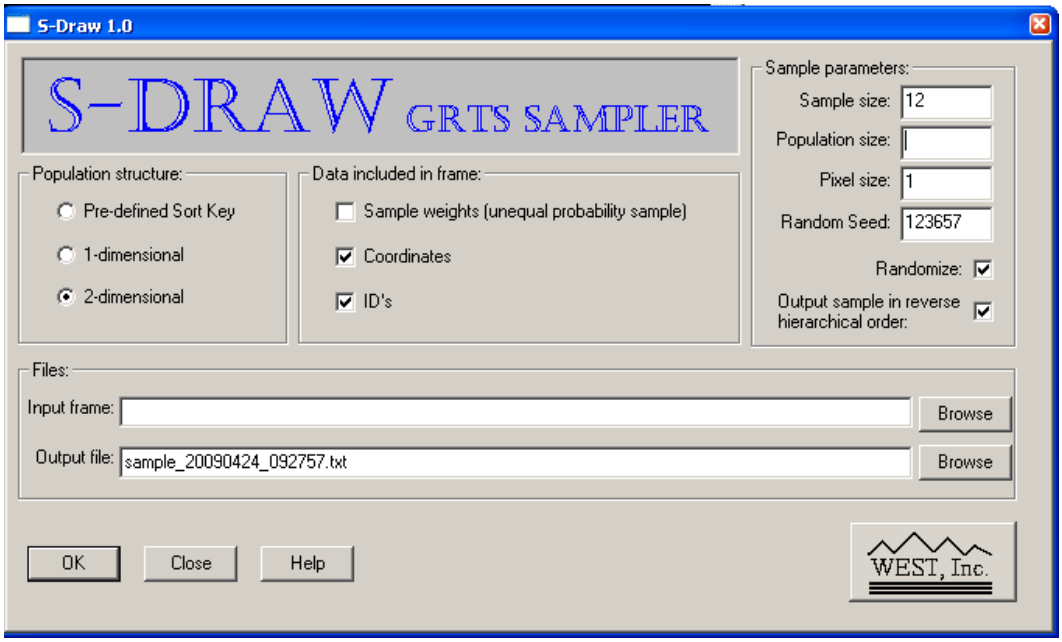
Step 6: Use S-DRAW to select GRTS samples of grid points from each .txt file created in **Step 5**.

6a: Place the S-Draw.exe file in the Txt_input folder on the relevant drive.

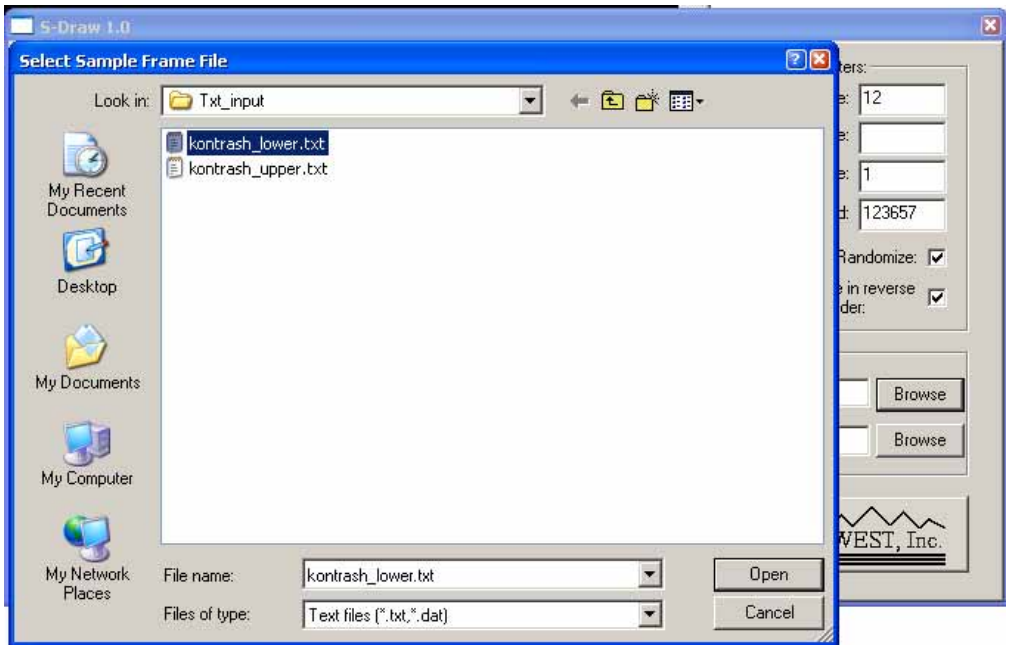
6b: Double-click on S-Draw.exe to initiate the program. The following window pops up.



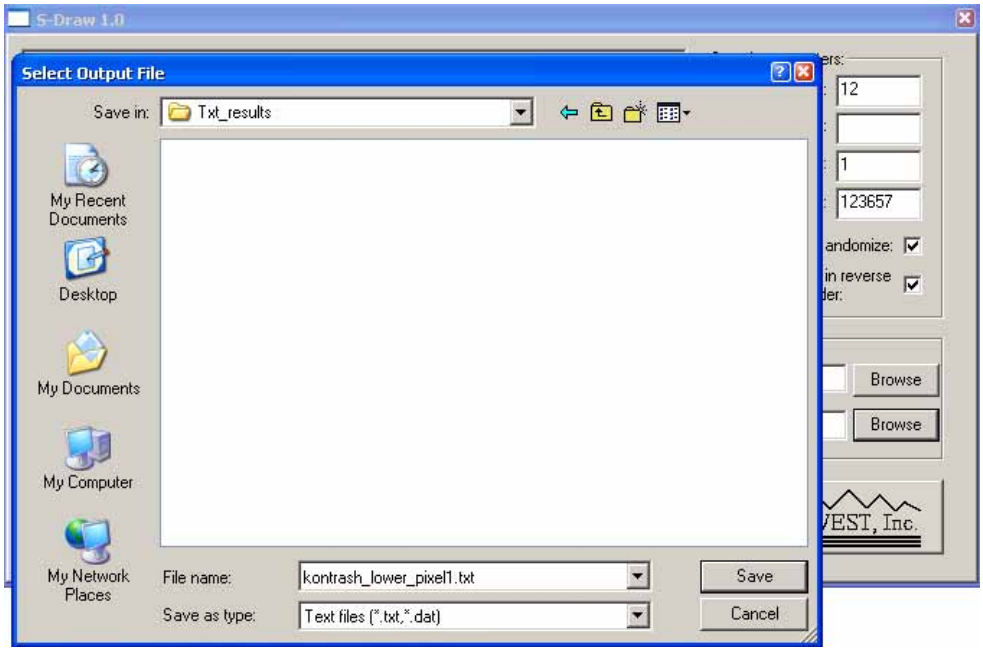
6c: Click on *2-dimensional*, *Coordinates*, and *ID's*. Type in the correct values for *Sample size* (=15 in this example), *Pixel size* (=1 as default) and *Random Seed* (choose a number between - 2 billion and + 2 billion or use the default -1). Use the default settings for *Randomize* and *Output sample in reverse hierarchical order*. The user can enter the total grid points in the input file into *Population Size* or leave this box blank and allow the program to enter this value. A *Random Seed* value of -1 draws a random number from the computer's clock. A GRTS sample can be replicated by using the same random number seed.



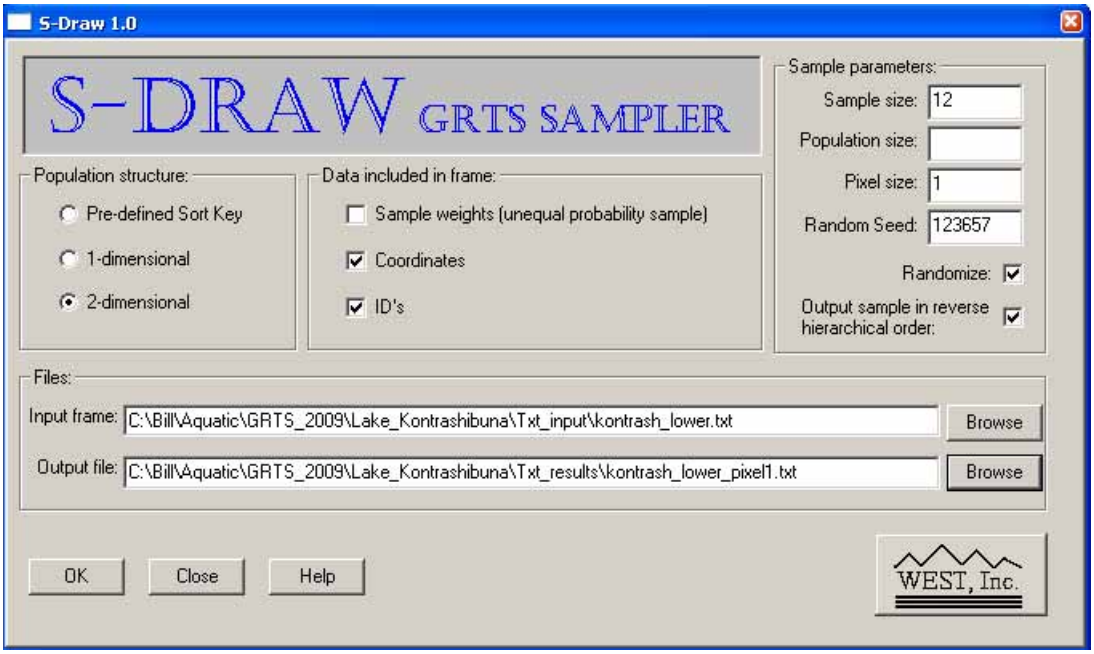
6d: Click on the *Browse* button next to the *Input frame* box, navigate to the .txt file created in **Step 5** (e.g., kontrash_lower.txt), single click on the file, and click on the *Open* button.



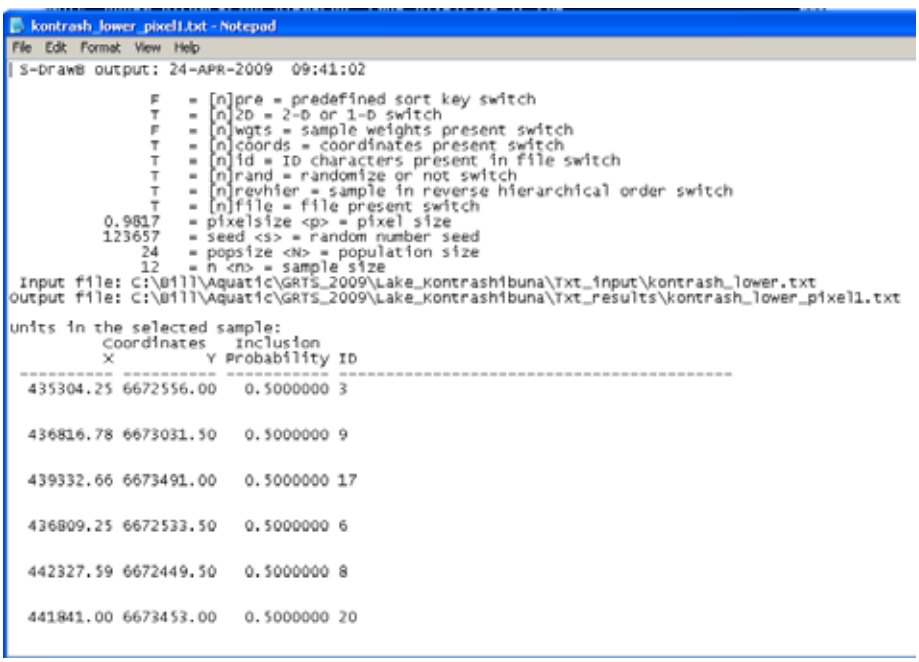
6e: Click on the *Browse* button next to the *Output file* box, navigate to the folder where you would like to save the output file (e.g., Txt_results from **Step 2**), type in the name of the output file (e.g., kontrash_lower_pixel1.txt), and click on the *Save* button.



6f: Click on the *OK* button to run the program and generate an output file containing the GRTS sample of grid points.



S-DRAW creates an output .txt file with the following information (in part).



```
kontrash_lower_pixel1.txt - Notepad
File  Edit  Format  View  Help
S-DrawB output: 24-APR-2009  09:41:02

              F   = [n]pre = predefined sort key switch
              T   = [n]2D = 2-D or 1-D switch
              F   = [n]wgts = sample weights present switch
              T   = [n]coords = coordinates present switch
              T   = [n]id = ID characters present in file switch
              T   = [n]rand = randomize or not switch
              T   = [n]revhier = sample in reverse hierarchical order switch
              T   = [n]file = file present switch
         0.9817   = pixelsize <p> = pixel size
         123657   = seed <s> = random number seed
             24   = popsize <N> = population size
             12   = n <n> = sample size
 Input file: C:\Bill\Aquatic\GRTS_2009\Lake_Kontrashibuna\Txt_input\kontrash_lower.txt
output file: C:\Bill\Aquatic\GRTS_2009\Lake_Kontrashibuna\Txt_results\kontrash_lower_pixel1.txt

units in the selected sample:
         Coordinates   Inclusion
         X          Y Probability ID
 ---------- ---------- ----------- ----------------------------------------
  435304.25 6672556.00   0.5000000 3

  436816.78 6673031.50   0.5000000 9

  439332.66 6673491.00   0.5000000 17

  436809.25 6672533.50   0.5000000 6

  442327.59 6672449.50   0.5000000 8

  441841.00 6673453.00   0.5000000 20
```

The UTM coordinates are rounded to 2 decimal places in the output file. Also, selecting the best pixel size to produce a spatially balanced sample is not straightforward. The default value of 1 will usually suffice, but it is recommended to reselect GRTS samples at other pixel sizes (e.g., 0.01, 10, and 25) for each input file to provide alternatives to review in case a pixel size of 1 is insufficient. Hence, the pixel size was included in the name of the output file in this example (i.e., kontrash_lower_pixel1.txt). Output file names produced from additional GRTS samples from the same input file would include the pixel size used (e.g., kontrash_lower_pixel01.txt for a pixel size of 0.01).

6g: Repeat the previous steps for each input file and pixel size.

Step 7: Use SAS to import the S-DRAW output files produced in **Step 6**, remove the header information from these files, and export them as .dbf files that can be read into ArcGIS 9.2.

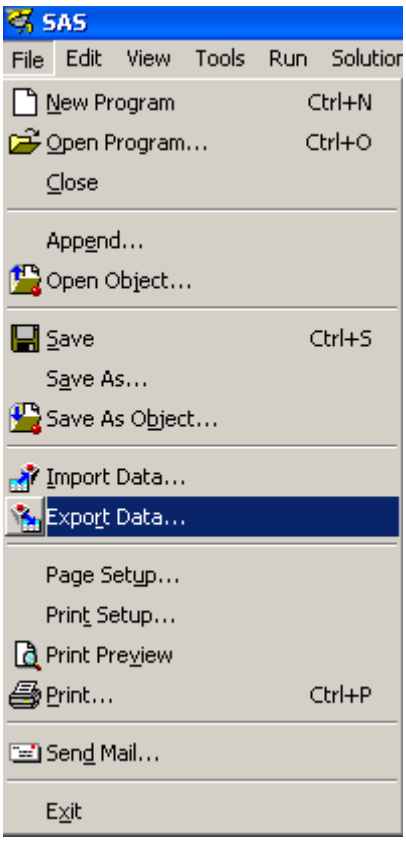
7a: Copy and paste the following lines of SAS code into the SAS Editor window, modify as needed, and click on the Run button in the top toolbar. The only modifications will be to the top lines of code beginning with "%let" and to the directory path/file name inserted in double quotes after the *infile* statement farther down the program. See the instructions after the asterisk on each line. This SAS code should be modified accordingly and rerun for each S-DRAW output file produced in **Step 6**.

```
%let outpfile=grtslake.kontr_low_pix1; * to the right of the equal sign,
                                         specify the name of the SAS library
                                         (before the period) and the name of
                                         of the SAS-formatted file
                                         containing the GRTS sample of grid
                                         points (after the period);
%let inpfile=grtslake.kontr_low_SDRAW; * to the right of the equal sign,
                                         specify the name of SAS library
                                         (before the period) and the name of
                                         SAS file of grid points in the input
                                         format of S-DRAW (after the period)
                                         that was created in Step 4b;
%let utm_x=xcoord_utm;                 * to the right of the equal sign,
                                         specify the variable name containing
                                         the UTM x-coordinate of each grid
                                         point;
%let utm_y=ycoord_utm;                 * to the right of the equal sign,
                                         specify the variable name containing
                                         the UTM y-coordinate of each grid
                                         point;

options noxwait noxsync;               * do not modify this code;

data a;                                * do not modify this code;
  %let _EFIERR_=0;                     * do not modify this code;


**** After the infile statement and within the double quotes, insert the
**** directory path and relevant S-DRAW output text file name produced in
**** Step 6. Do not modify the "delimiter" statement or any code following
**** it.;

infile

"C:\Bill\Aquatic\GRTS_2009\Lake_Kontrashibuna\Txt_results\kontrash_lower_pixe
l1.txt"


delimiter = ' ' MISSOVER DSD lrecl=32767 firstobs=21 ;

*********************************************************
**** DO NOT CHANGE ANYTHING BEYOND THIS POINT UNLESS ****
**** YOU KNOW WHAT YOU ARE DOING.                    ****
*********************************************************;

informat VAR1 $8. ; informat S_DrawB $13. ; informat XCoord 14.2 ;
informat YCoord 14.2 ; informat VAR5 $55. ; informat _3_55_41 $1. ;
informat Inclprob 9.8 ; informat ID 10. ; informat VAR9 $1. ;
```

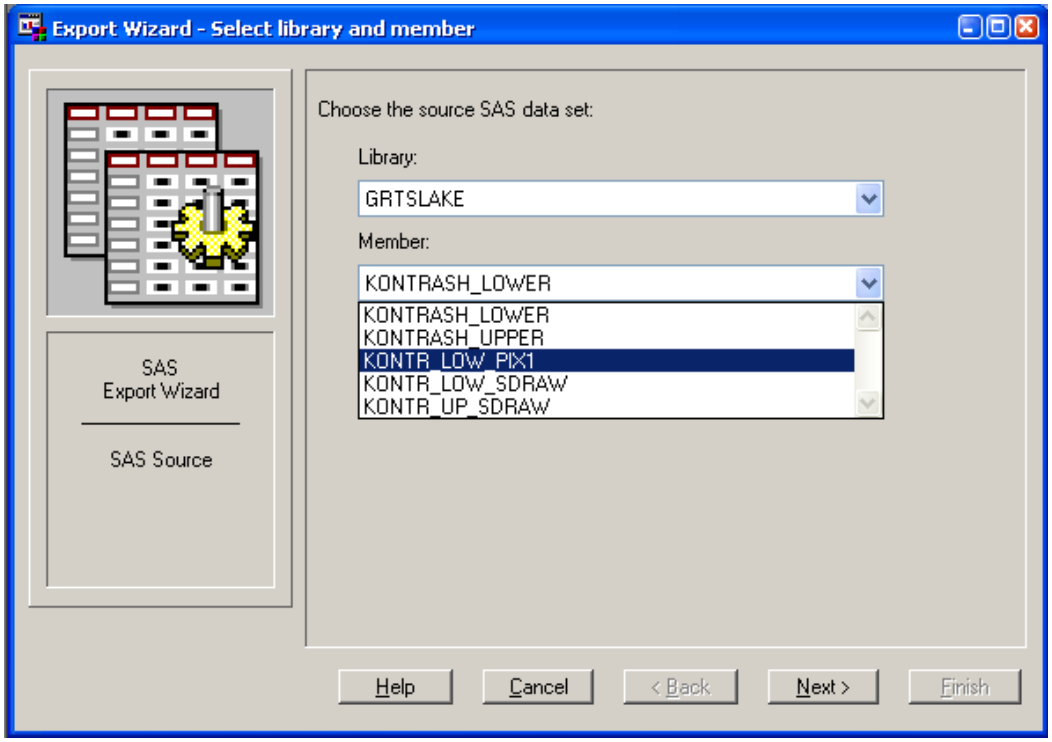
```
informat VAR10 $1. ; informat VAR11 $14. ; informat VAR12 $1. ;
informat VAR13 $1. ; informat VAR14 $12. ; informat VAR15 $12. ;
informat VAR16 $4. ; informat VAR17 $1. ; informat VAR18 $13. ;
informat VAR19 $5. ; informat VAR20 $12. ; informat VAR21 $4. ;
informat VAR22 $14. ; informat VAR23 $13. ; informat VAR24 $9. ;
informat VAR25 $15. ; informat VAR26 $6. ; informat VAR27 $6. ;

format VAR1 $8. ; format S_DrawB $13. ; format XCoord 14.2 ;
format YCoord 14.2 ; format VAR5 $55. ; format _3_55_41 $1. ;
format Inclprob 9.8 ; format ID 10. ; format VAR9 $1. ; format VAR10 $1. ;
format VAR11 $14. ; format VAR12 $1. ; format VAR13 $1. ; format VAR14 $12. ;
format VAR15 $12. ; format VAR16 $4. ; format VAR17 $1. ; format VAR18 $13. ;
format VAR19 $5. ; format VAR20 $12. ; format VAR21 $4. ;format VAR22 $14. ;
format VAR23 $13. ; format VAR24 $9. ; format VAR25 $15. ; format VAR26 $6. ;
format VAR27 $6. ;

input VAR1 $ S_DrawB $ XCoord YCoord VAR5 $ _3_55_41 $ Inclprob ID VAR9
$ VAR10 $ VAR11 $ VAR12 $ VAR13 $ VAR14 $ VAR15 $ VAR16 $ VAR17 $ VAR18
$ VAR19 $ VAR20 $ VAR21 $ VAR22 $ VAR23 $ VAR24 $ VAR25 $ VAR26 $ VAR27 $ ;
if _ERROR_ then call symputx('_EFIERR_',1);
&utm_x=xcoord;
&utm_y=ycoord;
keep &utm_x &utm_y ID;
run;

data b;
  set a;
  pt_order=_N_;
run;
data b1;
  set b;
  id_drop=1;
  keep pt_order id id_drop;
  proc sort;
     by id;
run;
data &outpfile;
  merge &inpfile b1;
    by id;
  if id_drop=1;
  drop id_drop id;
  proc sort;
    by pt_order;
run;
```

Step 7b: Use the Export Wizard in SAS to convert the SAS-formatted output files containing GRTS-chosen points that were generated in **Step 7a** to .dbf formats and place them in the DBF_results folder (**Step 2**).

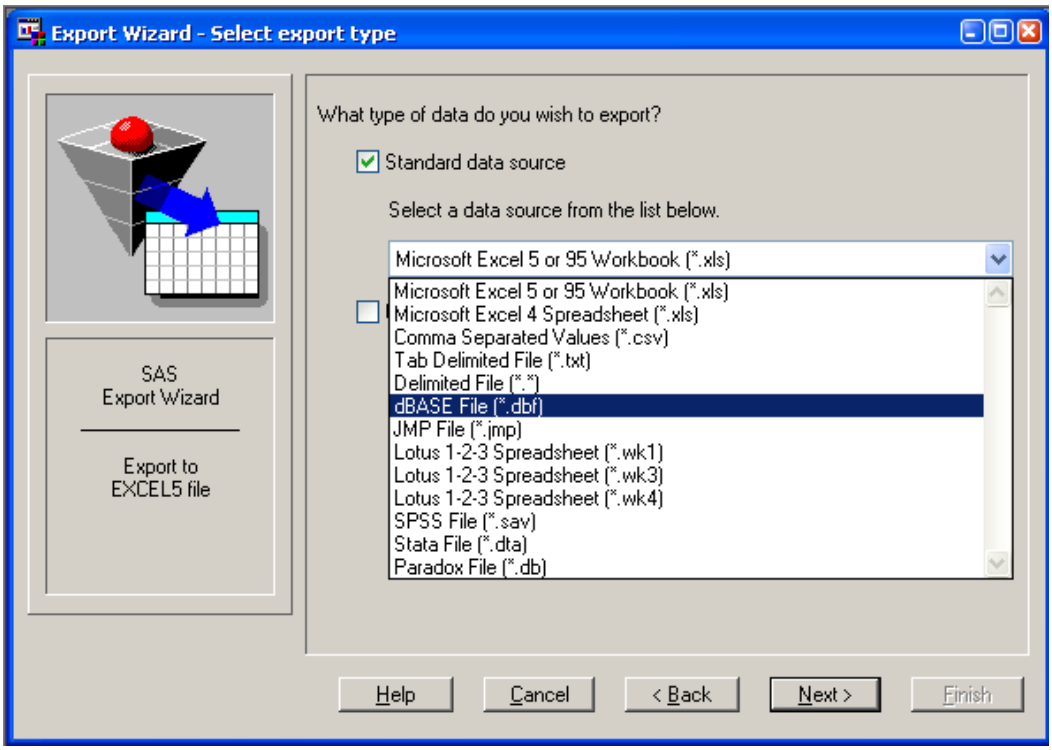
7b-i: Select *Export Data...* from the *File* drop-down menu.



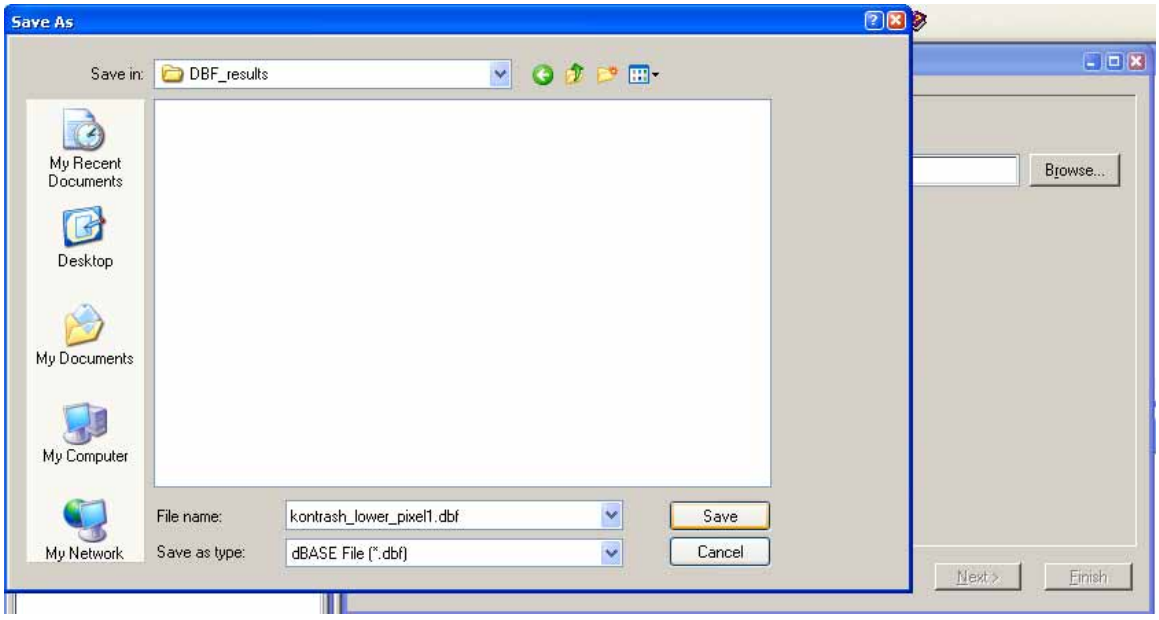
7b-ii: Use the drop-down arrow buttons next to the *Library:* box to select the SAS library (**Step 3**) and next to the *Member:* box to select the SAS file produced in **Step 7a**. Click on the *Next>* button.



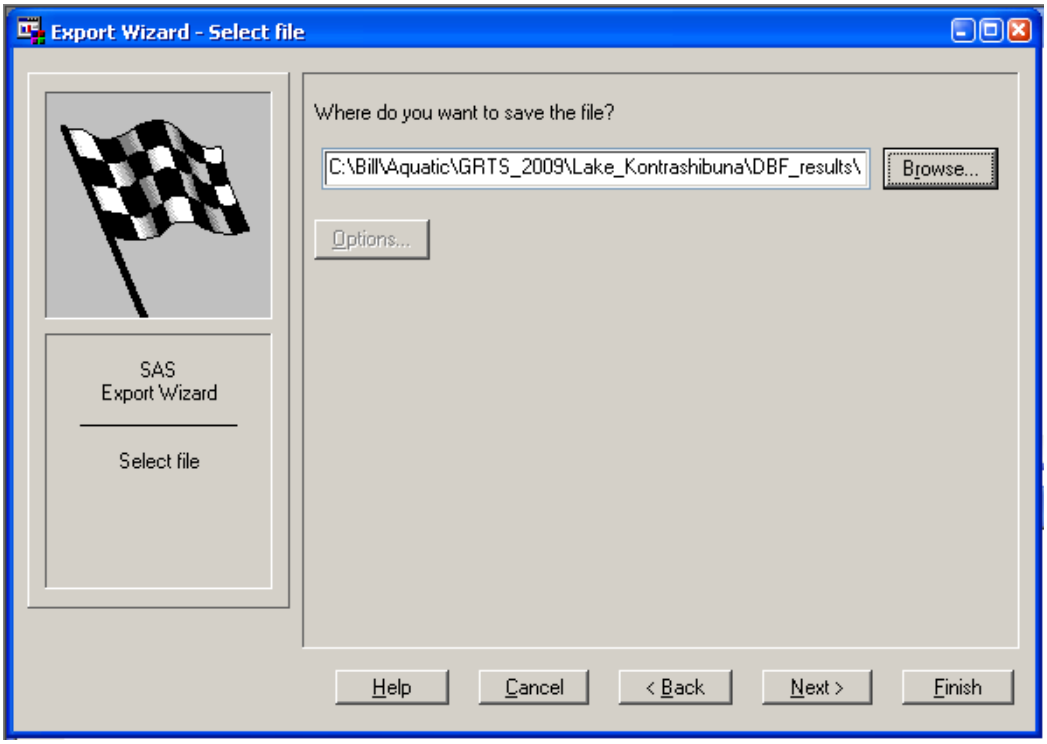
7b-iii: Select the file format (.dbf) for the export file from the drop-down list and click on the *Next>* button.



7b-iv: Click on the *Browse...* button, navigate to the DBF_results folder (**Step 2**) on the drive, type in the name of the text file (kontrash_lower_pixel1.dbf in this example) in the *File Name:* box, and click on the *Save* button.



7b-v: Click on the *Finish* button to export the file. The resulting .dbf file will contain the UTM x-coordinate, UTM y-coordinate and sample order of GRTS points (pt_order).


Export Wizard - Select file
SAS
Export Wizard
Select file
Where do you want to save the file?
C:\Bill\Aquatic\GRTS_2009\Lake_Kontrashibuna\DBF_results\
Browse...
Options...
Help
Cancel
< Back
Next >
Finish

Appendix D: Simulation results for evaluating minimum number of points and grids of points required to detect change in two landcover classes, Lake Clark National Park & Preserve

William L. Thompson, Quantitative Ecologist, Southwest Alaska Network

Introduction

We conducted simulations to investigate the minimum level of change that could be detected when either 20% or 50% of points (plots) associated with two landcover classes were changed across 2 time periods within various elevational zones from the current landcover map for Lake Clark National Park and Preserve (LACL). The remaining points associated with other landcover classes remained unchanged during these 2 time periods. Up to 50 samples of single points, 2 × 2 grids of points, and 3 × 3 grids of points were chosen in each simulation run under a generalized random-tessellation stratified (GRTS; Stevens and Olsen 2004) design from 2 landcover classes occurring at different observed frequencies (0.6% - 61%) within 3 elevation bands (Table D.1). Band 3 was further split into northern and southern portions of LACL. We also used simulations to evaluate effects of 30 m, 60 m, 120 m, and 240 m spacing among points (subplots) within 2 × 2 and 3 × 3 grids. All points in the reduced park-wide grid (sampled population) were spaced 30 m apart.

Methods

The following describes the general steps for performing the simulations:

1. Generate an ACCESS database containing UTM and Albers coordinates, elevation, and landcover class codes for each point deemed accessible in LACL from the existing landcover map.

2. Import the ACCESS database into program SAS (SAS Institute Inc. 2004, 2006) and assign stratum values (Table D.1) to each accessible point. Remove points with >10º slopes to ensure sampled locations will be on relatively flat areas and remove points with unwanted landcover class codes (i.e., water, marine mudflats, and unknown classification). Use SAS PROC SURVEYSELECT to randomly select 20% and 50% of points from each of 2 landcover classes (dwarf shrub tundra and prostrate shrub tundra) that spanned a range of percent frequencies (0.60% to 61%) in accessible areas across the 3 elevational zones. Assign a new landcover class code to the randomly selected point within a given landcover class and place this value in the relevant "20% change" and "50% change" columns while retaining the original landcover class values for all other points. Place the results in a separate file for each landcover class.

3. Use SAS to export the data into .txt files in formats that can be read by freeware program S-DRAW (http://www.west-inc.com/computer.php). Each file should be specific to each elevational zone category.

4. Use program S-DRAW to select 1000 GRTS samples of 50 single points in accessible areas from each elevational zone category. Import the 1000 sample results files for each elevational zone category into SAS.

5. Use SAS to generate 2 × 2 and 3 × 3 grids of points (and their coordinates) of various spacing (30 m, 60 m, 120 m, and 240 m) for each GRTS-selected single point in the results files. Match-merge the grid points by coordinates with the change files produced from Step 2 and assign appropriate attributes to the newly generated grid point records. Note that there may be less than 50 samples of 2 × 2 or 3 × 3 grids per simulation run because of the configuration and fragmentary nature of the access areas, e.g., a grid cannot be generated if the GRTS-selected single point is too close to the access boundary, the elevational zone boundary, the slope boundary (i.e., points on steep slopes were removed), or an adjacent GRTS-selected grid.

6. Use the simple random sample variance estimator in SAS PROC SURVEYMEANS to estimate the proportion of single points that changed landcover class codes from time 1 to time 2, and the associated 90% confidence interval, for each GRTS sample of size 2, 3, 4, …, 50 within each simulation run. Use the cluster sample variance estimator in SAS PROC SURVEYMEANS to estimate the proportion of 2 × 2 and 3 × 3 grid of points that changed landcover class codes from time 1 to time 2, and the associated 90% confidence interval, for each GRTS sample of size 2, 3, 4, …, 50 (or maximum sample size) within each simulation run. These two variance estimators are conservative approximations to the GRTS variance estimator, which is currently not available in SAS. The cluster sample estimator accounts for the spatial dependency of points within sample grids.

7. Compute the percentage of times that the lower 90% confidence limit of the estimated proportion is greater than and/or equal to some specified minimum detectable change (MDC) level for GRTS samples of size 2, 3, 4, …, 50 (or maximum sample size) across all simulations runs for single points (i.e., no./1000) and for grids of points various spacing and configurations (i.e., no./observed maximum with > 250 runs). This percentage represents the probability of detecting an MDC of the specified size based on a given GRTS sample size for each level of true change (Figure A2.1)

An important issue to keep in mind for Step 7 is the difference between the true change and the MDC. As soon as one takes a sample, there is uncertainty associated with the estimate so the change that can be detected (i.e., MDC) will be always less than the true change. Statistical power analysis is based on the null hypothesis of no change, which in this case is the same as assessing whether or not the lower 90% confidence limit is above 0. Note that statistical power increases with increasing effect size (i.e., true change, such as 20% or 50%) because the confidence interval, and hence the lower confidence limit, is shifted away from 0. Nonetheless, statistical power analysis only indicates if there was a *change* at a given level of confidence, unless you assume the cited true change value (model) is correct, i.e., a statistically significant trend equals the true trend value used in power calculations. Thus, it does not provide the *magnitude* of the change, nor does it allow an interpretation of the biological importance of the change level. For instance, it would be unsettling if the analysis only concluded evidence of a change (>0%) when the true change was 50%. Therefore, in this simulation exercise, we compared the lower 90% confidence limit to a range of MDCs to provide information on the magnitude of change that could be detected (i.e., >0%, ≥2.5%, ≥5%, ≥10%, ≥15%, and ≥0.20%) for a true change of either 20% or 50% applied to points with a specific landcover class. For

comparative purposes, an MDC >0% was included in results to show what a traditional "power analysis" would conclude.

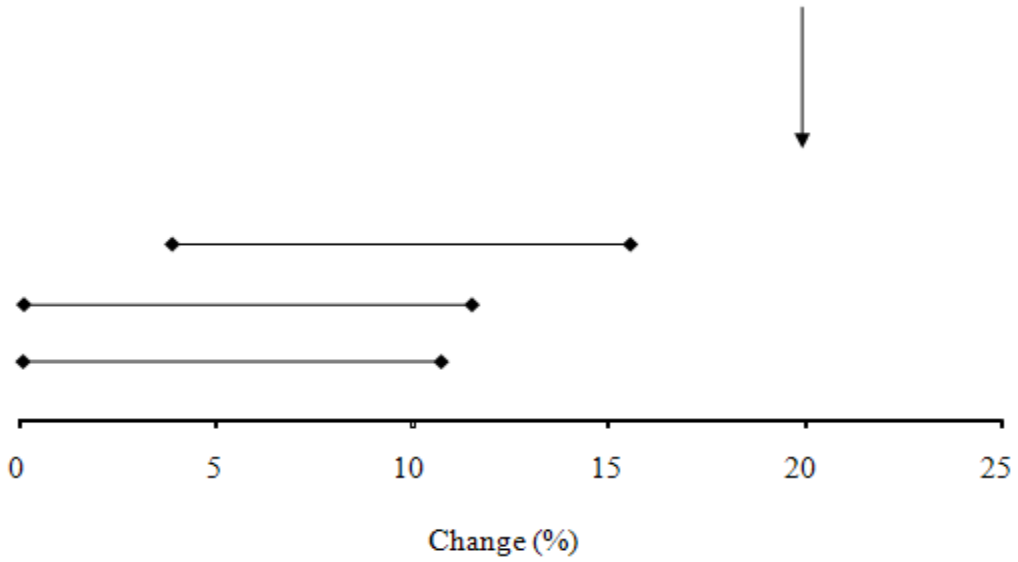


Figure D.1. An illustration of how the probability of detecting a change is calculated for different levels of true change. In this example, 90% confidence intervals (CIs; horizontal lines) of the change estimate are generated by three simulation runs from samples of points where 20% (true change; black arrow) of all points were changed from time 1 to time 2. The lower limit of the top 90% CI is greater than 0 so a change was detected, but the lower limits of the other 2 CIs were at 0 so they did not detect a change. Consequently, in this simple example, there is a 33% (1/3) chance of detecting a >0% change when the true change is 20%. The lower limit of the top CIs also exceeds 2.5%, so there is a 33% (1/3) chance of detecting at least a 2.5% change when the true change is 20%. None of the lower 90% confidence limits is at or above 5% so there is no chance of detecting a change with 90% confidence at this level and higher.

Results

Due to severe logistical limitations of sampling ground plots in SWAN parks, our simulation results should be interpreted based on the maximum number of points (plots) that could be measured in LACL during a given season. That is, at most 25 single points could be surveyed in LACL per year, whereas at most six 2 × 2 grids and three 3 × 3 grids could be sampled. Based on these criteria, we would have an approximately 80% chance to detect a change (>0%) with 90% confidence when there was actually a 50% change in points for landcover classes occupying 12%, 24%, 46% and 61% of a given elevational zone category (Table D.2). This level of change would be equivalent to a true change of 6% (i.e., 50% × 12% = 6%), 12%, 23%, and 30.5%, respectively, if extrapolated to all points and landcover classes in a given elevational zone if one assumes the changes applied to points of specific landcover classes exactly mimic the spatial patterns of change if applied across all points and landcover classes, which is very unlikely. The only instance when a change (>0%) could be detected for a true change of 20% in a landcover class code was when this landcover class occupied 61% of the points in an elevational zone category. This same scenario was also the only instance when an MDC was within an order of magnitude of the true change applied within a landcover class code (i.e., ≥5% MDC for a true 50% change; Table D.2).

Simulations based on 60 m spacing among points within both 2 × 2 (Table D.3) and 3 × 3 grids (Table D.4) produced the best results across all point spacing options so we will focus on their results. The only change scenario for sampling 2 × 2 grids that met the minimum criteria for probability of change detection (0.8 or 80%) and for sample size was when 50% of points were changed for a landcover class that occupied 61% of an elevation zone category. Simulations indicated that one could at best achieve an MDC (5%) that was within an order of magnitude of the true change (Table D.3). The results for 3 × 3 grids were even more sobering; one could at best expect to detect a change (>0%) when in fact a true change of 50% had occurred (Table D.4). Thus, GRTS samples of single points had a greater ability to detect change than either 2 × 2 or 3 × 3 grids requiring similar levels of sampling effort.

Literature Cited

SAS Institute Inc. 2004. SAS/STAT® 9.1 user's guide. SAS Institute, Inc., Cary, North Carolina, USA.

SAS Institute Inc. 2006. Base SAS® 9.1.3 procedures guide, Volumes 1, 2, 3, and 4. Second edition. SAS Institute Inc., Cary, North Carolina.

Stevens, D. L., Jr., and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. Journal of the American Statistical Association 99:262-278.

Table D.1. Number of total points and points of selected landcover classes (LC) in accessible areas with slopes ≤10° in 4 elevational zone categories in LACL that were used in change simulations. LC code 15 is dwarf shrub tundra and LC code 16 is prostrate shrub tundra.

Elevational zone identifier	Elevation	Total pts. in zone	LC code	No. pts. of LC code (freq. of occurrence)
1	≤457 m (1500 ft)	219355	15	14330 (7%)
			16	1268 (0.60%)
2	>457 m and ≤914 m (3000 ft)	191551	15	45336 (24%)
			16	14366 (8%)
3 (N)	>914 m - N of Turquoise Lake	26454	15	2448 (9%)
			16	12180 (46%)
3 (S)	>914 m - S of Turquoise Lake	1506	15	182 (12%)
			16	923 (61%)

Table D.2. Percentage of 1000 simulation runs in which the lower 90% confidence limit (CL) of the estimated change rate from 50 GRTS samples (*n*) of single points was equal to and/or above a specified change (= minimum detectable change) in a specific landcover class (LC; Table 1) occurring in various frequencies of occurrence for true changes of 20% and 50% during 2 time periods in accessible areas with slopes ≤10° in 4 elevational zone categories of LACL.

LC % frequency occurrence	Elev. zone cat.	True change (LC only)	Percentage of samples in 1000 simulation runs in which the lower 90% CL was equal to and/or above the specified change rate[a]					
			>0%[b]	≤2.5%	≤5%	≤10%	≤15%	≤20%
0.60	1	20%	0.2%	0%	0%	0%	0%	0%
		50%	1%	0%	0%	0%	0%	0%
8	2	20%	20%	0%	0%	0%	0%	0%
		50%	59%	15%	0%	0.%	0%	0%
12	3(S)	20%	64%	17%	3%	0%	0%	0%
		50%	**78% (*n*=24)**	78% (*n*=49)	52%	12%	1%	0%
24	2	20%	76%	27%	5%	0%	0%	0%
		50%	**78% (*n*=21)**	79% (*n*=31)	66%	26%	5%	2%
46	3(N)	20%	80% (*n*=35)	60%	22%	1%	0%	0%
		50%	**80% (*n*=13)**	**79% (*n*=19)**	**79% (*n*=25)**	74%	31%	7%
61	3(S)	20%	**80% (*n*=23)**	80% (*n*=42)	59%	18%	1%	0%
		50%	**79% (*n*=8)**	**79% (*n*=12)**	**80% (*n*=16)**	**81% (*n*=20)**	80% (*n*=30)	71%

[a] Sample sizes shown in parentheses indicate the observed number of GRTS samples (*n*) needed to have approximately an 80% chance or more of detecting the specified rate of change with 90% confidence given the true change within each elevational zone category. Values in bold font meet the minimum requirements for probability of change detection and for maximum number of points (plots) that could be realistically sampled during a single season.

[b] The >0% change category represents the traditional definition of statistical power, i.e., the probability of detecting a change regardless of its magnitude.

Table D.3. Percentage of simulation runs in which the lower 90% confidence limit (CL) of the estimated change rate for different numbers of GRTS samples (*n*) of 2 × 2 grids, with points spaced 60 m apart, was equal to and/or above a specified change (= minimum detectable change) in a specific landcover class (LC; Table 1) occurring in various frequencies for true changes of 20% and 50% during 2 time periods within accessible areas of ≤10º slope in 4 elevational zone categories of LACL. The maximum number of 2 × 2 grids that could be selected was less than 50 under each sampling scenario due to the asymmetrical configuration and fragmentary nature of accessible areas (elevational zone 1: *n*=41; elevational zone 2: *n*=41; elevational zone 3[N]: *n*=46; and elevational zone 3[S]: *n*=24). This also produced a variable number of simulation runs (range = 223 - 2158; nearly all ≥1000) across sample sizes, with lower numbers at the higher sample sizes. The percentages shown below were calculated based on the actual number of simulation runs for each sample size.

LC % frequency occurrence	Elev. zone cat.	True change (LC only)	Percentage of GRTS samples in simulation runs in which the lower 90% CL was equal to and/or above the specified change rate[a]					
			>0%[b]	≥2.5%	≥5%	≥10%	≥15%	≥20%
0.60	1	20%	1%	0%	0%	0%	0%	0%
		50%	7%	0%	0%	0%	0%	0%
8	2	20%	62%	1%	0%	0%	0%	0%
		50%	80% (*n*=30)	15%	3%	0%	0%	0%
12	3(S)	20%	81% (*n*=20)	26%	4%	0%	0%	0%
		50%	79% (*n*=10)	81% (*n*=20)	51%	7%	1%	0%
24	2	20%	79% (*n*=15)	57%	7%	0%	0%	0%
		50%	82% (*n*=8)	83% (*n*=14)	80% (*n*=23)	40%	2%	1%
46	3(N)	20%	82% (*n*=11)	79% (*n*=28)	52%	1%	0%	0%
		50%	91% (*n*=7)	81% (*n*=8)	81% (*n*=11)	80% (*n*=27)	54%	7%
61	3(S)	20%	85% (*n*=7)	82% (*n*=12)	80% (*n*=21)	32%	7%	0%
		50%	**83% (*n*=4)**	**86% (*n*=5)**	**83% (*n*=5)**	80% (*n*=7)	84% (*n*=11)	81% (*n*=18)

[a] Numbers shown in parentheses indicate the observed number of GRTS samples (*n*) of 2 × 2 grids of points needed for about an 80% percent chance or more of detecting the specified rate of change with 90% confidence within a given elevational zone category. Values in bold font meet the minimum requirements for probability of change detection and for maximum number of grids that could be realistically sampled during a single season.
[b] The >0% change category represents the traditional definition of statistical power, i.e., the probability of detecting a change regardless of its magnitude.

Table D.4. Percentage of simulation runs in which the lower 90% confidence limit (CL) of the estimated change rate for different numbers of GRTS samples (*n*) of 3 × 3 grids, with points spaced 60 m apart, was equal to and/or above a specified change (= minimum detectable change) in a specific landcover class (LC; Table 1) occurring in various frequencies for true changes of 20% and 50% during 2 time periods within accessible areas of ≤10º slope in 4 elevational zone categories of LACL. The maximum number of 3 × 3 grids that could be selected was less than 50 under each sampling scenario due to the asymmetrical configuration and fragmentary nature of accessible areas (elevational zone 1: *n*=32; elevational zone 2: *n*=34; elevational zone 3[N]: *n*=41; and elevational zone 3[S]: *n*=12). This also produced a variable number of simulation runs (range = 269 - 2232; nearly all ≥1000) across sample sizes, with lower numbers at the higher sample sizes. The percentages shown below were calculated based on the actual number of simulation runs for each sample size.

LC % frequency occurrence	Elev. zone cat.	True change (LC only)	Percentage of GRTS samples in simulation runs in which the lower 90% CL was equal to and/or above the specified change rate[a]					
			>0%[b]	≥2.5%	≥5%	≥10%	≥15%	≥20%
0.60	1	20%	2%	0%	0%	0%	0%	0%
		50%	3%	0%	0%	0%	0%	0%
8	2	20%	81% (*n*=31)	0%	0%	0%	0%	0%
		50%	80% (*n*=20)	10%	0%	0%	0%	0%
12	3(S)	20%	84% (*n*=11)	28%	5%	0%	0%	0%
		50%	83% (*n*=7)	79% (*n*=12)	60%	10%	0%	0%
24	2	20%	80% (*n*=8)	79% (*n*=29)	15%	0%	0%	0%
		50%	85% (*n*=6)	80% (*n*=8)	79% (*n*=13)	52%	3%	0%
46	3(N)	20%	87% (*n*=7)	80% (*n*=16)	64%	0%	0%	0%
		50%	86% (*n*=5)	82% (*n*=6)	80% (*n*=8)	79% (*n*=19)	52%	5%
61	3(S)	20%	80% (*n*=4)	87% (*n*=6)	83% (*n*=8)	51%	6%	0%
		50%	**85% (*n*=3)**	93% (*n*=4)	89% (*n*=4)	85% (*n*=5)	81% (*n*=6)	81% (*n*=10)

[a] Numbers shown in parentheses indicate the observed number of GRTS samples (*n*) of 3 × 3 grids of points needed for about an 80% percent chance or more of detecting the specified rate of change with 90% confidence within a given elevational zone category. Values in bold font meet the minimum requirements for probability of change detection and for maximum number of grids that could be realistically sampled during a single season.
[b] The >0% change category represents the traditional definition of statistical power, i.e., the probability of detecting a change regardless of its magnitude.

Appendix E: Simulation results for evaluating minimum sample size and sample frequency required for detecting a specified total change in vegetation plots within SWAN parks

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Introduction

We conducted simulations to investigate the minimum level of total change that could be detected with 95% confidence by various sample sizes of plots (n = 6, 8, 12, and 24) measured in a given year at two different sampling frequencies (5 and 10 years) under a rotating panel design for populations subjected to different levels of true total change (30%, 40%, and 50%) during 31-year periods. A panel refers to the number of plots that is always sampled during the same year (McDonald 2003). Preliminary fieldwork in SWAN parks indicated that 24 plots would be the maximum number that could be measured with certainty in any given year, whereas 6 plots were conjectured to be the minimum necessary for reasonably precise trend estimators. We included two other factors of 24 (i.e.., 8 and 12 plots) as additional sample size alternatives to evaluate via simulation. Preliminary simulation results were similar for cover proportions between 5%-50%, so we used cover proportions of 5%, 25% and 45% and averaged their results for each run. The simulation approach detailed below is adapted from Kissling et al. (2007), with results presented in the subsequent section.

Methods

The following describes the general steps for performing the simulations.

1. Randomly generate 1000, 31-year time series for all combinations of 24 plots with true cover proportions (p) of 5%, 25%, and 45% across a range of coefficients of variation ($\mathrm{CV}[p]$; 5%-50% by 5% increments) under a specified finite rate of population growth (λ).

   a. Randomly generate λ estimates (i.e., $\hat{\lambda}$) in the time series for each plot from a truncated Normal distribution whose mean is the specified growth rate raised to the power of the relevant year i (i.e., λ^i) and whose standard error ($\mathrm{SE}[\lambda]$) is based on the average for three populations of *Astrocaryum mexicanum* ($\mathrm{SE}[\lambda] = 0.0162$; Alvarez-Buylla and Slatkin 1994). Although this species is not native to Alaska, we used it in the simulations because it was the only published value for a SE of lambda that we could find in the literature. The lower and upper limits of this Normal distribution are set to the possible extremes for λ (e.g., 0.1 and 1.5). The range of λ values used in the simulations correspond to the desired levels of true total change for each plot over 31 years, which are $\lambda = 0.978$ (50% change), $\lambda = 0.9835$ (40% change), and $\lambda = 0.9885$ (30% change).

   b. Randomly generate a different initial estimated cover proportion ($\hat{p}_0$; time 0) for each plot from a truncated Normal distribution whose mean is the specified value (5%, 25%, or 45%) and whose standard error ($\mathrm{SE}[p]$) corresponds to the specified cover proportion

and coefficient of variation (5%-50% by 5% increments), where $\mathrm{SE}(p) = p \times \mathrm{CV}(p)$. The truncated Normal distribution has a lower bound of 0 and an upper bound of 1. Calculate the estimated proportions ($\hat{p}_i$) of each plot for years i =1 to 31 in each simulated time series based on $\hat{p}_i = \hat{p}_0 \hat{\lambda}^i$ (Eberhardt 1987), where the carets (^) refer to estimators of each parameter.

c. This step incorporates temporal (process) variation through the randomly generated $\hat{\lambda}$s for each time step and sampling variation by randomly generating $\hat{p}_0$s for each time step and plot-specific time series of observations.

2. Estimate the trend in estimated cover proportions for each simulated time series and compute the percentage of times in 1000 simulation runs that the upper limit of the one-sided 95% confidence interval of each trend estimate is either equal to and/or below the annual rates of change (decline) associated with levels of total change of interest for a 31-year period (Fig. A6.1).

   a. Take the natural log of the response (cover proportion) variables to account for the multiplicative nature of how the $\hat{\lambda}$s were generated.

   b. Use AICc model selection criterion (Burnham and Anderson 2002) to choose the best-fitting covariance structure for the repeated measures, log-linear regression model based on a single randomly simulated times series of 24 plots per year for 31 years (generated as described in Step 1).

   c. Use the covariance structure and model chosen in Step 2.b. to estimate trend for each simulated time series under the different rotating panel designs (i.e., 6, 8, 12 or 24 plots measured in a given year every 5 or 10 years; Fig. A6.2), coefficients of variation (5%-50%), and true total change (30%, 40% or 50%) during a 31-year period.

   d. Summarize the number of times out of 1000 that the upper one-sided 95% confidence interval of each trend estimate is either equal to and/or below the annual rates of change (decline) associated with levels of total change of interest for a 31-year period for each combination of sample size, sample frequency and coefficient of variation. (Note: the upper confidence limit of a 95% confidence

3. Use results from Step 2 to generate graphs displaying the percent chance of detecting a user-specified minimum total change (minimum detectable total change [MDTC]) with 95% confidence for given the level of true total change (30%, 40% or 50%) over 31 years for different sample size-sample frequency combinations across the range of coefficients of variation (0%-50% by 1% increments).

   a. Use a statistical software program (e.g., SAS; SAS 2008) or freeware program (e.g., R; http://www.r-project.org/) to fit simulation results from Step 2 (5%-50% $\mathrm{CV}[p]$ by 5% increments) with a logistic regression model to estimate predicted probabilities of detecting the user-specified MDTC across the range of coefficients of variation (0%-50%) by 1% increments.

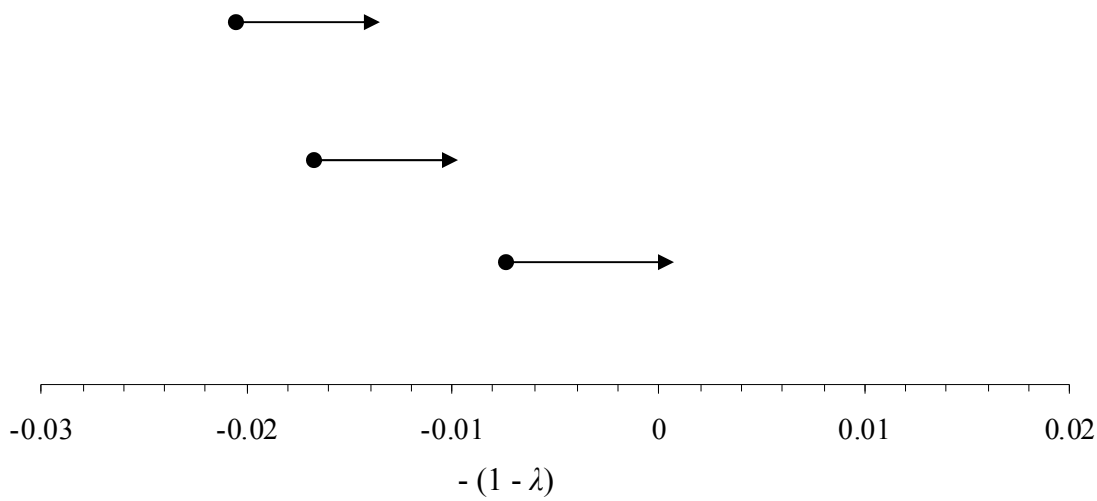

Figure E.1. An illustration of how we used simulations to calculate chance of detecting a given total change for different levels of true change. In this example, one-side 95% confidence intervals (horizontal lines with terminal arrows) of the annual change estimate (- [1 - λ]) were generated by three simulation runs within which a -50% true total change ($\lambda = 0.978$ or annual change estimate = -0.022) was applied to three simulated, 31-year time series of observations. The upper limit of the bottom 95% confidence interval is greater than 0 so no change was detected, but the upper limits of the other 2 confidence intervals were below 0 so they did detect a change. Consequently, in this simple example, there is a 67% (2/3) chance of detecting a <0% total change, with 95% confidence, when the true change was -50%. The upper limit of the top two confidence intervals also were less than or equal to -0.007 (equivalent to a 20% decline over 31 years), so there was a 67% (2/3) chance of detecting up to a -20% total change when the true total change was -50%.

b. The response variable in the logistic regression model in Step 3a. is the number of times out of 1000 that the upper one-sided 95% confidence interval of each trend estimate is either equal to and/or below the annual rates of change (decline) associated with levels of total change of interest for a 31-year period, whereas the predictor variable is the associated $\mathrm{CV}(p)$ (5%-50% by 5% increments).

Results and Discussion

We used a -25% total change as our desired MDTC for a CV≤30% based on interannual variability in 4-6 plots/vegetation class sampled in Lake Clark National Park and Preserve (Miller et al. 2009) and rates of change reported in the literature (Chapin et al. 2005, Boucher and Mead 2006, Bowman et al. 2006, Canone et al. 2007). Further, we felt this MDTC would be reflective of an even greater, and likely ecologically important, true change.

	Year																													
Panel design	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
5 panels sampled every 5 years	X					X					X					X					X					X					X
		X					X					X					X					X					X				
			X					X					X					X					X					X			
				X					X					X					X					X					X		
					X					X					X					X					X					X	
5 panels sampled every 10 years	X										X										X										X
		X										X										X									
			X										X										X								
				X										X										X							
					X										X										X						
10 panels sampled every 10 years	X										X										X										X
		X										X										X									
			X										X										X								
				X										X										X							
					X										X										X						
						X										X										X					
							X										X										X				
								X										X										X			
									X										X										X		
										X										X										X	

Figure E.2. Simulations were based on the top row of each panel design with 1 year added for another sample point. A complete rotating design with either 7 temporal sample points (5-year interval) or 4 temporal sample points (10-year interval) per panel would require a 35-year series for sampling 5 panels and a 40-year series for sampling 10 panels. Simulation results among rows within each panel design were similar.

Both sampling and temporal variability were associated with each estimate of total change, so our goal was to use simulation results to determine the sampling effort (no more than 24 plots per year) and frequency required to achieve an MDTC that was as close to the true total change as logistically feasible for a CV≤30%. There were no sample size and sampling frequency combinations under a true change of -30% that would allow us to feasibly meet our objectives under our samping constraints. Conversely, simulation results for a true total change of -50% (Table E.3) met our sampling objectives but this true change was not close enough to our MDTC. However, under a true total change of -40%, we would be able to sample 8 plots per vegetation class × elevation band × park combination (total = 24 plots per year) every five years that would provide us with at least an 80% chance to detect at least a -20% total change over 31 years with 95% confidence (Table E.2). Our simulation results indicated this same level of sampling effort/frequency had a similar chance of detecting at least a -25% total change, with the same level of confidence, given a true -50% change (Table E.3).

Simulation models are approximations; we never know what the true change or trend is in reality so we cannot assume that a "statistically significant" change (e.g., <0%) observed from actual data corresponds exactly to the true change value used in simulations. Specifying an MDTC as the benchmark comparison in simulations ensures a conservative estimate of sampling effort/frequency (i.e., larger samples, collected more often). For instance, if we used <0% as the benchmark comparison, we would only need to sample half as many plots per vegetation class × elevation band × park combination (Table E.2). Our simulations also did not include the 4-6 vegetation plots that would be co-located with weather stations so that results would be even more conservative. Given the large uncertainty inherent in forecasting future sampling conditions, it is better to oversample than to undersample.

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Table E.1. Ability to detect different levels of total decline for a true average total decline of 30% over 31 years with 95% confidence for a range of sample sizes (plots/yr), coefficients of variation for vegetation cover proportions (CV[$\hat{p}$]), and sample intervals. Five, 25 and 45 percent cover were used as estimated cover proportions in simulations and their results were averaged for each combination to obtain the percent chance to detect a change. Years 1, 6, 11, 16, 21, 26, and 31 were sampled for a 5-year interval and years 1, 11, 21, and 31 for a 10-year interval.

			Estimated percent (%) chance of detecting the listed or more positive total change given a true average total change of -30%[a]						
Plots/ yr	Sample interval (yr)	CV($\hat{p}$) (%)	<0%[b]	≤-5%	≤-10%	≤-15%	≤-20%	≤-25%	≤-30%
6	5	5	**100**	**100**	**100**	**100**	**100**	**87**	4
		10	**100**	**100**	**>99**	**99**	**90**	41	4
		15	**>99**	**>99**	**97**	**83**	60	23	4
		20	**97**	**93**	**80**	61	40	15	4
		25	**86**	76	61	45	28	12	4
		30	72	61	46	32	21	10	4
		35	58	48	36	26	18	10	5
		40	47	39	30	22	15	9	4
		45	38	31	24	18	14	8	5
		50	36	29	22	17	13	8	5
	10	5	**100**	**100**	**100**	**100**	**>99**	75	4
		10	**100**	**100**	**>99**	**96**	78	32	4
		15	**99**	**97**	**89**	72	49	19	5
		20	**90**	**82**	67	49	32	13	4
		25	76	65	51	37	22	11	4
		30	61	51	38	26	18	10	5
		35	48	40	31	23	16	9	5
		40	41	34	26	20	14	9	5
		45	33	28	22	17	14	9	6
		50	31	26	21	16	12	8	5
8	5	5	**100**	**100**	**100**	**100**	**100**	**92**	5
		10	**100**	**100**	**100**	**>99**	**94**	50	5
		15	**100**	**>99**	**98**	**90**	70	30	6

Table E.1.---continued.

Plots/ yr	Sample interval (yr)	CV($\hat{p}$) (%)	Estimated percent (%) chance of detecting the listed or more positive total change given a true average total change of -30%[a]						
			<0%[b]	≤-5%	≤-10%	≤-15%	≤-20%	≤-25%	≤-30%
8	5	20	**99**	**96**	**88**	71	49	21	5
		25	**92**	**85**	70	53	36	16	5
		30	**80**	70	55	41	27	13	5
		35	66	57	45	32	23	12	6
		40	56	46	36	26	18	11	6
		45	46	38	29	21	16	9	6
		50	43	35	28	22	16	10	6
	10	5	**100**	**100**	**100**	**100**	**100**	**83**	5
		10	**100**	**100**	**>99**	**98**	**86**	40	6
		15	**>99**	**98**	**94**	**80**	59	25	7
		20	**95**	**89**	77	59	41	18	5
		25	**83**	74	61	45	30	15	6
		30	68	59	46	34	24	12	6
		35	57	48	38	29	20	12	7
		40	48	41	31	24	18	10	6
		45	40	35	27	21	17	11	7
		50	38	33	27	20	16	11	7
12	5	5	**100**	**100**	**100**	**100**	**100**	**97**	6
		10	**100**	**100**	**100**	**100**	**98**	64	7
		15	**100**	**100**	**>99**	**97**	**83**	39	7
		20	**>99**	**99**	**95**	**82**	62	29	7
		25	**97**	**92**	**82**	66	46	22	6
		30	**90**	**82**	68	52	35	17	7
		35	77	67	54	41	29	16	7
		40	67	58	47	34	25	13	7
		45	57	49	38	29	20	12	7
		50	53	45	36	28	20	12	8

Table E.1.---continued

Plots/ yr	Sample interval (yr)	CV($\hat{p}$) (%)	Estimated percent (%) chance of detecting the listed or more positive total change given a true average total change of -30%[a]						
			<0%[b]	≤-5%	≤-10%	≤-15%	≤-20%	≤-25%	≤-30%
12	10	5	**100**	**100**	**100**	**100**	**100**	**92**	6
		10	**100**	**100**	**100**	**>99**	**94**	54	6
		15	**>99**	**>99**	**99**	**90**	72	33	8
		20	**99**	**96**	**87**	72	52	23	7
		25	**90**	**83**	72	57	41	20	6
		30	79	72	58	43	30	16	8
		35	67	58	47	35	26	15	8
		40	59	51	42	31	22	13	7
		45	49	42	34	26	20	13	8
		50	46	40	33	26	21	13	8
24	5	5	**100**	**100**	**100**	**100**	**100**	**>99**	9
		10	**100**	**100**	**100**	**100**	**100**	**82**	10
		15	**100**	**100**	**100**	**>99**	**96**	57	10
		20	**100**	**100**	**>99**	**96**	**80**	43	10
		25	**>99**	**99**	**95**	**83**	65	32	10
		30	**98**	**94**	**85**	69	52	27	10
		35	**93**	**86**	74	58	42	23	10
		40	**84**	76	63	51	38	21	9
		45	79	69	57	44	32	18	9
		50	71	62	51	41	30	18	9
	10	5	**100**	**100**	**100**	**100**	**100**	**99**	10
		10	**100**	**100**	**100**	**100**	**99**	71	11
		15	**100**	**100**	**100**	**99**	**89**	48	11
		20	**>99**	**99**	**97**	**88**	70	38	11
		25	**98**	**95**	**87**	73	56	30	11
		30	**91**	**85**	74	59	45	26	11
		35	**83**	75	63	50	38	23	12
		40	74	66	55	45	34	21	11

Table E.1.---continued

Plots/ yr	Sample interval (yr)	CV($\hat{p}$) (%)	Estimated percent (%) chance of detecting the listed or more positive total change given a true average total change of -30%[a]						
			<0%[b]	≤-5%	≤-10%	≤-15%	≤-20%	≤-25%	≤-30%
24	10	45	67	60	50	39	31	19	11
		50	61	54	46	37	29	20	12

[a] Average percent of 1000 simulation runs in which the upper one-sided 95% confidence limit of the annual change estimate (- [1 - λ] in Fig. A4.1; extrapolated to estimated total change) was equal to or greater than each listed total change. Values in bold font indicate at least an 80% chance of detecting the stated minimum detectable total change.

[b] The <0% change category represents the traditional definition of statistical power, i.e., the chance of detecting a change regardless of its magnitude, given that it is present.

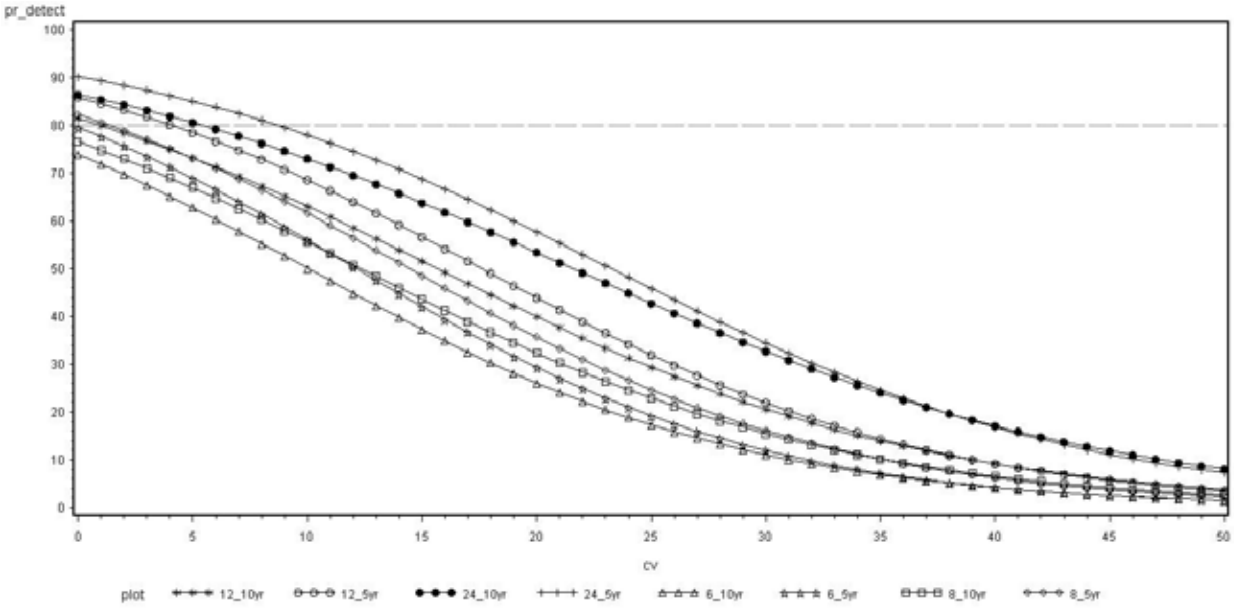


Figure E.3. Probability of recording a minimum detectable change of 20% over a 31-year period with 95% confidence when the true change is 30%. Response curves are for replicate plots (n = 6-24) sampled over 5- and 10-year intervals. Coefficient of variation (CV) in the plot variable (e.g., cover, frequency) is shown on the X-axis. A CV of up to 10% is tolerated when a high number of replicates (n = 24 plots/yr) and short sampling interval (5 yr) are used.

Table E.2. Ability to detect different levels of total decline for a true average total decline of 40% over 31 years with 95% confidence for a range of sample sizes (plots/yr), coefficients of variation for vegetation cover proportions (CV[$\hat{p}$]), and sample intervals. Five, 25 and 45 percent cover were used as estimated cover proportions in simulations and their results were averaged for each combination to obtain the percent chance to detect a change. Years 1, 6, 11, 16, 21, 26, and 31 were sampled for a 5-year interval and years 1, 11, 21, and 31 for a 10-year interval.

			Estimated percent (%) chance of detecting the listed or more positive total change given a true average total change of -40%[a]								
Plots/ yr	Sample interval (yr)	CV($\hat{p}$) (%)	<0%[b]	≤-5%	≤-10%	≤-15%	≤-20%	≤-25%	≤-30%	≤-35%	≤-40%
6	5	5	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**96**	4
		10	**100**	**100**	**100**	**100**	**100**	**>99**	**95**	56	4
		15	**100**	**100**	**100**	**>99**	**99**	**92**	68	31	4
		20	**100**	**>99**	**99**	**96**	**90**	72	47	21	4
		25	**98**	**96**	**93**	**86**	75	56	34	16	4
		30	**92**	**87**	79	68	57	40	24	12	4
		35	**82**	75	64	54	44	31	20	11	4
		40	70	64	54	44	36	25	18	11	6
		45	61	54	46	38	31	22	16	10	5
		50	55	48	40	34	28	21	14	10	5
	10	5	**100**	**100**	**100**	**100**	**100**	**100**	**>99**	**89**	5
		10	**100**	**100**	**100**	**100**	**100**	**99**	**85**	45	4
		15	**100**	**>99**	**>99**	**98**	**96**	**82**	55	25	4
		20	**99**	**98**	**95**	**90**	**80**	60	37	18	5
		25	**94**	**90**	**84**	75	64	44	27	15	4
		30	**84**	78	68	58	47	32	20	11	4
		35	71	65	56	47	39	28	18	10	4
		40	61	54	46	39	32	23	15	10	5
		45	53	47	40	33	27	20	14	10	6
		50	46	41	36	30	25	19	14	10	5
8	5	5	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**99**	6
		10	**100**	**100**	**100**	**100**	**100**	**>99**	**97**	66	6
		15	**100**	**100**	**100**	**100**	**>99**	**96**	78	39	6

Table E.2.---continued.

Plots/ yr	Sample interval (yr)	CV($\hat{p}$) (%)	Estimated percent (%) chance of detecting the listed or more positive total change given a true average total change of -40%[a]								
			<0%[b]	≤-5%	≤-10%	≤-15%	≤-20%	≤-25%	≤-30%	≤-35%	≤-40%
8	5	20	**100**	**>99**	**>99**	**98**	**95**	**81**	55	28	6
		25	**99**	**98**	**95**	**90**	**83**	64	41	21	6
		30	**96**	**92**	**86**	77	66	48	30	16	5
		35	**87**	**82**	72	63	52	38	26	14	6
		40	77	72	63	53	44	32	22	13	6
		45	70	63	55	45	38	26	18	12	7
		50	63	56	48	40	33	24	16	11	6
8	10	5	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**94**	6
		10	**100**	**100**	**100**	**100**	**100**	**>99**	**91**	54	6
		15	**100**	**100**	**>99**	**>99**	**98**	**88**	65	32	6
		20	**>99**	**99**	**98**	**94**	**87**	70	46	25	6
		25	**97**	**94**	**89**	**82**	71	54	34	19	7
		30	**89**	**85**	77	67	56	40	27	15	6
		35	78	72	64	56	47	35	24	14	6
		40	69	63	55	47	39	29	20	13	6
		45	60	55	47	40	34	25	18	12	7
		50	54	48	41	35	30	23	17	12	7
12	5	5	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**>99**	7
		10	**100**	**100**	**100**	**100**	**100**	**100**	**99**	79	7
		15	**100**	**100**	**100**	**100**	**100**	**99**	**88**	50	7
		20	**100**	**100**	**100**	**>99**	**99**	**90**	69	36	7
		25	**>99**	**>99**	**99**	**97**	**92**	76	53	29	7
		30	**99**	**98**	**94**	**87**	77	58	39	21	6
		35	**94**	**90**	**84**	75	64	47	32	18	7
		40	**87**	**82**	75	65	56	41	27	16	7
		45	**81**	75	66	57	47	35	24	15	7
		50	75	68	59	51	43	32	23	14	7

Table E.2.---continued.

Plots/ yr	Sample interval (yr)	CV($\hat{p}$) (%)	Estimated percent (%) chance of detecting the listed or more positive total change given a true average total change of -40%[a]								
			<0%[b]	≤-5%	≤-10%	≤-15%	≤-20%	≤-25%	≤-30%	≤-35%	≤-40%
12	10	5	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**98**	7
		10	**100**	**100**	**100**	**100**	**100**	**100**	**98**	67	7
		15	**100**	**100**	**100**	**>99**	**99**	**95**	78	42	8
		20	**>99**	**>99**	**>99**	**98**	**94**	**81**	58	31	8
		25	**99**	**98**	**95**	**90**	**83**	66	45	26	8
		30	**94**	**91**	**85**	77	67	50	34	19	7
		35	**87**	**82**	74	66	56	42	30	19	7
		40	78	73	66	58	48	37	25	16	8
		45	71	65	57	49	42	31	23	15	8
		50	65	60	52	45	37	29	21	14	9
24	5	5	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	9
		10	**100**	**100**	**100**	**100**	**100**	**100**	**>99**	**94**	10
		15	**100**	**100**	**100**	**100**	**100**	**100**	**98**	70	9
		20	**100**	**100**	**100**	**100**	**>99**	**99**	**87**	53	11
		25	**100**	**100**	**100**	**>99**	**99**	**92**	72	42	11
		30	**>99**	**>99**	**99**	**97**	**92**	79	57	33	9
		35	**99**	**98**	**96**	**91**	**83**	67	47	28	10
		40	**97**	**94**	**89**	**82**	73	58	40	25	10
		45	**94**	**90**	**84**	76	67	52	35	22	9
		50	**89**	**85**	79	69	60	46	32	20	9
	10	5	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**>99**	10
		10	**100**	**100**	**100**	**100**	**100**	**100**	**>99**	**85**	11
		15	**100**	**100**	**100**	**100**	**100**	**99**	**92**	60	11
		20	**100**	**100**	**>99**	**>99**	**99**	**94**	76	46	12
		25	**100**	**>99**	**99**	**98**	**94**	**82**	62	37	12
		30	**99**	**98**	**95**	**91**	**84**	69	49	29	11
		35	**96**	**93**	**88**	**82**	74	59	42	27	11
		40	**90**	**86**	79	71	63	50	37	25	12

Table E.2.---continued.

Plots/ yr	Sample interval (yr)	CV($\hat{p}$) (%)	Estimated percent (%) chance of detecting the listed or more positive total change given a true average total change of -40%[a]								
			<0%[b]	≤-5%	≤-10%	≤-15%	≤-20%	≤-25%	≤-30%	≤-35%	≤-40%
24	10	45	**85**	**80**	74	66	58	45	34	22	12
		50	**80**	75	69	61	53	42	30	20	11

[a] Average percent of 1000 simulation runs in which the upper one-sided 95% confidence limit of the annual change estimate (- [1 - λ] in Fig. A6.1; extrapolated to estimated total change) was equal to or greater than each listed total change. Values in bold font indicate at least an 80% chance of detecting the stated minimum detectable total change.

[b] The <0% change category represents the traditional definition of statistical power, i.e., the chance of detecting a change regardless of its magnitude, given that it is present.

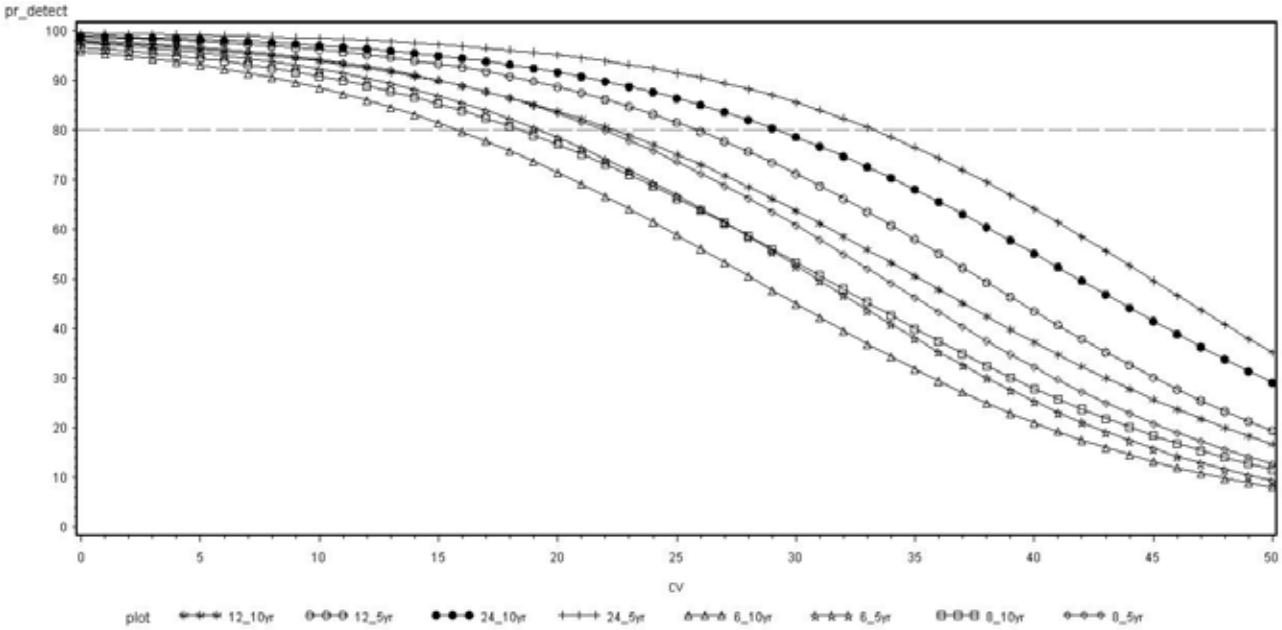


Figure E.4. Probability of recording a minimum detectable change (MDC) of 20% over a 31-year period with 95% confidence when the true change is 40%. Response curves are for replicate plots (n = 6-24) sampled over 5 and 10-year intervals. Coefficient of variation (CV) in the plot variable (e.g., cover, frequency) is shown on the X-axis. Greater CVs are tolerated when the MDC<<true change.

Table E.3. Ability to detect different levels of total decline for a true average total decline of 50% over 31 years with 95% confidence for a range of sample sizes (plots/yr), coefficients of variation for vegetation cover proportions (CV[$\hat{p}$]), and sample intervals. Five, 25 and 45 percent cover were used as estimated cover proportions in simulations and their results were averaged for each combination to obtain the percent chance to detect a change. Years 1, 6, 11, 16, 21, 26, and 31 were sampled for a 5-year interval and years 1, 11, 21, and 31 for a 10-year interval.

			Estimated percent (%) chance of detecting the listed or more positive total change given a true average total change of -50%[a]										
Plots/ yr	Sample interval (yr)	CV($\hat{p}$) (%)	<0%[b]	≤-5%	≤-10%	≤-15%	≤-20%	≤-25%	≤-30%	≤-35%	≤-40%	≤-45%	≤-50%
6	5	5	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**98**	5
		10	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**96**	60	5
		15	**100**	**100**	**100**	**100**	**100**	**100**	**>99**	**97**	76	35	5
		20	**100**	**100**	**100**	**>99**	**>99**	**98**	**94**	**83**	53	24	5
		25	**>99**	**>99**	**99**	**98**	**97**	**92**	**80**	63	37	18	4
		30	**98**	**97**	**95**	**92**	**87**	77	66	50	29	15	5
		35	**94**	**92**	**88**	**83**	75	65	52	38	23	12	4
		40	**87**	**83**	77	70	63	53	42	31	19	11	5
		45	79	75	68	62	55	46	37	27	17	10	5
		50	73	68	62	55	49	40	32	24	16	10	6
	10	5	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**>99**	**92**	6
		10	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**>99**	**89**	49	5
		15	**100**	**100**	**100**	**100**	**100**	**>99**	**98**	**90**	63	30	5
		20	**100**	**100**	**>99**	**99**	**98**	**94**	**86**	70	43	22	5
		25	**99**	**99**	**97**	**95**	**90**	**81**	68	52	31	15	5
		30	**95**	**92**	**89**	**84**	78	67	56	42	25	13	5
		35	**87**	**84**	78	72	65	54	44	34	21	12	5
		40	78	73	67	61	55	46	37	27	17	10	5
		45	70	65	59	53	47	39	31	24	16	10	6
		50	63	59	53	48	42	35	29	22	16	10	6
8	5	5	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**99**	7
		10	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**98**	70	6

Table E.3.---continued.

Plots/ yr	Sample interval (yr)	CV($\hat{p}$) (%)	Estimated percent (%) chance of detecting the listed or more positive total change given a true average total change of -50%[a]										
			<0%[b]	≤-5%	≤-10%	≤-15%	≤-20%	≤-25%	≤-30%	≤-35%	≤-40%	≤-45%	≤-50%
8	5	15	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**99**	**83**	44	7
		20	**100**	**100**	**100**	**100**	**>99**	**99**	**96**	**88**	63	31	7
		25	**>99**	**>99**	**>99**	**99**	**98**	**95**	**87**	72	46	22	6
		30	**99**	**99**	**98**	**95**	**92**	**84**	73	58	36	19	7
		35	**96**	**94**	**92**	**88**	**82**	73	60	47	29	16	6
		40	**91**	**88**	**84**	79	72	60	49	38	24	14	6
		45	**86**	**82**	76	70	64	53	44	34	22	14	6
		50	**81**	76	70	64	57	47	38	29	19	12	6
	10	5	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**95**	7
		10	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**>99**	**94**	58	7
		15	**100**	**100**	**100**	**100**	**100**	**>99**	**99**	**94**	72	37	7
		20	**100**	**100**	**>99**	**>99**	**99**	**97**	**91**	78	52	28	8
		25	**>99**	**99**	**99**	**97**	**94**	**88**	76	60	39	20	7
		30	**97**	**95**	**92**	**89**	**84**	75	63	49	32	18	8
		35	**91**	**88**	**84**	**80**	74	63	51	41	27	16	8
		40	**84**	**81**	75	68	62	52	44	33	22	13	7
		45	77	73	67	61	54	45	37	30	20	13	7
		50	71	67	61	56	50	42	34	27	18	12	7
12	5	5	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**>99**	8
		10	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**>99**	**81**	8
		15	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**>99**	**92**	55	9
		20	**100**	**100**	**100**	**100**	**100**	**>99**	**99**	**95**	75	41	9
		25	**>99**	**>99**	**>99**	**>99**	**>99**	**98**	**94**	**84**	56	30	8
		30	**>99**	**>99**	**99**	**98**	**96**	**91**	**83**	69	45	25	9
		35	**98**	**98**	**96**	**94**	**91**	**83**	72	58	38	21	8
		40	**96**	**95**	**92**	**87**	**82**	72	60	47	31	18	7
		45	**93**	**90**	**86**	**80**	75	64	53	42	28	16	7

Table E.3.---continued.

Plots/ yr	Sample interval (yr)	CV($\hat{p}$) (%)	Estimated percent (%) chance of detecting the listed or more positive total change given a true average total change of -50%[a]										
			<0%[b]	≤-5%	≤-10%	≤-15%	≤-20%	≤-25%	≤-30%	≤-35%	≤-40%	≤-45%	≤-50%
12	5	50	**90**	**86**	**81**	75	69	58	47	37	24	14	7
	10	5	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**99**	9
		10	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**98**	71	9
		15	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**98**	**83**	46	10
		20	**100**	**100**	**100**	**100**	**>99**	**99**	**96**	**87**	64	35	10
		25	**>99**	**>99**	**>99**	**99**	**98**	**94**	**86**	72	47	26	9
		30	**99**	**98**	**96**	**94**	**91**	**83**	74	60	40	23	10
		35	**95**	**94**	**91**	**87**	**82**	73	63	50	33	21	10
		40	**91**	**88**	**84**	79	72	63	53	42	28	18	8
		45	**86**	**82**	76	70	65	56	46	37	25	17	8
		50	**80**	77	71	66	59	50	42	34	24	16	9
24	5	5	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	11
		10	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**95**	12
		15	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**99**	74	12
		20	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**>99**	**90**	57	12
		25	**100**	**100**	**100**	**>99**	**>99**	**>99**	**99**	**95**	76	44	11
		30	**100**	**100**	**100**	**>99**	**>99**	**99**	**95**	**85**	62	38	12
		35	**>99**	**>99**	**>99**	**99**	**98**	**94**	**88**	75	53	32	12
		40	**>99**	**99**	**99**	**98**	**95**	**89**	78	65	44	27	11
		45	**99**	**98**	**96**	**94**	**90**	**82**	71	58	39	23	10
		50	**98**	**96**	**94**	**90**	**86**	77	66	53	36	22	9
	10	5	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	12
		10	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**86**	13
		15	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**84**	63	14
		20	**100**	**100**	**100**	**100**	**100**	**100**	**>99**	**97**	**81**	50	14
		25	**>99**	**>99**	**>99**	**>99**	**>99**	**99**	**96**	**87**	65	39	13
		30	**>99**	**>99**	**99**	**99**	**98**	**94**	**87**	75	54	35	14

Table E.3.---continued.

Plots/ yr	Sample interval (yr)	CV($\hat{p}$) (%)	Estimated percent (%) chance of detecting the listed or more positive total change given a true average total change of -50%[a]										
			<0%[b]	≤-5%	≤-10%	≤-15%	≤-20%	≤-25%	≤-30%	≤-35%	≤-40%	≤-45%	≤-50%
24	10	35	**99**	**99**	**98**	**96**	**93**	**87**	78	66	47	30	15
		40	**98**	**97**	**95**	**91**	**87**	78	69	57	40	26	12
		45	**95**	**93**	**90**	**85**	**81**	72	62	51	36	24	12
		50	**92**	**90**	**86**	**81**	76	67	57	47	34	23	12

[a] Average percent of 1000 simulation runs in which the upper one-sided 95% confidence limit of the annual change estimate (- [1 - λ] in Fig. A6.1; extrapolated to estimated total change) was equal to or greater than each listed total change. Values in bold font indicate at least an 80% chance of detecting the stated minimum detectable total change.

[b] The <0% change category represents the traditional definition of statistical power, i.e., the chance of detecting a change regardless of its magnitude, given that it is present.

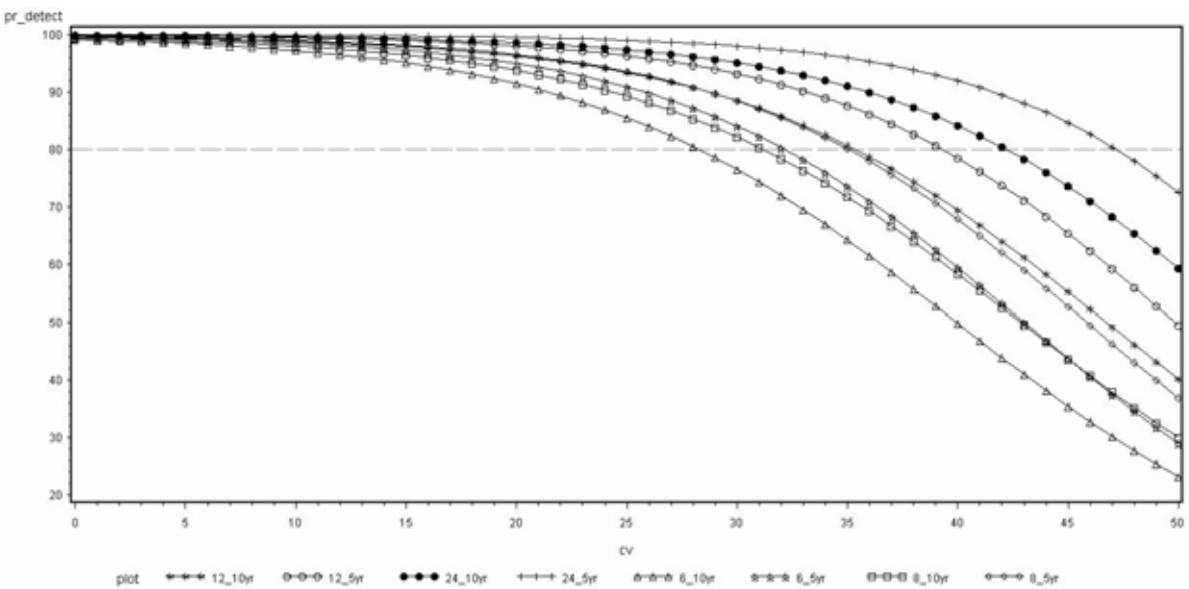


Figure E.5. Probability of recording a minimum detectable change (MDC) of 20% over a 31-year period with 95% confidence when the true change is 50%. Response curves are for replicate plots (n = 6-24) sampled over 5- and 10-year intervals. Coefficient of variation (CV) in the plot variable (e.g., cover, frequency) is shown on the X-axis. High CVs are tolerated and change is generally detected when the MDC<<true change.

Appendix F: SAS Code for Summary Statistics

William L. Thompson, SWAN Quantitative Ecologist

1 Species Abundance: Nested Frequency Data

```
*************** Freq_SummaryStats_20100505.sas *******************
*                                                                *
* This program summarizes plant species count data for 5         *
* nested quadrats (0.25m^2 < 1m^2 < 4m^2) along 3 transects at   *
* GRTS-selected vegetation monitoring sites.  The program code   *
* below that is followed by a comment field in UPPERCASE text    *
* has to be modified by the user. Changes to macrovariables      *
* (preceded by %let) should ONLY occur on the RIGHTHAND side of  *
* the equal sign.  This is where the user specifies the name of  *
* that variable in the imported raw data file.                   *
*                                                                *
*                          Written by Bill Thompson              *
*                            NPS SWAN Quantitative Ecologist     *
*                             7 February 2008                    *
*                                                                *
*                          Last Modified 5 May 2010              *
*                                                                *
******************************************************************;

%let inpfil=grts.freq1;                  * SPECIFY THE SAS LIBRARY AND FILE
NAME CONTAINING THE RAW SPECIES FREQUENCY DATA;
%let outfil1=grts.freq_within_results;  * SPECIFY THE SAS LIBRARY AND FILE
FOR THE RESULTS FILE CONTAINING SUMMARIZED QUADRAT
                                          FREQUENCY DATA AND SITE-LEVEL
SPECIES OCCURRENCE DATA WITHIN SITES;
%let outfil2=grts.freq_across_results;  * SPECIFY THE SAS LIBRARY AND FILE
FOR THE RESULTS FILE CONTAINING SUMMARIZED QUADRAT
                                          FREQUENCY DATA AND SITE-LEVEL
SPECIES OCCURRENCE DATA ACROSS SITES;
%let site_id=site_id;                    * SPECIFY VARIABLE NAME CONTAINING
SITE IDENTIFIER;
%let date=date;                          * SPECIFY VARIABLE NAME CONTAINING
DATE;
%let elev_bnd=elev_bnd;                  * SPECIFY VARIABLE NAME CONTAINING
ELEVATION BAND;
%let veg_class=veg_clas;                 * SPECIFY VARIABLE NAME CONTAINING
VEGETATION COVER CLASS;
%let year=year;                            * SPECIFY VARIABLE NAME CONTAINING
YEAR;
%let transect=transect;                  * SPECIFY VARIABLE NAME CONTAINING
TRANSECT IDENTIFIER;
%let quad_no=quad_no;                    * SPECIFY VARIABLE NAME CONTAINING
QUADRAT IDENTIFIER;
%let species=species;                    * SPECIFY VARIABLE NAME CONTAINING
THE PLANT SPECIES;

*******************************************************
****** Please do not change anything beyond this ******
****** point unless you know what you are doing. ******
*******************************************************;

****** This section of code summarizes the "nested frequency data," i.e.,
*******
```

```
****** the number of occurrences of each species within 3 nested quadrats,
*******
****** where freq1 = 0.25m^2, freq2 = 1m^2, and freq3=4m^2 within sites
*******
****** and across sites by elevation band, veg class and species.
*******;

ods listing close;                  * suppress unwanted printing;
run;
data a;
  set &inpfil;
  drop &date &year;
  proc sort;
    by &elev_bnd &veg_class &site_id &transect &quad_no; *  Sort data to the
finest temporal (date) and spatial (quadrat) scales;
run;
proc transpose data=a out=b;                              * Transpose the data
to convert data to numeric format and for summarization;
  by &elev_bnd &veg_class &site_id &transect &quad_no;
run;
data b;
  set b;                                                  * Proc Transpose
uses "col1" as the default variable name for the column of
                                                            transposed data;
if col1=1 then cat1=1;                                    * Create a variable
indicating a "hit" for a given species in the 0.25m^2 quadrat;
if col1=2 then cat2=1;                                    * Create a variable
indicating a "hit" for a given in the 1m^2 quadrat;
if col1=3 then cat3=1;                                    * Create a variable
indicating a "hit" for a given species in the 4m^2 quadrat;
if cat1=. then cat1=0;
if cat2=. then cat2=0;
if cat3=. then cat3=0;
if cat1=1 then cat3=1;                                    * Account for
0.25m^2 quadrat being nested within 4m^2 quadrat;
if cat2=1 then cat3=1;                                    * Account for 1m^2
quadrat being nested within 4m^2 quadrat;
if cat1=1 then cat2=1;                                    * Account for
0.25m^2 quadrat being nested within 1m^2 quadrat;
rename _name_=&species;
drop col1 _label_;
proc sort;
  by &elev_bnd &veg_class &site_id &species;
run;
proc surveymeans data=b mean stderr cv;                     * within-site
estimates for 0.25m^2 quadrats;
  cluster &site_id;
  cluster &transect;
  domain &elev_bnd*&veg_class*&species*&site_id;
  var cat1;
  ods output Domain=freq_025m2_within;
run;

proc surveymeans data=b mean stderr cv;                     * within-site
estimates for 1m^2 quadrats;
  cluster &site_id;
  cluster &transect;
  domain &elev_bnd*&veg_class*&species*&site_id;
  var cat2;
  ods output Domain=freq_1m2_within;
run;
```

```
proc surveymeans data=b mean stderr cv;                    * within-site
estimates for 4m^2 quadrats;
  cluster &site_id;
  cluster &transect;
  domain &elev_bnd*&veg_class*&species*&site_id;
  var cat3;
  ods output Domain=freq_4m2_within;
run;

data freq1;
  set freq_025m2_within (drop=varname);
  rename mean=mean_025m2;
  rename stderr=stderr_025m2;
  rename cv=cv_025m2;
  proc sort;
    by &elev_bnd &veg_class &site_id &species;
run;

data freq2;
  set freq_1m2_within (drop=varname);
  rename mean=mean_1m2;
  rename stderr=stderr_1m2;
  rename cv=cv_1m2;
  proc sort;
    by &elev_bnd &veg_class &site_id &species;
run;

data freq3;
  set freq_4m2_within (drop=varname);
  rename mean=mean_4m2;
  rename stderr=stderr_4m2;
  rename cv=cv_4m2;
  proc sort;
    by &elev_bnd &veg_class &site_id &species;
run;

data &outfil1;                                          * final results file
for within-site estimates;
  merge freq1 freq2 freq3;
    by &elev_bnd &veg_class &site_id &species;
      drop domainlabel;
run;

proc surveymeans data=b mean stderr cv;                    * across-site
estimates for 0.25m^2 quadrats;
  cluster &site_id;
  cluster &transect;
  domain &elev_bnd*&veg_class*&species;
  var cat1;
  ods output Domain=freq_025m2_across;
run;

proc surveymeans data=b mean stderr cv;                    * across-site
estimates for 1m^2 quadrats;
  cluster &site_id;
  cluster &transect;
  domain &elev_bnd*&veg_class*&species;
  var cat2;
  ods output Domain=freq_1m2_across;
run;
```

```
proc surveymeans data=b mean stderr cv;                    * across-site
estimates for 4m^2 quadrats;
  cluster &site_id;
  cluster &transect;
  domain &elev_bnd*&veg_class*&species;
  var cat3;
  ods output Domain=freq_4m2_across;
run;

data freq1a;
  set freq_025m2_across (drop=varname);
  rename mean=mean_025m2;
  rename stderr=stderr_025m2;
  rename cv=cv_025m2;
  proc sort;
    by &elev_bnd &veg_class &species;
run;

data freq2a;
  set freq_1m2_across (drop=varname);
  rename mean=mean_1m2;
  rename stderr=stderr_1m2;
  rename cv=cv_1m2;
  proc sort;
    by &elev_bnd &veg_class &species;
run;

data freq3a;
  set freq_4m2_across (drop=varname);
  rename mean=mean_4m2;
  rename stderr=stderr_4m2;
  rename cv=cv_4m2;
  proc sort;
    by &elev_bnd &veg_class &species;
run;

data &outfil2;                                            *  final results
file for within-site estimates;
  merge freq1a freq2a freq3a;
    by &elev_bnd &veg_class &species;
      drop domainlabel;
run;

ods listing;
run;
```

2 Percent Cover by Species: Point-intercept Data

```
************ PtIntcpt_SummaryStats_SAS_20091203.sas ************
*                                                              *
* This program has two parts.  The first part summarizes plant *
* species count data for 59 0.5m points along 3, 30m transects *
* at GRTS-selected vegetation monitoring sites.  This part of  *
* the program is labeled _Count Data Summary Stats_.  Results  *
* are generated only for those species encountered at least    *
* once.  The program code below that is followed by a comment  *
* field in UPPERCASE text has to be modified by the user.      *
* Changes to macrovariables (preceded by %let) should ONLY     *
* occur on the RIGHTHAND side of the equal sign.  This is      *
* where the user specifies the name of that variable in the    *
* imported raw data file.  Also, there is a line of code near  *
* the bottom of this part of the program (followed by a        *
* comment in UPPERCASE text) that can be commented out with an *
* asterisk if the user wishes to include plant species that    *
* were not encountered at a given site.                        *
*                                                              *
* The second part of this program estimates proportions,       *
* approximate std errors and approximate CVs from plant        *
* species count data for the transects described above.  This  *
* part of the program is labeled _Propns, SEs and CVs_.  These *
* estimates are approximations because SAS currently does not  *
* have the GRTS variance estimator.  Results are generated     *
* only for those species specified by the user.  There are two *
* lines of code in the middle of the second part of this       *
* program (preceded by comments in UPPERCASE text) that may be *
* modified by the user to specify the plant species of         *
* interest in height class=1 and height class=1-4.             *
*                                                              *
*                       Written by Bill Thompson               *
*                         NPS SWAN Quantitative Ecologist      *
*                         7 February 2008                      *
*                                                              *
*                       Last Modified 3 December 2009          *
*                                                              *
****************************************************************;

%let inpfil=grts.pt_intcpt1;                    * SPECIFY THE SAS LIBRARY AND
FILE NAME CONTAINING
                                                  THE RAW POINT INTERCEPT
COUNTS OF PLANT SPECIES;
%let outfil1=grts.pt_intcpt1_results;           * SPECIFY THE SAS LIBRARY AND
FILE FOR THE RESULTS
                                                  FILE CONTAINING SUMMARIZED
POINT INTERCEPT DATA
                                                  BY SITE, DATE, HEIGHT
CLASS, AND SPECIES;
%let outfil2=grts.pt_intcpt1_insite1_results;   * SPECIFY THE SAS LIBRARY AND
FILE FOR THE RESULTS FILE
                                                  CONTAINING ESTIMATED
PROPORTIONS, STD ERRORS, and CVS
                                                  WITHIN SITES FOR HT
CLASS=1;
%let outfil3=grts.pt_intcpt1_insite14_results;  * SPECIFY THE SAS LIBRARY AND
FILE FOR THE RESULTS FILE
                                                  CONTAINING ESTIMATED
PROPORTIONS, STD ERRORS, and CVS
```

```
                                                WITHIN SITES FOR HT
CLASSES=1-4;
%let outfil4=grts.pt_intcpt1_acrsite1_results;  * SPECIFY THE SAS LIBRARY AND
FILE FOR THE RESULTS FILE
                                                CONTAINING ESTIMATED
PROPORTIONS, STD ERRORS, and CVS
                                                ACROSS SITES FOR HT
CLASS=1;
%let outfil5=grts.pt_intcpt1_acrsite14_results; * SPECIFY THE SAS LIBRARY AND
FILE FOR THE RESULTS FILE
                                                CONTAINING ESTIMATED
PROPORTIONS, STD ERRORS, and CVS
                                                ACROSS SITES FOR HT
CLASSES=1-4;

%let site_id=site_id;                      * SPECIFY VARIABLE NAME CONTAINING
SITE IDENTIFIER;
%let elev_bnd=elev_bnd;
%let veg_class=veg_class;
%let transect=transect;              * SPECIFY VARIABLE NAME CONTAINING
TRANSECT IDENTIFIER;
%let point_m=point_m;                      * SPECIFY VARIABLE NAME CONTAINING
TRANSECT POINT IDENTIFIER;
%let ht_class=ht_class;                    * SPECIFY VARIABLE NAME CONTAINING
HEIGHT CLASS CATEGORY;
%let year=year;
%let date=date;
%let species=species;
%let elev_bnd=elev_bnd;
%let veg_class=veg_class;                          * SPECIFY VARIABLE NAME
CONTAINING DATE IDENTIFIER;
%let transect=transect;              * SPECIFY VARIABLE NAME CONTAINING
TRANSECT IDENTIFIER;
%let point_m=point_m;                      * SPECIFY VARIABLE NAME CONTAINING
TRANSECT POINT IDENTIFIER;
%let ht_class=ht_class;                    * SPECIFY VARIABLE NAME CONTAINING
HEIGHT CLASS CATEGORY;
%let htnum1=1;                             * SPECIFY VALUE OF HEIGHT CLASS
FOR SUBSETTED SPECIES FOR HEIGHT CLASS=1;
%let htnum4=4;                             * SPECIFY VALUE OF HEIGHT CLASS
FOR SUBSETTED SPECIES FOR HEIGHT CLASS=1-4;


*****************************************************
****** Please do not change anything beyond this ******
****** point unless you know what you are doing. ******
*****************************************************;

ods listing close;                                        * Suppress
unwanted printed output from PROC SURVEYMEANS;
run;


*****************************************************
***************Count Data Summary Stats ***************
*****************************************************;

data a1;
  set &inpfil;
  drop &date &year;
  proc sort;
```

```
    by &site_id &elev_bnd &veg_class &ht_class &transect &point_m;  * Sort
data to the finest temporal (date) and spatial (point) scales;
run;
proc transpose data=a1 out=b1;                        * Transpose the data to
convert them to numeric format and for summarization;
  by &site_id &elev_bnd &veg_class &ht_class &transect &point_m;
run;
data b1;
  set b1;
proc sort;
  by &site_id &elev_bnd &veg_class &ht_class _name_;
run;
proc means sum noprint data=b1;                       * Sum across all counts
(1 or 0) to generate total number of hits across all 0.5m points;
    var col1;
      by &site_id &elev_bnd &veg_class &ht_class _name_;
      output out=c1 sum=pt_int_hits;
run;

**** create output file of results for first part of program;

Data &outfil1;
  set c1;
  rename _name_= species;

  if pt_int_hits ne 0;                                * THIS LINE CAN BE
COMMENTED OUT BY PLACING AN ASTERISK AT THE BEGINNING OF THIS LINE
                                                        IF YOU WANT TO INCLUDE
SPECIES THAT WERE NOT ENCOUNTERED AT A SITE;

  pct_cover=(pt_int_hits/_freq_)*100;                 * Divide the number of
hits by the total number of 0.5m points;
  pct_cover=round(pct_cover,0.01);
  drop _type_ _freq_;
run;


************************************************************
****************** Propns, SEs and CVs *********************
************************************************************;


data a;
  set &inpfil;
  proc sort;
    by &site_id &elev_bnd &veg_class &ht_class &transect &point_m;     * Sort
data to the finest temporal (date) and spatial (point) scales;
run;
proc transpose data=a out=b name=&species;                  * Transpose the
data to convert them to numeric format and for summarization;
  by &site_id &elev_bnd &veg_class &ht_class &transect &point_m;
run;

***** ht class=1 species;

data c;
  set b;
if &ht_class=&htnum1;

**************************************************
****** SPECIFY THE PLANT SPECIES FOR HEIGHT ******
```

```
****** CLASS = 1 THAT WILL BE USED IN THIS  ******
****** ANALYSIS.                            ******
*************************************************;

if &species= 'CACA4' or &species='EMNI' or &species='LEPAD' or
&species='VAUL' or &species='VAVI' or &species='LI'
   or &species='BEGL' or &species='BEGL_SD'or &species='ARAL2' or
&species='ARFR2' or &species='ARARA2' or &species='PIGL' or &species='CALU2'
or &species='SAGL' or &species='SAPU15'
or &species='ALVIS' or &species='CAMI4' or &species='CAUN2' or
&species='COSU4' or &species='DILA' or &species='DROC' or &species='FEAL' or
&species='HIAL3' or &species='TRSP2'
 or &species='SABA3' or &species='SABE2' or &species='SPST3' or
&species='SAAR27' or &species='LOPR' or &species='RHCA5' or &species='SARE2';

**************************************************
*************************************************,

********** variance estimates within sites, ht class=1 species;

proc sort data=c;
  by &site_id ;
run;

proc surveymeans data=c mean stderr cv;
cluster &transect;
var col1;
domain &species*&ht_class;
by &site_id;
ods output Domain=ht1_within;
run;

********* variance estimates across sites, ht class=1 species;

proc sort data=c;
by &elev_bnd &veg_class;
run;

proc surveymeans data=c mean stderr cv;
cluster &site_id;
domain &species*&ht_class;
var col1;
by &elev_bnd &veg_class;  * estimates by sampled (non-domain) components;
ods output Domain=ht1_across;
run;

***** ht class=1-4 species;

data d;
  set b;
  if &ht_class<=&htnum4;

**************************************************
****** SPECIFY THE PLANT SPECIES FOR HEIGHT ******
****** CLASS = 1-3 THAT WILL BE USED IN     ******
****** THIS ANALYSIS.                       ******
*************************************************;

if &species= 'BEGL' or &species='BEGL_SD' or &species='PIGL';

**************************************************
```

```
**************************************************;


********** variance estimates within sites, ht class=1-4 species;

proc sort data=d;
  by &site_id &elev_bnd &veg_class;
run;

proc surveymeans data=d mean stderr cv;
cluster &transect;
domain &species*&ht_class;
var col1;
by &site_id &elev_bnd &veg_class;    * estimates by sampled (non-domain)
components;

ods output Domain=ht14_within;
run;

********* variance estimates across sites, ht class=1-4 species;

proc sort data=d;
  by &elev_bnd &veg_class;
run;


proc surveymeans data=d mean stderr cv;
cluster &site_id;
domain &species*&ht_class;
var col1;
by &elev_bnd &veg_class;       * estimates by sampled (non-domain)
components;

ods output Domain=ht14_across;
run;

******** create output files of results for second part of program;

data &outfil2;
  set ht1_within;
  drop varname domainlabel;
  if cv=. then cv=0;
  proc sort;
    by &site_id &ht_class &species;
run;


data &outfil3;
  set ht14_within;
  drop varname domainlabel;
  if cv=. then cv=0;
  proc sort;
    by &site_id &ht_class &species;
run;

data &outfil4;
  set ht1_across;
  drop varname domainlabel;
  if cv=. then cv=0;
  if stderr=. then stderr=0;
  proc sort;
```

```
    by &ht_class &species;
run;

data &outfil5;
  set ht14_across;
  drop varname domainlabel;
  if cv=. then cv=0;
  if stderr=. then stderr=0;
  proc sort;
    by &ht_class &species;
run;

ods listing;                            * re-engage printed output;
run;
```

3 Percent Cover by Growth Form: Ocular Estimates

```
************* lacl_grts_cover_4m2_var_090209.sas **************
*                                                             *
* This program estimates proportions, approximate standard    *
* errors, and approximate CVs of growth forms within 5, 4m^2  *
* quadrats along 3, 30m transects at GRTS-selected sites.     *
* The program code below that is followed by a comment field  *
* in UPPERCASE text has to be modified by the user.           *
*                                                             *
*                       Written by Bill Thompson              *
*                         NPS SWAN Quantitative Ecologist     *
*                          22 February 2008                   *
*                                                             *
*                       Last Modified 9 February 2009         *
*                                                             *
***************************************************************;

%let inpfil=grts.cover_4m2;                          * SPECIFY THE SAS LIBRARY
AND FILE NAME CONTAINING THE RAW POINT INTERCEPT
                                                          COUNTS OF PLANT
SPECIES;
%let outfil_wi=grts.cover_4m2_within_site_results;  * SPECIFY THE SAS LIBRARY
AND FILE FOR THE RESULTS FILE CONTAINING
                                                          ESTIMATED
PROPORTIONS, STD ERRORS, AND CVS WITHIN SITES BY YEAR;
%let outfil_acr=grts.cover_4m2_across_site_results; * SPECIFY THE SAS LIBRARY
AND FILE FOR THE RESULTS FILE CONTAINING
                                                          ESTIMATED
PROPORTIONS, STD ERRORS, AND CVS ACROSS SITES BY YEAR AND GROWTH
                                                          FORM;
%let site_id=site_id;                       * SPECIFY VARIABLE NAME CONTAINING
SITE IDENTIFIER;
%let date=date;                             * SPECIFY VARIABLE NAME CONTAINING
DATE IDENTIFIER;
%let year=year;                             * SPECIFY VARIABLE NAME CONTAINING
YEAR IDENTIFIER;
%let vegclass=veg_class;                    * SPECIFY VARIABLE NAME CONTAINING
VEGETATION CLASS;
%let elev=elev_bnd;
%let transect_no=transect;               * SPECIFY VARIABLE NAME CONTAINING
TRANSECT IDENTIFIER;
%let quad_no=quad_no;                       * SPECIFY VARIABLE NAME CONTAINING
QUADRAT IDENTIFIER;
%let growth_form=growth_form;               * SPECIFY VARIABLE NAME CONTAINING
GROWTH FORM;
%let growth_form_label='growth_form';       * SPECIFY LABEL FOR GROWTH FORM;


*******************************************************
****** Please do not change anything beyond this ******
****** point unless you know what you are doing. ******
*******************************************************;

ods listing close;                                     * Suppress unwanted
printed output from PROC SURVEYMEANS;
run;

data a;
  set &inpfil;
```

```
  *if &date =1;


  proc sort;
    by &year &vegclass &elev &site_id &date &transect_no &quad_no;
* Sort data to the finest temporal (date) and spatial (quadrat)
                                                              scales;
run;
proc transpose data=a out=b name=&growth_form;         * Transpose the data
to convert them to numeric format and for summarization;
  by &year &vegclass &elev &site_id &date &transect_no &quad_no;
run;

data b;
  set b;
  label &growth_form=&growth_form_label;

proc sort data=b;
  by &year;
  run;

proc surveymeans data=b mean stderr cv;                * within-site
estimates;
cluster &site_id;
cluster &transect_no;
domain &elev*&vegclass*&growth_form*&site_id;
var col1;
by &year;
ods output Domain=cov_4m2_within;
run;

proc surveymeans data=b mean stderr cv;                * across-site
estimates;
cluster &site_id;
domain &elev*&vegclass*&growth_form;
var col1;
by &year;
ods output Domain=cov_4m2_across;
run;

data &outfil_wi;                                       * final results file
for within-site estimates;
  set cov_4m2_within;
  drop varname;
  proc sort;
  by &year &elev &vegclass &site_id &growth_form;
run;
data &outfil_acr;                                       * final results file
for across-site estimates;
  set cov_4m2_across;
  drop varname;
  proc sort;
    by &year &elev &vegclass &growth_form;
run;

ods listing;                                           * re-engage output
window printing;
run;
```

4 Transposing Cover and Frequency Data to List Format

```
************* SAS_transpose_cover_freq_data_20100317.sas **************
*                                                                     *
* This program transposes the cover frequency data collected in veg   *
* quadrats and recorded in an MS Excel file to list format for data   *
* analyses (e.g., PC-ORD). This program assumes the original Excel    *
* file has been imported into SAS, converted to a SAS file format,    *
* and saved to a SAS library.  The example code below assumes this    *
* converted Excel file is in the SAS Temporary (i.e., Work) directory *
* but a user-defined library can be used instead.  The 64-bit version *
* of SAS will only import an Excel 95 or earlier file via the Import  *
* Wizard - see the instructions in the following file for how to      *
* import an Excel 97 or later file into SAS-64.                       *
*                                                                     *
* SAS_64bit_Import_Export_EXCEL_ACCESS_files_instructions_090126.doc  *
*                                                                     *
* The user should enter the variable (column) names from the          *
* converted SAS data file into the the righthand side of the equal    *
* signs in the specified section below.  Theses variables will be the *
* ones appearing in list format in the fianl results file.  Be sure   *
* the variables names to the right of the equal sign are entered      *
* EXACTLY as they appear in the imported SAS data file (formerly, the *
* original Excel file).  In the next section after that, the user     *
* should list all other variables contained in the imported SAS data  *
* so they can be removed from the final, list-formatted results file  *
* generated by this program.  These appear as macro variables in the  *
* DROP statement in the first data step.  The results file produced   *
* by this program (as defined in the macro variable "outfil") must    *
* be exported from SAS into Excel format - the simplest way to do     *
* this is via the SAS Export Wizard (see instruction file cited above *
* for other options).                                                 *
*                                                                     *
*                              Program Written By:                    *
*                                Bill Thompson, SWAN Quant. Ecologist *
*                                16 March 2010                        *
*                                                                     *
*                                Last Modified: 17 March 2010         *
***********************************************************************;

%let inpfil=work.nonvasc;             * SPECIFY THE SAS LIBRARY AND FILE NAME
CONTAINING THE RAW SPECIES FREQUENCY DATA;
%let outfil=work.nonvasc_freq;        * SPECIFY THE SAS LIBRARY AND FILE FOR
THE RESULTS FILE CONTAINING THE LIST
                                      *   FORMAT OF THE QUADRAT FREQUENCY
DATA;

*** ENTER VARIABLE NAMES IN SAS DATA FILE HERE ***;

%let site_id=site_id;                 * SPECIFY VARIABLE NAME CONTAINING SITE
IDENTIFIER;
%let transect_no=transect;            * SPECIFY VARIABLE NAME CONTAINING
TRANSECT IDENTIFIER;
%let quad_no=QUAD_NO;                 * SPECIFY VARIABLE NAME CONTAINING
QUADRAT IDENTIFIER;
%let species=SPECIES;                 * SPECIFY VARIABLE NAME CONTAINING
SPECIES;
%let quad_loc=QUAD_LOC;               * SPECIFY VARIABLE NAME CONTAINING
QUADRAT LOCATION
                                         (I.E., 0.25 M^2, 1 M^2, or 4 M^2);
```

```
*** SPECIFY ALL OTHER VARABLES THAT ARE NOT TO BE ***
***   INCLUDED IN THE FINAL RESULTS FILE (EXCLUDE   ***
*** SPECIES VARIABLES FROM THIS LIST).            ***;

%let vegclass=veg_class;
%let year=year;
%let elev=elev_band;
%let park=park;
%let date=date;

data a;
  set &inpfil;
  drop &vegclass &year &elev &park &date;    * SPECIFY VARIABLES THAT WILL
NOT BE INCLUDED IN THE FINAL RESULTS FILE;

  ****************************************************
  * DO NOT CHANGE ANYTHING BEYOND THIS POINT UNLESS *
  * YOU KNOW WHAT YOU ARE DOING.                    *
  ****************************************************;
  proc sort;
    by &site_id &transect_no &quad_no;       * Sort data to the finest
temporal (date) and spatial (quadrat) scales;
run;
proc transpose data=a out=b;                 * Transpose the data to convert
data to numeric format and for summarization;
  by &site_id &transect_no &quad_no;
run;

data c;
  set b;
  drop _label_;
  if col1 ne .;
  rename col1=&quad_loc;
  &species=_name_;
  drop _name_;
  run;
data &outfil;
  retain &site_id &species &transect_no &quad_no &quad_loc;
set c;
run;
```

Appendix G: Using BugsXLA and WinBUGS to Estimate Trends from Vegetation Plot Data

William L. Thompson, Quantitative Ecologist, Southwest Alaska Network

1 Introduction

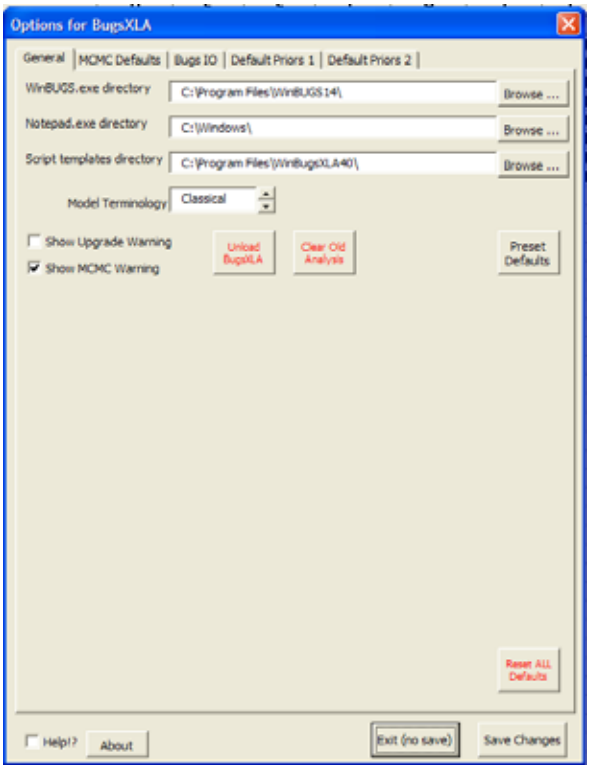
This appendix describes how to use an MS Excel add-in, BugsXLA (Woodward 2005), and freeware program WinBUGS (Lunn et al. 2000) to fit Bayesian hierarchical models (Royle and Dorazio 2008) for estimating trends from vegetation data collected on ground plots. BugsXLA serves as the front-end interface for WinBUGS so that all data analyses described in this appendix can be performed from within MS Excel. Interested readers should consult the reference guide for BugsXLA (http://www.axrf86.dsl.pipex.com/) for more details regarding its use. Lawson (2008) used BugsXLA to estimate variance components within a staggered nested design.

2 Software Requirements and Installation

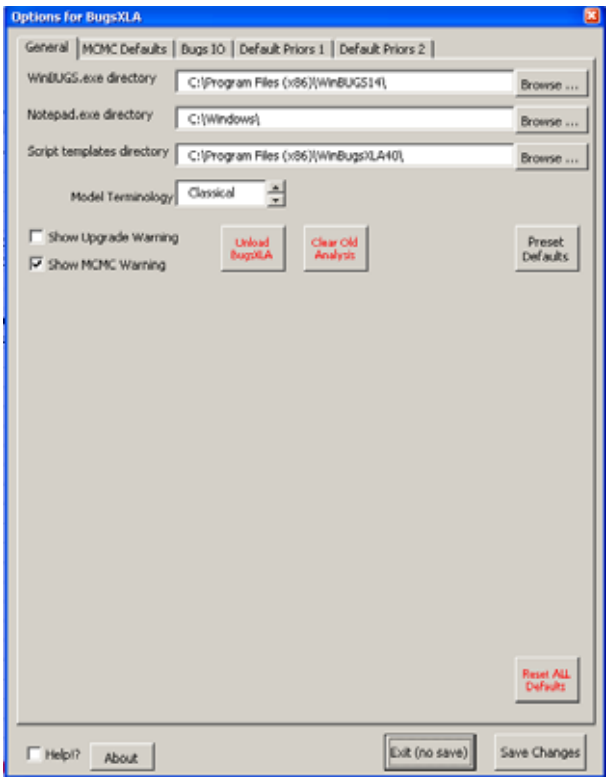
This analysis requires a 32-bit or a 64-bit version of MS Windows 98 or later, MS Notepad, MS Excel 2000 or later, WinBUGS version 1.4.x or later (Lunn et al. 2000), and BugsXLA version 4.0 or later. MS Excel and MS Notepad are standard components of the MS Office suite and MS Windows, respectively. Installation instructions for WinBUGS and BugsXLA are described on their websites, http://www.mrc-bsu.cam.ac.uk/bugs/winbugs/contents.shtml and http://www.axrf86.dsl.pipex.com/. Users of Windows Vista and/or a 64-bit Windows operating system should note the following recommendations from the WinBUGS webpage:

> *There appears to be a problem with installing WinBUGS and/or various patches in Windows Vista. Vista doesn't seem to like anyone overwriting files in the "C:\Program Files" directory (regardless of permissions). Hence we recommend that WinBUGS be installed elsewhere, e.g. "C:\".*
>
> *If all else fails (for example with a 64-bit machine), you can download a zipped version of the whole file structure (http://www.mrc-bsu.cam.ac.uk/bugs/winbugs/winbugs14.zip) and unzip it into Program Files or wherever you want it. WinBUGS makes no changes to the Registry.*

WinBUGS should be installed first, along with its latest patch, before BugsXLA is installed as an add-in to Excel. Users of Windows Vista and/or a 64-bit Windows operating system will likely have to change the default file locations of the WinBUGS program specified within the BugsXLA add-in to the file locations created as per the above recommendations. This can be done either during installation or after via the BugsXLA Options button on the Excel toolbar. The *Options for BugsXLA* pop-up window shows the default file locations for a 32-bit Windows operating system other than Vista.



The same pop-up window below shows modified WinBUGS file locations under a 64-bit operating system.



Be sure to click on Save Changes before exiting this window. This same window can be used to modify default settings of the categories listed in the tabs across the top.

3 Example Analysis in BugsXLA – Estimating a Trend in Vegetation Cover

This section provides a step-by-step description for fitting a Bayesian hierarchical model in BugsXLA and WinBUGS to estimate a trend in vegetation cover data. This example is based on simulated vegetation cover data that mimic those that will be collected as part of SWAN's ground vegetation monitoring program. Thus, we simulated cover proportions for 5 quadrats within 3 transects within 8 random plots sampled once every 5 years over 31 years (*n*=7 time samples per plot). An annual decline was applied to each time series of cover percentages for each plot that produced an overall decline of 35% over 31 years ($\lambda = 0.985$ or trend of -0.115; e.g., see Appendix E). These data are for a single species, but multispecies data can be easily accommodated as described below.

3.1 Data Entry Format

Estimated cover proportions (e.g., *est_p*) and unique identifiers for *year*, *plot*, *transect* and *quadrat* should be entered into Excel in column format such as the following truncated example (i.e., data are in 840 rows containing all combinations of *year* [7], *plot* [8], *transect* [3] and *quadrat* [5]). Note the user can name these variables as desired.

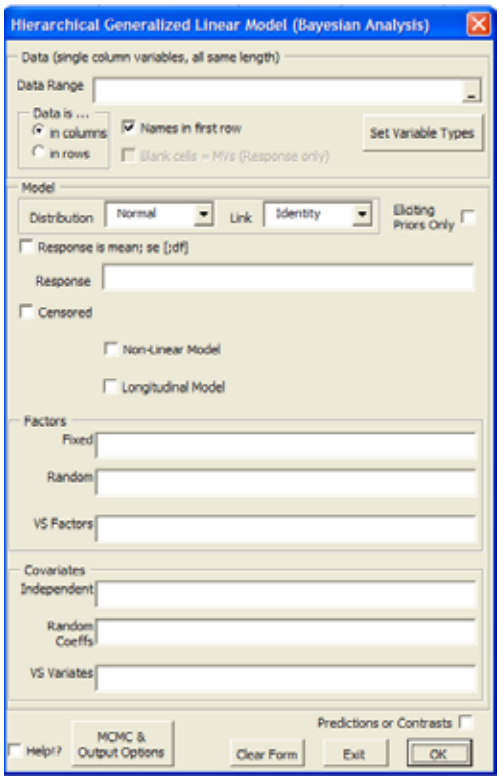
	A	B	C	D	E
1	est_p	year	plot	transect	quadrat
2	0.031878338	1	1	1	1
3	0.049335341	6	1	1	1
4	0.043417398	11	1	1	1
5	0.04831056	16	1	1	1
6	0.029822791	21	1	1	1
7	0.027665259	26	1	1	1
8	0.024996898	31	1	1	1
9	0.031536529	1	1	1	2
10	0.035379532	6	1	1	2
11	0.02127116	11	1	1	2
12	0.059347922	16	1	1	2
13	0.037132656	21	1	1	2
14	0.035393671	26	1	1	2
15	0.027227419	31	1	1	2
16	0.033367632	1	1	1	3
17	0.040738945	6	1	1	3
18	0.041308088	11	1	1	3
19	0.042187992	16	1	1	3
20	0.054932629	21	1	1	3
21	0.034476548	26	1	1	3
22	0.030223358	31	1	1	3
23	0.037113396	1	1	1	4
24	0.047395921	6	1	1	4
25	0.05124265	11	1	1	4
26	0.040178756	16	1	1	4
27	0.039631553	21	1	1	4
28	0.040374565	26	1	1	4
29	0.02353182	31	1	1	4
30	0.042707204	1	1	1	5
31	0.042072127	6	1	1	5
32	0.052961246	11	1	1	5
33	0.039096314	16	1	1	5
34	0.031675638	21	1	1	5
35	0.036912935	26	1	1	5
36	0.032406525	31	1	1	5
37	0.038356614	1	1	2	1
38	0.029812329	6	1	2	1
39	0.046592617	11	1	2	1
40	0.043345356	16	1	2	1
41	0.046111186	21	1	2	1
42	0.049052416	26	1	2	1
43	0.038442504	31	1	2	1
44	0.043723174	1	1	2	2

The unique identifiers for *plot*, *transect* and *quadrat* are numerical in the above example, but can be text or alphanumeric as well. More columns can be added for other factors of interest, such as species, if desired. Count data, such as are collected via point-intercept sampling, would include columns with the count (number of hits) of each plant species (e.g., a variable called *y*) in 59 points sampled within each transect (e.g., a variable called *n*).

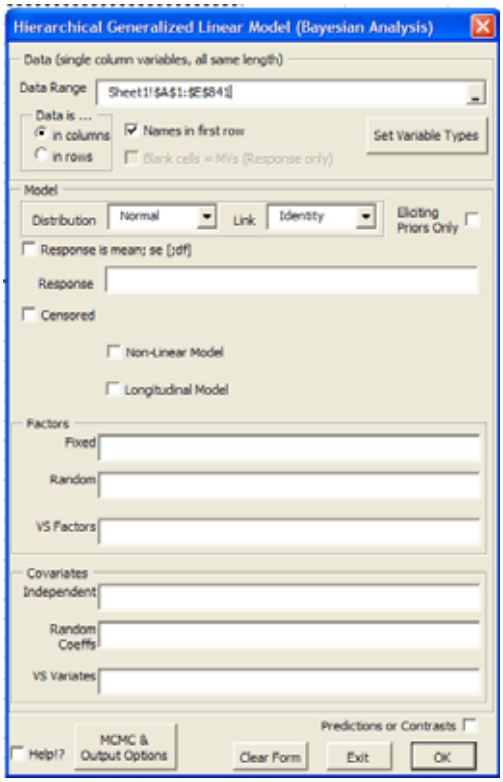
3.2 Data and Model Specifications

3.2.1 Reading Data into BugsXLA

After data have been entered into Excel, click on the Bayesian Hierarchical Generalized Linear Model (HGLM) icon in the Excel toolbar to generate the following pop-up window.



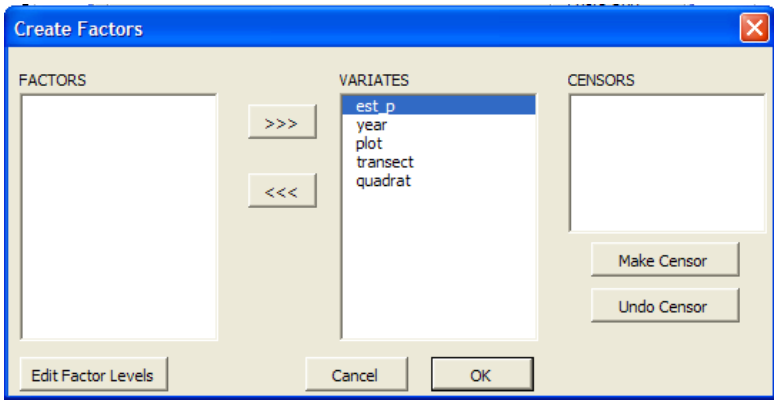
Click inside the *Data Range* box and highlight the columns and rows that contain the data. Keep the default settings of "Data is ... in columns" and "Names in first row."



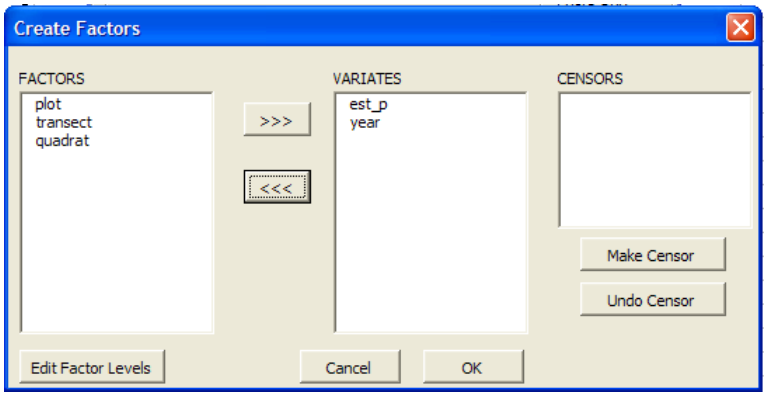
Note that all columns of data read into BugsXLA must have the same number of rows.

3.2.2 Defining Variable Types

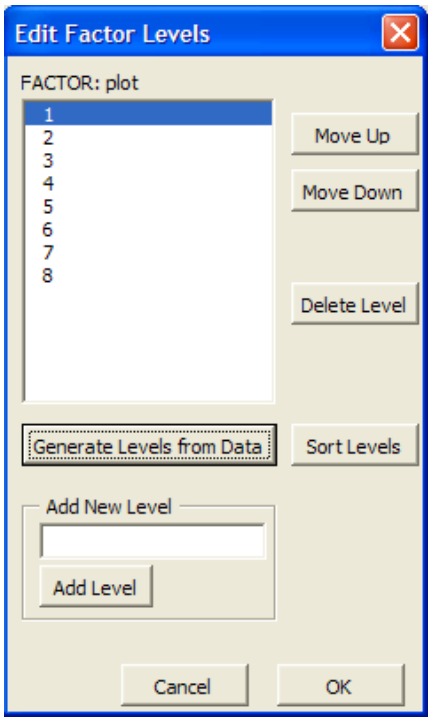
The next step is to define the variables as variates (continuous variables) or factors (discrete or categorical variables). The default setting lists all variables as variates. *Plot*, *transect* and *quadrat* are all factors so they will have to be redefined as such. Click on the *Set Variable Types* button to bring up the *Create Factors* pop-up window.



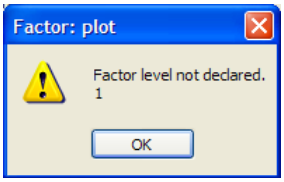
Click on *plot*, *transect* and *quadrat*, in turn, and use the button to move each one into the FACTORS panel.



Next, the levels within each factor have to be defined in their desired order. The default is to list them as they appear in the data, e.g., 1-8 for *plot*, 1-3 for *transect*, and 1-5 for *quadrat*. Even though these are the desired number and order that will be used in this analysis, the factor levels have to be confirmed for each one via the Edit Factor Levels button. Click on the plot variable to highlight it and then click on Edit Factor Levels to bring up the *Edit Factor Levels* window.



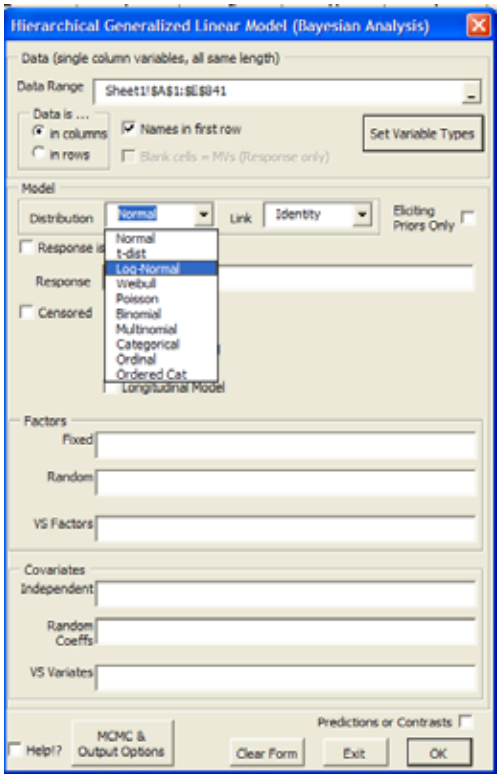
Click on OK to set the factor levels for plot. Repeat this procedure for the other factor level variables and then click on OK in the *Create Factors* window. Again, the *Edit Factor Levels* procedure has to be performed even if the default levels will be used as specified; otherwise, the following error window will be generated when attempting to run a model.



These changes are now set in the Excel worksheet so this process will not have to be repeated for future analyses performed in this file.

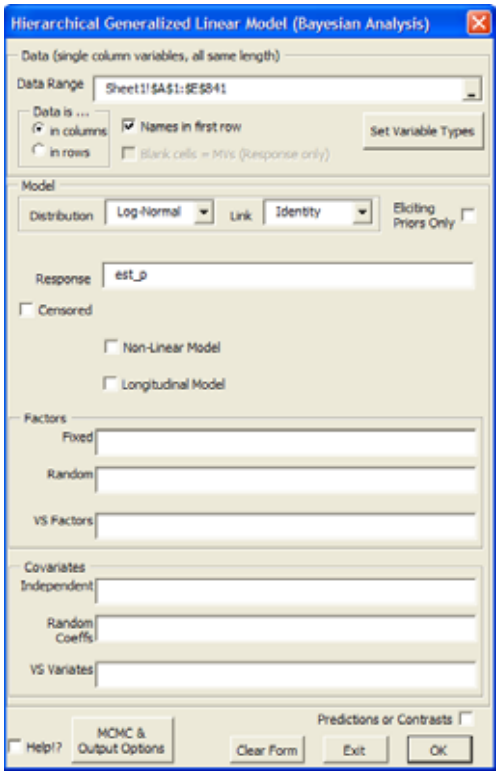
3.2.3 Choosing a Model

A response variable in the form of an estimated proportion is typically modeled using a binomial error distribution and a logit link. However, BugsXLA will only accept proportions in the form of counts/total (e.g, *y*/*n* mentioned in the Data Entry Format section), which works for point-intercept data but not for single estimates of percent cover collected in quadrats under SWAN's vegetation protocol. Therefore, we recommend starting with a lognormal distribution and an identity link because the lower bound is zero like the estimated proportions. This model should provide a reasonable fit as long as the observed proportions do not vary a lot over the 0-1 interval, even though the lognormal's upper bound is infinity. The adequacy of the fit of any model must be checked (see Assessing Model Fit) before accepting the output as reasonable. If this or other model options offered in BugsXLA are concluded to be inadequate, then the data will have to be modeled directly in WinBUGS, which has a steeper learning curve but offers extensive modeling options, or via some other program such as freeware program R (R Core Development Team 2009) that can run WinBUGS from within it (e.g., R2WinBUGS library; Sturtz et al. 2005). Begin with a distribution whose limits best match those of the response variable; truncating the lower and/or upper limits of a distribution may be a possibility as well. The lognormal and other error distributions can be selected from the drop-down menu under *Distribution* as shown below. The identity link is the only option with the lognormal.



3.2.4 Specifying the Response Variable

The name of the response variable (e.g., est_p) should be entered into the box next to Response.



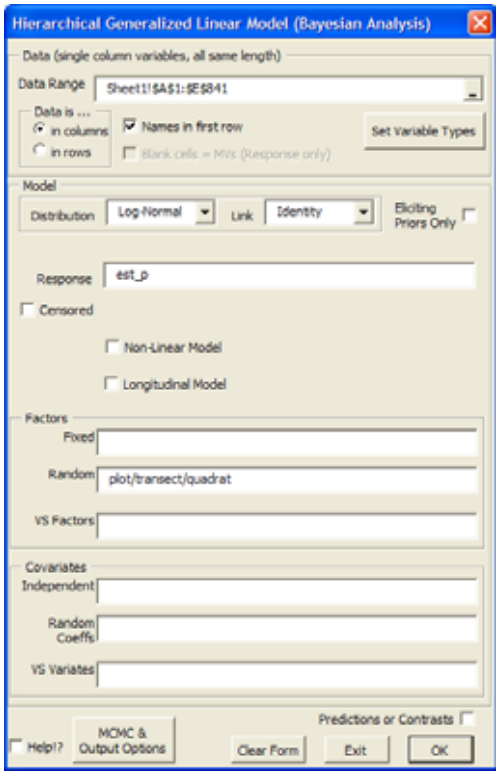
If these were data collected under point-intercept sampling, the response variable would be entered in the *y*/*n* format, which is the column of total counts of a given species per transect (e.g., *y*) divided by the column of total points sampled in a transect (e.g., *n*) (note that the user can name these variables whatever he or she wishes).

3.2.5 Specifying and Selecting a Covariance Structure

Data on vegetation composition and structure will be collected repeatedly from the same plots over time, referred to as repeated measures data, so temporal dependency among samples must be properly accounted for in the model through inclusion of a covariance structure. BugsXLA offers two or three options for specifying the covariance structure in WinBUGS (depending on the error distribution): 1) autoregressive 1 (AR1; exponential correlation model); 2) AR1 with measurement error (not available for the Poisson distribution); and 3) compound symmetry (uniform correlation model).

AR1 structures are implemented by clicking in the box to the left of *Longitudinal Model* in the *Hierarchical Generalized Linear Model* window and entering the a model statement in the form *<model type>*{*<Unit>*/[*<Time>*]} in a larger box that appears to the right of *Longitudinal Model*. Note that this format only allows specification of the topmost factor level or *Unit*, which is *plot* in our example. The *Time* option does not have to be included when observations are equally spaced and in sequence (see the BugXLA reference guide and help files for more details).

A compound symmetry structure is incorporated through the *Random* option under *Factors* in the *Hierarchical Generalized Linear Model* window. A factor or nested factor (see next section) is entered into the box to the right of *Random*.



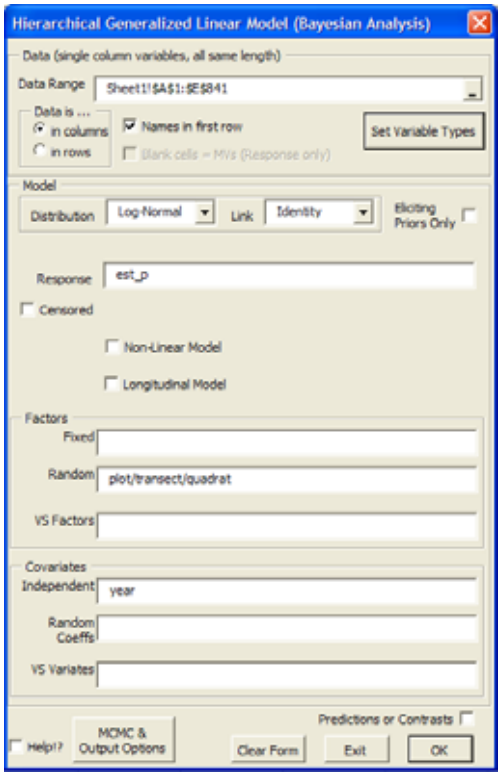
An important step in modeling repeated measures data is choosing a reasonable covariance structure. One approach is to run the model of interest with different covariance structures, compute the DIC model selection criterion (Spiegelhalter et al. 2002) for each run, and select the covariance structure that produces the lowest DIC value (see Specifying Prior Distributions Model Checking Criteria). In our example, we used a compound structure because of how the example data were simulated, but generally the user should use the DIC criterion to select the best-fitting covariance structure.

3.2.6 Specifying Factors

Factor variables are entered into the relevant option box under *Factors* in the *Hierarchical Generalized Linear Model* window. A nested structure is specified using the "/" character between two factors or among three or more factors, where the higher level factor is listed first. In our example, quadrats are nested within transects and transects are nested within plots, so we denote this as "plot/transect/quadrat". Other operators are accepted by BugsXLA, such as the product operator "*" to denote interaction; see the BugsXLA reference guide or help files for a complete list and examples.

3.2.7 Specifying Covariates

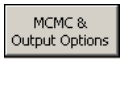
Covariates are entered into the relevant option box under *Covariates* in the *Hierarchical Generalized Linear Model* window. In our example, *year* is an independent covariate whose estimated coefficient provides the trend estimate so it is entered into the box to the right of *Independent*. If we were interested in trend estimates by some factor level, such as by vegetation height category, we would use the product operator (*) to create an interaction between *year* and the factor variable containing vegetation height category.



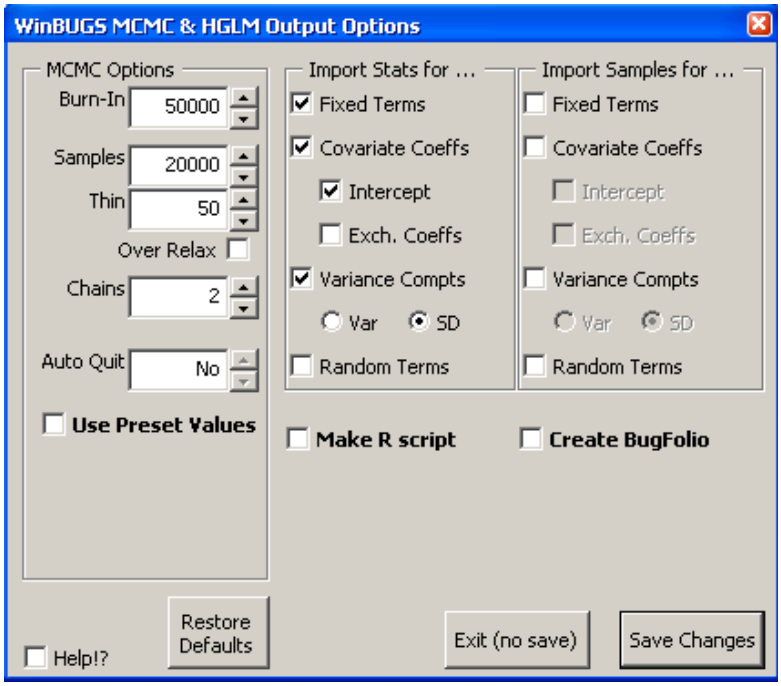
3.3 Markov Chain Monte Carlo (MCMC) and Output Options

The Markov Chain Monte Carlo (MCMC) procedure requires an adequate number of "burn-in" samples to be discarded to achieve convergence so that reasonable parameter estimates can be obtained from the posterior distribution. What is "adequate" depends on the nature of the data and the complexity of the specified model. Based on the literature and on his experience modeling various data sets, Woodward (2005) offered suggestions on number of burn-in samples, number of samples from the posterior distribution, thinning, and number of chains for simple, regular and complex models. These default values are offered in BugsXLA.

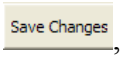
In our example for modeling repeated measures data, we conservatively set the burn-in to 50,000; BugsXLA allows a maximum burn-in of 100,000 to be specified. We also set the number samples to 20,000, the thinning interval to 50, and the chains to 2, which are consistent with default values for a complex model. Note that the thinning interval retrieves every *K*th sample from those taken from the posterior distribution and is used to reduce effects of high autocorrelation when present. It is much better to err on the side of being overly conservative in setting these values; the cost of being too conservative will only be longer computing time, whereas being too liberal could yield unreasonable model results. As discussed in the next section, we recommend running at least two chains to help assess convergence.

Click on 

to bring up the *WinBUGS MCMC & HGLM Options* window.



Use the up or down arrows to set each of the *MCMC Options*. The *Auto Quit* option is automatically set to *No* when two or more chains are specified; this option keeps the WinBUGS program window open after the model has been run so that various model assessment tools can be accessed (see Assessing Model Fit). *Make R script* and *Create BugFolio* create output text files containing R and WinBUGS code and related material, respectively, in case the user would like to manually edit the code and run it directly in R or in WinBUGS. BugsXLA also will export data in a format that can be read directly into WinBUGS.

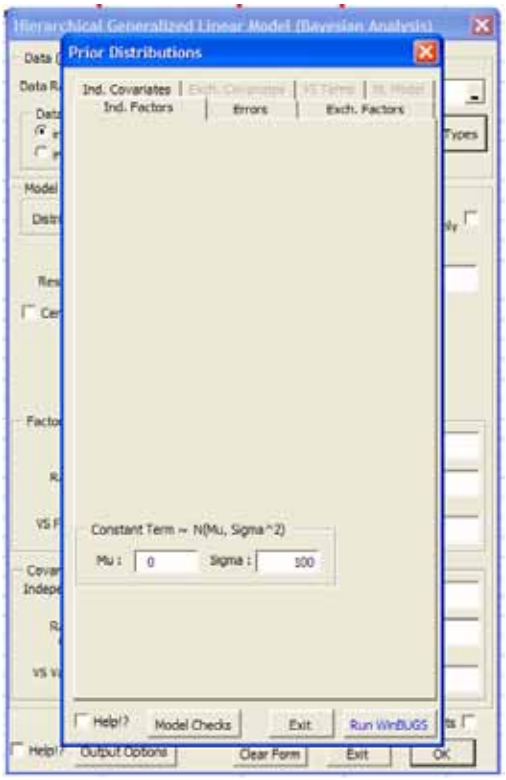
Click on 

, which returns you to the *Hierarchical Generalized Linear Model* window.

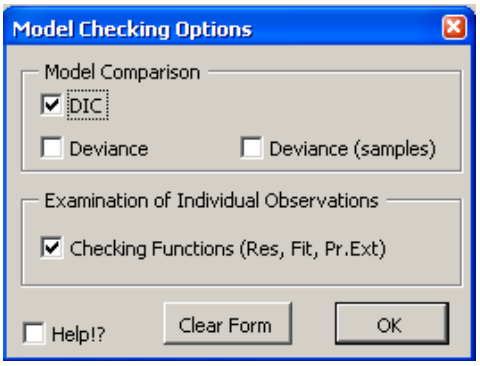
3.4 Specifying Prior Distributions and Model Checking Criteria

An advantage of Bayesian modeling is the ability to incorporate prior information in the form of prior distributions. When prior information is not available, noninformative or diffuse priors often are used. BugsXLA provides default settings for all parameters that approximate diffuse priors based on those recommended in the literature (Woodward 2005). See the BugsXLA reference guide and help files for an extensive discussion of specifying prior distributions. We will use the default priors in BugsXLA for our example.

Click on *OK* in the *Hierarchical Generalized Linear Model* window to bring up the *Prior Distributions* window.



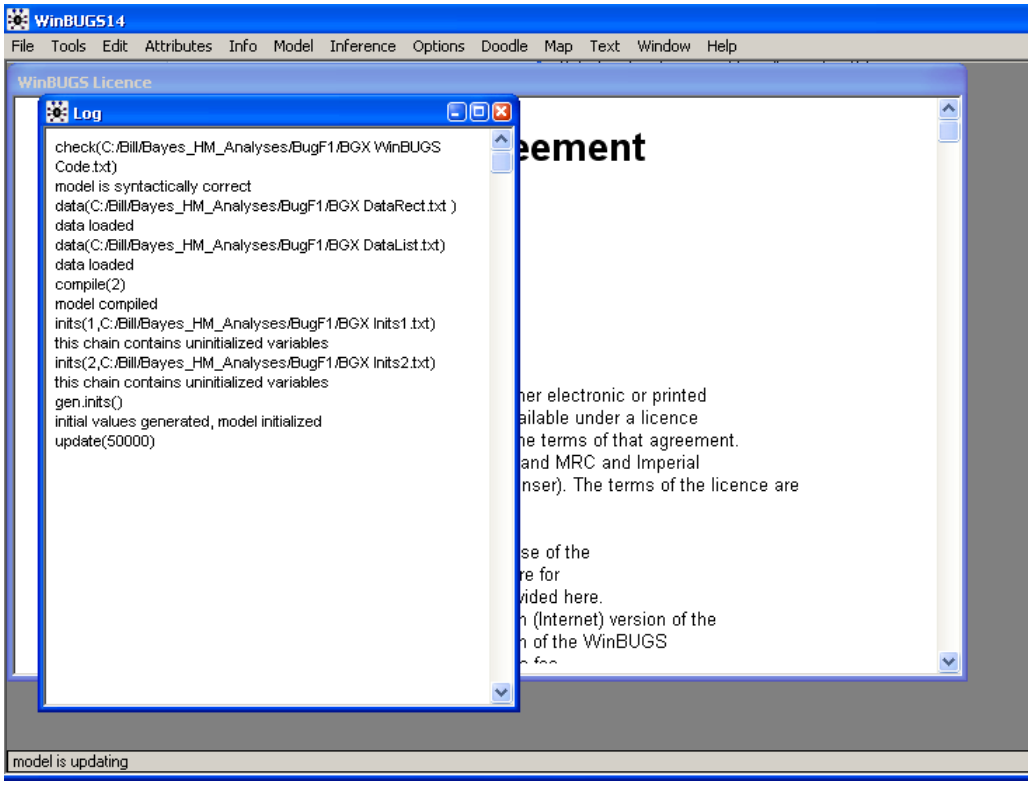
Click on Model Checks to display the *Model Checking Options* window.



Click on *DIC* and *Checking Functions* to save the DIC value, Bayesian p-values and residual plots to the output sheets after the model has been run in WinBUGS. Click *OK* to return to the *Prior Distributions* window.

3.5 Initiating WinBUGS from BugsXLA

Once the model and outputs have been specified, click on Run WinBUGS to initiate the WinBUGS program. Three windows are spawned from this action - the WinBUGS program, the WinBUGS License Agreement, and the WinBUGS Log file (Notepad). The Log file shows the progress of the model run. The progress is also displayed in the left of the gray bottom margin of the WinBUGS program window (i.e., "model is updating").



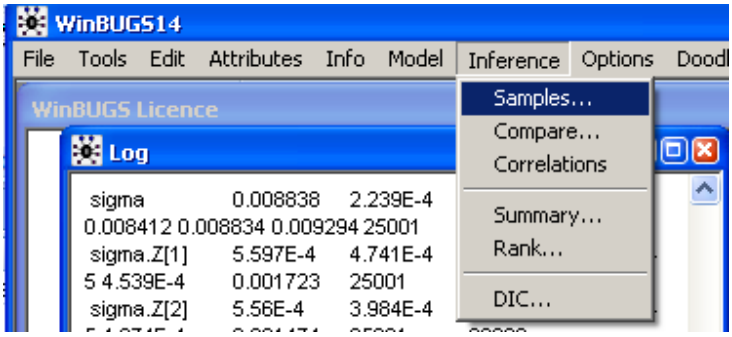
When the model run has completed, the message in the bottom left margin changes to something like "updates took 6521 s", where "s" refers to the number of seconds. The log file will have show some of the estimated coefficients, and will end with the text "display(window)" and a blinking cursor. DO NOT CLOSE the log window or the WinBUGS program window at this point. WinBUGS will need to be active to access some of its model assessment tools (see next section).

3.6 Model Outputs

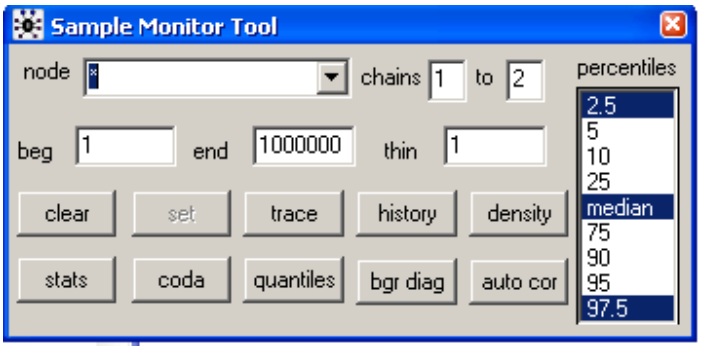
3.6.1 Assessing Model Fit

Assessing the fit of the model is an essential step in modeling process, regardless of the model form or software program in use. Model convergence is an important component of any model, but is especially relevant to hierarchical generalized linear models, whether they are fitted based on Frequentist (likelihood) or Bayesian (likelihood plus prior) approaches. There is no single criterion that indicates goodness of fit in Bayesian hierarchical generalized linear models, so we will discuss several tools that should be used in conjunction with one another to assess convergence and model fit.

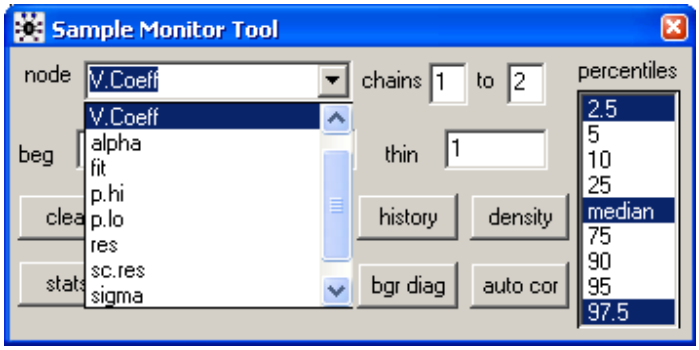
Sample Monitor Tool: Click on *Inference=>Samples...* in the WinBUGS program menu bar



to bring up the *Sample Monitor Tool* window.

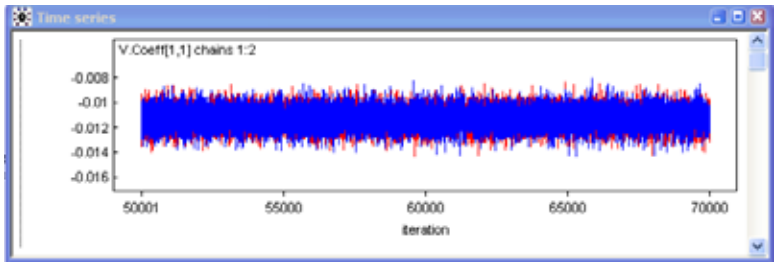


The *node* box contains a list of random variables fitted in the model. These can be used to assess model fit. The default * will generate results for all variables listed in the drop-down menu. We will focus on "V.Coeff" for this example, which is the WinBUGS name for the *year* variable in our simulated data. Click on the down arrow of the drop-down menu and select "V.Coeff".



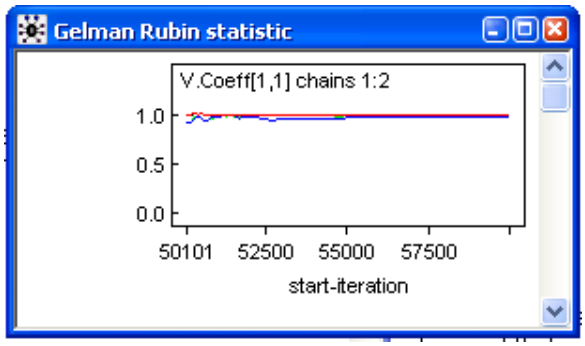
We will be using the history, bgr diag, auto cor and density tools to assess different aspects of model fit.

Click on history to display a plot of both chains of values from the MCMC samples.



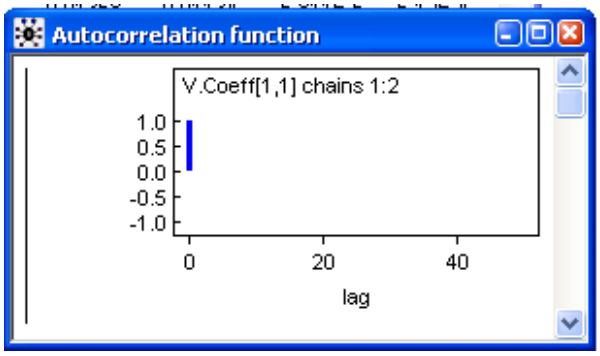
The chains are shown in two colors and should be mixed together rather than one chain separated from the other (see p. 55 in the WinBUGS reference manual [http://www.mrc-bsu.cam.ac.uk/bugs/winbugs/manual14.pdf] for an example of poorly mixed chains). The above plot indicates that a *lack of* mixing did not occur, but this diagnostic alone cannot be used to confirm proper mixing occurred.

Click on bgr diag to display a plot of the modified Gelman-Rubin convergence statistic (Gelman and Rubin 1992, Brooks and Gelman 1998).



The lines should stabilize around the 1.0 value to indicate convergence. There will be some initial bounce in the blue line as the algorithm gets started. The above plot indicates convergence.

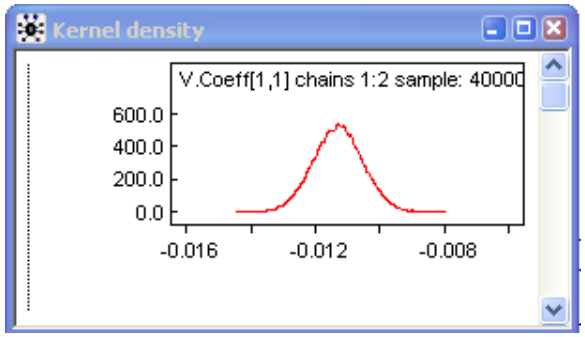
Click on auto cor to generate a plot showing the degree of autocorrelation in the chains for the parameter of interest.



The desired condition is to have the mass mostly or entirely on 0 lag, as above. This is where the thinning interval plays an important role.

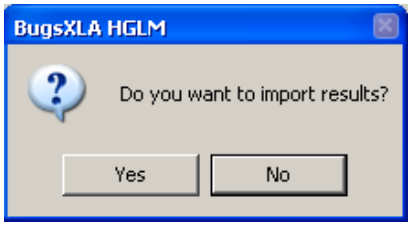
Click on

to view a plot displaying the estimated posterior distribution.

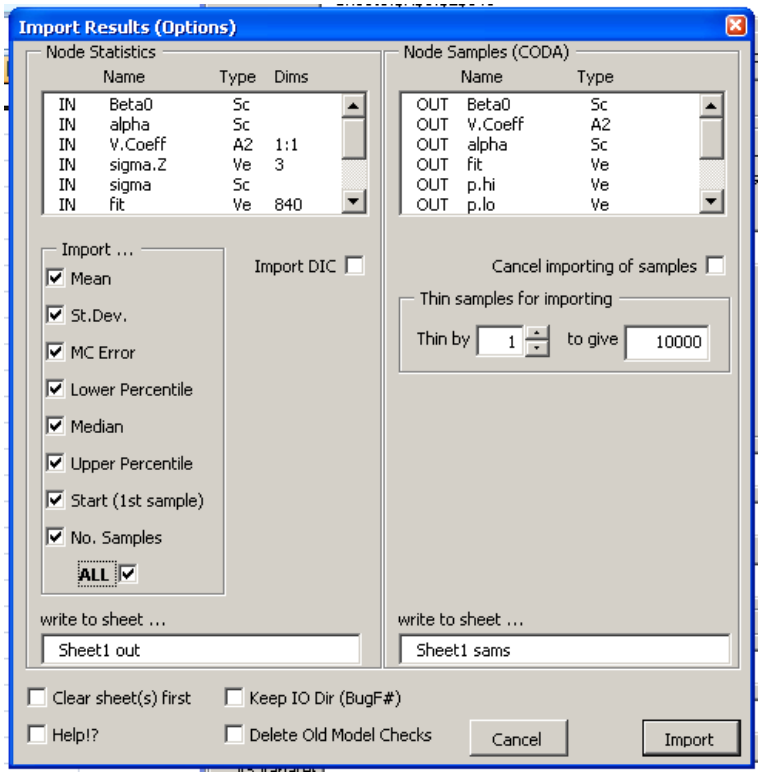


This distribution should be unimodal (i.e., one obvious peak) and not severely skewed. The data for our example were simulated from a truncated Normal distribution, so it is not surprising that the posterior distribution also approximates a Normal.

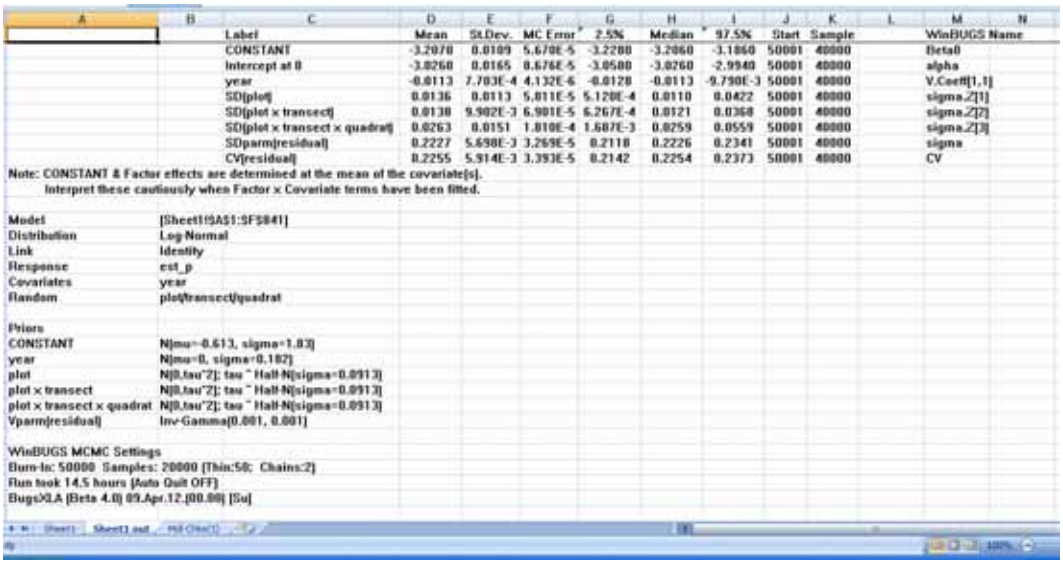
After reviewing these various plots and confirming reasonable convergence and model fit, proceed to the BugsXLA window by closing the WinBUGS program window, which generates the following pop-up window.



Click *Yes* and the *Import Results (Options)* window will appear.



Click on the box next to *All* in the left-hand panel. Either keep the default names of the Excel sheets that will be generated (*write to sheet...*) or rename them as desired. Click Import and, once the import process is complete, Excel spreadsheets containing model output and model diagnostics will be added to the existing Excel file. The default brings up the model output sheet ("Sheet1 out" under the default name).



Label	Mean	St.Dev.	MC Error	2.5%	Median	97.5%	Start	Sample	WinBUGS Name
CONSTANT	-3.2078	0.0109	5.670E-5	-3.2288	-3.2060	-3.1860	50001	40000	Beta0
Intercept at 0	-3.0268	0.0165	8.676E-5	-3.0580	-3.0260	-2.9940	50001	40000	alpha
year	-0.0113	7.703E-4	4.132E-6	-0.0128	-0.0113	-9.790E-3	50001	40000	V.Coeff[1,1]
SD[plot]	0.0136	0.0113	5.811E-5	5.120E-4	0.0110	0.0422	50001	40000	sigma.Z[1]
SD[plot x transect]	0.0138	9.902E-3	6.901E-5	6.267E-4	0.0121	0.0368	50001	40000	sigma.Z[2]
SD[plot x transect x quadrat]	0.0263	0.0151	1.810E-4	1.687E-3	0.0259	0.0559	50001	40000	sigma.Z[3]
SDparm[residual]	0.2227	5.698E-3	3.269E-5	0.2118	0.2226	0.2341	50001	40000	sigma
CV[residual]	0.2255	5.914E-3	3.393E-5	0.2142	0.2254	0.2373	50001	40000	CV

Note: CONSTANT & Factor effects are determined at the mean of the covariate(s).
Interpret these cautiously when Factor x Covariate terms have been fitted.

Model	[Sheet1!$A$1:$F$841]
Distribution	Log Normal
Link	Identity
Response	est_p
Covariates	year
Random	plot/transect/quadrat
Priors	
CONSTANT	N[mu=-0.613, sigma=1.83]
year	N[mu=0, sigma=0.182]
plot	N[0,tau^2]; tau ~ Half-N[sigma=0.0913]
plot x transect	N[0,tau^2]; tau ~ Half-N[sigma=0.0913]
plot x transect x quadrat	N[0,tau^2]; tau ~ Half-N[sigma=0.0913]
Vparm[residual]	Inv-Gamma[0.001, 0.001]

WinBUGS MCMC Settings
Burn-In: 50000 Samples: 20000 [Thin:50; Chains:2]
Run took 14.5 hours [Auto Quit OFF]
BugsXLA [Beta 4.0] 09.Apr.12.[00.00] [Su]

The top eight rows display the model parameters and their estimated coefficients, measures of precision and 95% credible intervals. The last column shows the WinBUGS name for these parameters, which match those listed in the drop-down menu of the *Sample Monitor Tool* discussed previously. The rest of the information in this sheet refers to model specifications and

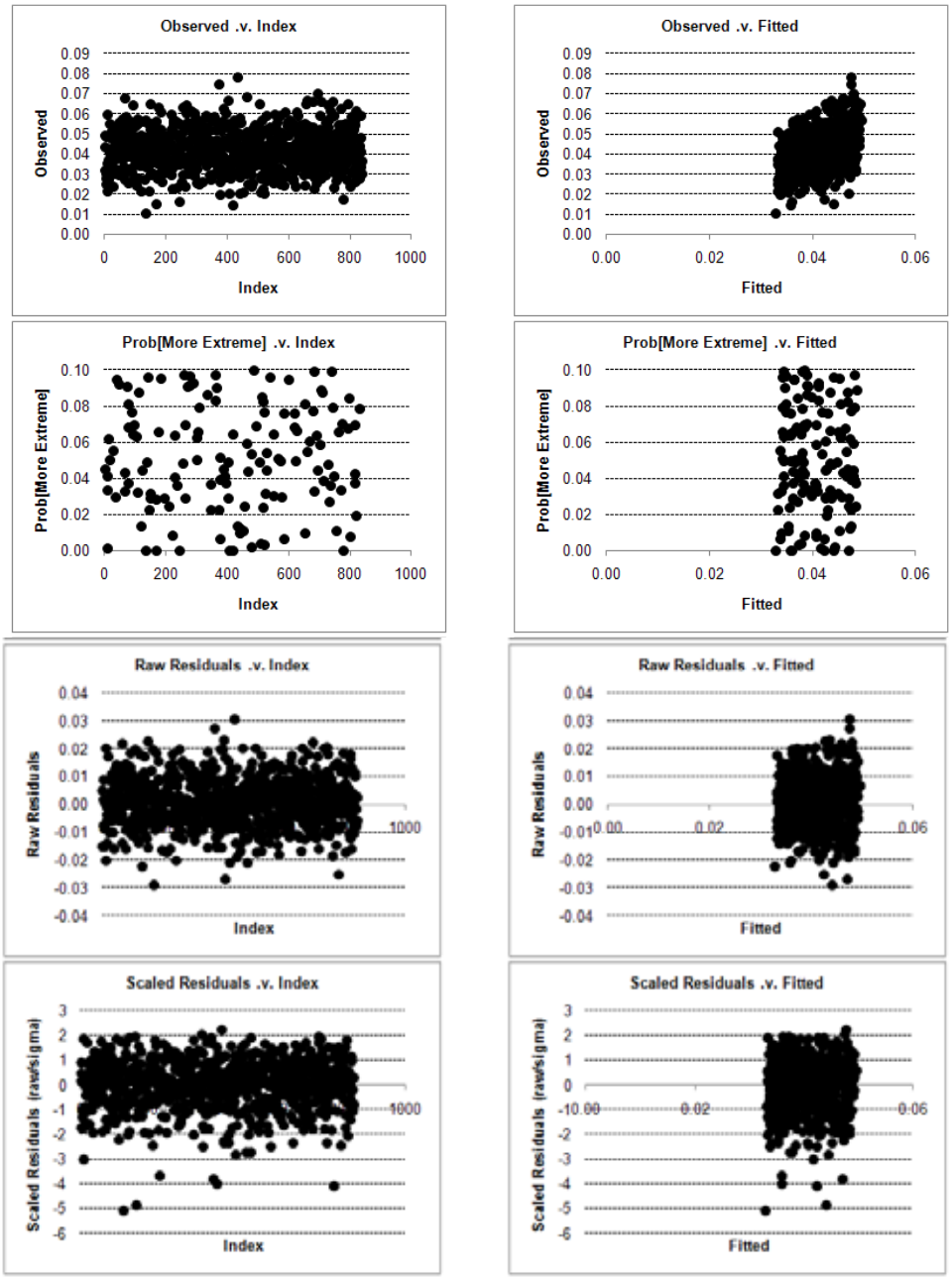
run time (note that WinBUGS can take hours to run [14.5 in this case] when fitting large data sets and complex models).

Bayesian P-values and Residual Plots: Click on the "Modl Chks(1)" tab at the bottom of the Excel file to bring up the sheet containing model diagnostics requested under *Checking Functions* in the *Model Checking Options* window.

	A	B	C	D	F	G	H	I
1	Model	[Sheet1!$A$1:$F$841]	Index	Obs	Fit	RawRes	ScRes	PrExt
2	Distribution	Log-Normal	1	0.031878	0.0469	-0.0150	-1.73	0.05
3	Link	Identity	2	0.049335	0.0443	0.0050	0.49	0.31
4	Response	est_p	3	0.043417	0.0419	0.0016	0.17	0.43
5	Covariates	year	4	0.048311	0.0396	0.0087	0.90	0.19
6	Random	plot/transect/quadrat	5	0.029823	0.0374	-0.0076	-1.01	0.16
7			6	0.027665	0.0353	-0.0077	-1.10	0.14
8	Priors		7	0.024997	0.0334	-0.0084	-1.30	0.10
9	CONSTANT	N(mu=-0.613, sigma=1.83)	8	0.031537	0.0467	-0.0151	-1.76	0.04
10	year	N(mu=0, sigma=0.182)	9	0.03538	0.0441	-0.0087	-0.99	0.16
11	plot	N(0,tau^2); tau ~ Half-N(sigma=0.0913)	10	0.021271	0.0417	-0.0204	-3.02	0.00
12	plot x transect	N(0,tau^2); tau ~ Half-N(sigma=0.0913)	11	0.059348	0.0394	0.0200	1.85	0.03
13	plot x transect x quadrat	N(0,tau^2); tau ~ Half-N(sigma=0.0913)	12	0.037133	0.0372	-0.0001	-0.01	0.50
14	Vparm[residual]	Inv-Gamma[0.001, 0.001]	13	0.035394	0.0352	0.0002	0.03	0.49
15			14	0.027227	0.0333	-0.0060	-0.89	0.19
16			15	0.033368	0.0474	-0.0140	-1.57	0.06
17			16	0.040739	0.0448	-0.0040	-0.42	0.34
18			17	0.041308	0.0423	-0.0010	-0.10	0.46
19			18	0.042188	0.0400	0.0022	0.24	0.41
20			19	0.054933	0.0378	0.0171	1.68	0.05
21			20	0.034477	0.0357	-0.0012	-0.15	0.43
22			21	0.030223	0.0338	-0.0035	-0.49	0.31
23			22	0.037113	0.0474	-0.0103	-1.09	0.14
24			23	0.047396	0.0448	0.0026	0.26	0.40
25			24	0.051243	0.0423	0.0089	0.86	0.20
26			25	0.040179	0.0400	0.0002	0.02	0.49
27			26	0.039632	0.0378	0.0018	0.22	0.41
28			27	0.040375	0.0357	0.0047	0.55	0.29
29			28	0.023532	0.0338	-0.0102	-1.62	0.06
30			29	0.042707	0.0474	-0.0047	-0.47	0.32
31			30	0.042072	0.0448	-0.0027	-0.28	0.39
32			31	0.052961	0.0423	0.0106	1.01	0.16
33			32	0.039096	0.0400	-0.0009	-0.10	0.46
34			33	0.031676	0.0378	-0.0061	-0.78	0.21

Sheet1 | Sheet1 out | Mdl Chks(1)

Calculating Bayesian or posterior p-values involves generating a replicate data set and counting the number of times the replicate is more extreme than the observation. The closer these values are to 0.5, the better the replicated data match the observed data. Values closer to 0 or 1 indicate larger differences and may indicate a poorly fitting model when there are many such values (Ntzoufras 2009). Bayesian p-values are listed under the column labeled "PrExt"; values highlighted in red may indicate suspect values. Plots of these values that are less than 0.1 are shown in the second of four rows of plots to the right of the tabular data.



The other three rows contain standard residual plots and are interpreted as such. Although there are some values close to 0 in the second row of plots, overall the plots look okay and seem to indicate a reasonable, albeit not close, fit.

3.6.2 Interpreting Model Output

The estimates of interest are the median, 2.5% (lower credible limit) and 97.5% (upper credible limit) of the *year* parameter, which provide the estimate of trend and its 95% Bayesian credible interval. These estimates were obtained from the posterior distribution, which in this case was very nearly symmetrical, so the mean and the median are the same. However, posterior distributions are often skewed so the mean and median will not be the same. the median is the estimate that should be used.

C	D	E	F	G	H	I	J	K	L	M	N
Label	Mean	St.Dev.	MC Error	2.5%	Median	97.5%	Start	Sample		WinBUGS Name	
CONSTANT	-3.2070	0.0109	5.670E-5	-3.2280	-3.2060	-3.1860	50001	40000		Beta0	
Intercept at 0	-3.0260	0.0165	8.676E-5	-3.0580	-3.0260	-2.9940	50001	40000		alpha	
year	-0.0113	7.703E-4	4.132E-6	-0.0128	-0.0113	-9.790E-3	50001	40000		V.Coeff[1,1]	
SD(plot)	0.0136	0.0113	5.811E-5	5.120E-4	0.0110	0.0422	50001	40000		sigma.Z[1]	
SD(plot x transect)	0.0138	9.902E-3	6.901E-5	6.267E-4	0.0121	0.0368	50001	40000		sigma.Z[2]	
SD(plot x transect x quadrat)	0.0263	0.0151	1.810E-4	1.687E-3	0.0259	0.0559	50001	40000		sigma.Z[3]	
SDparm(residual)	0.2227	5.698E-3	3.269E-5	0.2118	0.2226	0.2341	50001	40000		sigma	
CV(residual)	0.2255	5.914E-3	3.393E-5	0.2142	0.2254	0.2373	50001	40000		CV	

The modeling results indicate an average decline of 1.13% per year over 31 years, with a 95% credible interval of -0.0128 to -0.00979. These results are similar to those obtained by using likelihood-based PROC GLIMMIX (SAS Institute, Inc. 2008) to fit a generalized linear mixed model with a binomial error distribution and a logit link (trend estimate = -0.116, 95% confidence interval: -0.01308 to -0.01012). The interpretation of the credible interval is that there is a 95% chance that the true trend (i.e., -0.115) occurs within -0.01280 and -0.00979 because parameters are considered random variables under the Bayesian paradigm. This differs from the proper interpretation of a Frequentist-based confidence interval, which would indicate that if the same data were sampled over many times in the same way, on average 95% of the confidence intervals would contain the true trend. The other parameter estimates displayed in the output sheet include intercept, variance components (plot, transect within plot, and quadrat within transect within plot), overall variance, and residual precision (CV of random residual component).

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Appendix H: Guidelines for Voucher Collections

David F. Murray and Carolyn Parker, University of Alaska Museum - Herbarium

Introduction

The vascular plant flora is not well known over large areas of Alaska. Each new collection gives us more information about the species of plants present, their various forms, and their overall distribution. This information is of primary interest to plant taxonomists and is essential background for plant geographers and ecologists. It has also become increasingly obvious that an inventory of plant diversity is a foundation for efforts to conserve natural resources, and plant specimens are the physical documentation of this diversity.

Plant collections, suitably preserved and mounted, provide a permanent physical record of our natural history heritage. The following remarks and guidelines are intended to aid the student, amateur botanist, and professional from fields other than taxonomy to prepare plant collections. Certain minimum standards must be observed so that the specimens can be identified and also be of lasting scientific value.

Methods

How to Collect

The Plant Conservation Roundtable, an informal group of botanists and conservationists in Washington, D. C., has prepared Conservation Guidelines (Natural Areas Journal, 1986, vol. 6, no. 3, pgs. 31, 32), which provide ethical standards for plant collecting. Several of their points need mentioning here. To paraphrase: we must obtain permission and permits as required by law and the standards of decent behavior; collect with discretion lest we encourage others who might collect indiscriminately; avoid placing any population of plants at risk of extirpation--if there is any doubt, do not collect. Therefore, avoid collecting rare plants (see Candidate Threatened and Endangered Plants of Alaska by Murray and Lipkin, available from the U.S. Fish and Wildlife Service, Anchorage, and the University of Alaska Museum, Fairbanks).

Look for plants with well-developed flowers and/or fruits. The taxonomy of vascular plants is based on complete and mature specimens, therefore accurate identifications are more likely with good material at hand. The exceptions are trees and shrubs, which generally can be determined from mature leaf and stem structures alone. Unless you want to show some unusual form of variation, take plants that are representative of the population you are sampling. While the plants are fresh and tissues are still flexible, gently tap the root mass against your foot or the ground to remove as much soil as you can. Whenever possible, entire plants should be collected; that rule is, of course, limited to those plants small enough to be placed within a single sheet of folded newspaper. Although we emphasize that flowers and fruits are generally essential, do not fail to get the basal leaves and roots as well. Usually a sturdy trowel will suffice to dig up plants. An army surplus trenching tool or an old ice-axe is excellent too. Remember to replace your divots.

A pocket knife is adequate for collecting portions of trees, shrubs, and large herbs, but pruning shears make the job much easier. Shrubs and trees can be collected by taking the tips of branches or sections of stems with mature leaves (and flowers or fruits,whenever possible). Be sure to note the total height of the plant. Very large herbaceous plants, such as tall umbellifers, are often a problem. Cut away and discard most of the stem, but retain at least a representative leaf with

petiole and short section of attached stem, the infloresence, and the stem base with a portion of the root. Collect enough material to fill a folded sheet of newspaper.

A plant press is unwieldy, to say the least, and it is best left in the vehicle, at home, or at the base camp. Protect the specimens in large, plastic freezer bags. If you plan to carry the fresh specimens with you all day, "zip-locks" are good containers, since you can blow air into them before zipping them shut; the air will act as a cushion and offer some protection against damage while in a backpack. Plastic tupperware-like boxes are the high-tech solution.

Documentation

The scientific value of specimens depends on the specimen and on the data you take when making the collection. It is important to adopt a system to insure that the data for each specimen are recorded faithfully and consistently. Remember that these notes must be intelligible to another worker who may be processing your plants later on. If you are collecting just a few plants, you may write all the field notes directly on the newspaper in which the plant is pressed. Preferably, every collector should keep a pocket-size field notebook in which you record each collection. This is critical; don't trust your memory!

If this is your first collection, simply start with #1 and proceed consecutively so that each collection has a unique number. Assign a new collection number to each collection from a single locality on any one day. If the same species is collected on the same day, but at a different locality, assign it a different number. If the same species is collected again at the same location as before, but on a different day, give it a different number also. Do not mix different species of plants on a sheet.

Essential data include where (general and specific locality, general and specific habitat, elevation), when (day, month, year), and by whom collected (your name). Additional information may include exposure (N, S, E, W), slope angle (flat, gentle, steep) soil texture (gravel, sand, loam) and moisture (wet, moist, dry), flower color (some blossoms fade with drying, some colors intensify), odor, relative abundance (abundant, common, infrequent, rare), and conspicuous use by animals. A page of your field notebook may look like this:

Kodiak Island

21 Jul 1994
Monaska Bay - sea cliffs behind beach - elev. 1-10 m.s.m.

245. *Campanula* sp.
common in s-facing rock crevices, flowers blue
246. *Draba hyperborea*
rare in dry rock crevices
247. unknown shrub
1.5 m. tall, growing in seepage at base of cliff in wet, rocky soil

Monaska Bay - gravel strand beaches - elev. 1-2 m.s.m.

248. *Senecio pseudo-arnica*
common, growing with Leymus, upper gravel beach zone
` 249. unknown crucifer
rare, purple flowers, scattered plants in sand, lower beach zone

When pressing the specimens, the collection number is placed on the sheet of newspaper containing the specimens, which relates those specimens back to the data in your notebook. Ideally, this field notebook becomes part of the permanently curated collection.

Specimen Preservation

Place the fresh specimens in a sheet of folded newspaper. When folded, the size of the paper should conform to the size of the plant press, blotters, and cardboard ventilators. The dried specimens will be mounted on a sheet of herbarium paper a bit smaller than the folded newspaper, thus each paper of specimens equals a minimum of one finished herbarium sheet.

A little extra time taken while pressing plants will make a critical difference in the quality of the herbarium specimens. Lay out the plant(s) in a "natural pose". Bend or fold the stems into V or N shapes as necessary to fit the plants within the folded sheet of newspaper. Be certain that both leaf surfaces are exposed and flower/fruit parts are clearly visible, that is not covered by stems or leaves. When placing several small plants in a sheet of newspaper, arrange them so they do not overlap. In essence, attempt to display all diagnostic features so they will show after the plant has been dried and firmly glued to a herbarium sheet. Cut open thick, moist stems, rootstocks, dense cushions, etc., so the specimens will be flatter and dry more quickly. A deep longitudinal cut will allow you to expose the inner portions of both halves of thick roots and stems with the uncut portion serving as a hinge. Plants such as water lily, skunk cabbage, moss campion, and broomrape require this sort of special handling.

Place each sheet of specimens between two botanical blotters and these in turn between two cardboard ventilators. Repeat this arrangement until all the specimens have been processed. Tie the press tightly with straps or rope. Place the press in the sun where it will be exposed to breezes or over a source of gentle heat.

Dry the plants as quickly as possible. Dried correctly, the specimens retain much of their original color. The best practice is to check your press every day to determine progress and remove dry plants. Be alert for signs of mold or darkening plant tissues; the appearance of either means the plants are drying too slowly and a heat source is called for. Be very careful, however, with artificial heat. Do not "cook" or scorch the plants, as they will become discolored and very brittle.

You can increase the rate of drying by exchanging wet blotters for dry ones (the first change after 24 hours), using extra cardboards, and putting the thicker and more succulent specimens toward the outside of the press. Even these efforts are challenged by the lush herbaceous vegetation in wetter regions of Alaska, unless you have a source of warm, dry air--a heated indoor space.

If you have only a few specimens, they can be kept in the press until you are ready to process them. More commonly you will need the press space for more plants, so remove the dry plants, leaving them in their newspapers. When you have accumulated a stack three or four inches thick, wrap the specimens in newspaper and tie them snugly between cardboards. The bundles of dry specimens should be placed in sturdy boxes. Dried, bundled, and boxed specimens can be mailed directly to the Curator of the Herbarium, 907 Yukon Drive, University of Alaska Museum, Fairbanks AK 99775-6960.

Appendix I: Plant Association Descriptions

Selected plant communities (Viereck Level V) of Kenai Fjords National Park, Lake Clark National Park and Preserve, and Katmai National Park and Preserve

List includes plant communities (Viereck Level V; Viereck et al. 1992) that fall within broad vegetation classes targeted for sampling in SWAN. Interior and alpine communities are referenced in Viereck et al. (1992) and described elsewhere (citations follow). Sitka spruce and coastal alpine communities are also referenced in DeVelice et al. (1999). Due to the lack of data from south central and southwest Alaska, not all communities encountered may have been previously described. Viereck Level IV and V classes sampled by the Central Alaska Network (CAKN) are marked with an asterisk (*).

1 Coastal Sitka spruce forest (0-450 m)

I.A.1.a. Sitka spruce closed forest (60-100% cover)

Picea sitchensis/Echinopanax horridum (DeVelice et al. 1999)
Picea sitchensis/Rubus spectabilis-Echinopanax horridum (DeVelice et al. 1999)
Picea sitchensis/Vaccinium ovalifolium (DeVelice et al. 1999)
Picea sitchensis/Vaccinium ovalifolium-Echinopanax horridum (DeVelice et al. 1999)
Picea sitchensis/Vaccinium ovalifolium/Dryopteris dilatata (DeVelice et al. 1999)
Picea sitchensis/Oplopanax horridus-Rubus spectabilis/Cornus canadensis (Alaback 1980b; Martin et al. 1985; Neiland 1971a; Stephens et al. 1969)
Picea sitchensis/Oplopanax horridus/Circaea alpina (Pawuk and Kissinger 1989)

2 Interior low and mid-elevation white spruce (0-900 m)

I.A.2.e. White spruce open forest (25-60% cover)

**Picea glauca-P. mariana/Ledum groelandicum-Vaccinium vitis-idaea/Pleurozium schreberi* (Viereck 1989)
**Picea glauca/Betula glandulosa/Hylocomium splendens* (Hettinger and Janz 1974; Viereck 1970b, 1975, 1979; Williamson and Peyton 1962)
**Picea glauca/Betula nana-Vaccinium uliginosum/*feathermosses (Craighead et al. 1988)
Picea glauca/Betula glandulosa/Cladonia spp. (Racine and Anderson 1979; Viereck 1979)
Picea glauca/Salix spp./*Ledum decumbens/Vaccinium vitis-ideae* (Yarie 1983)

I.A.3.c. White spruce woodland (10-25% cover)

**Picea glauca/Betula glandulosa*/feathermosses-*Cladonia* spp. (Hettinger and Janz 1974; Racine 1975; Viereck 1975, 1979; Williamson and Peyton 1962)
**Picea glauca/Vaccinium* spp.-*Empetrum nigrum* (Craighead et al. 1988)
**Picea glauca/Vaccinium uliginosum-Carex bigelowii* (Craighead et al. 1988)
**Picea glauca/Ledum groenlandicum-Vaccinium vitis-ideae*/feathermosses (Dyrness et al. 1988)
Picea glauca/Cladonia spp. (Racine 1976)

I.A.3.e. White spruce-black spruce woodland (10-25% cover)

**Picea mariana-P. glauca/Betula glandulosa*/feathermosses (Viereck 1979)
Picea glauca-P. mariana/lichens (Foote 1983)
Picea mariana-P. glauca/Rubus chamaemorus-Ledum decumbens-Vaccinium spp. (Craighead et al. 1988)

3 Interior mid-elevation low and dwarf shrub communities (0-900 m)

II.C.1.a. Shrub birch – closed low scrub

**Betula nana* (Craighead et al. 1988, Racine and Anderson 1979, Hopkins and Sigafoos 1951)

II.C.2.c. Mesic shrub birch-ericaceous shrub – open low scrub

**Betula glandulosa/Vaccinium uliginosum-Empetrum nigrum-Ledum decumbens*/lichens (Anderson 1974; Batten 1977; Hanson 1953; Hettinger and Janz 1974; Hultén 1966; Jorgenson 1984; Kessel et al. 1960; Pegau 1968; Steigers et al. 1983; Webber et al. 1978; Young and Racine 1978)
**Betula glandulosa/Festuca altaica-Vaccinium* spp./feathermosses-lichen (Hanson 1951; Hettinger and Janz 1974; Pegau 1972; Viereck 1963)
**Betula glandulosa-Vaccinium* spp.-*Carex bigelowii* (Churchill 1955; Hanson 1950)
**Betula glandulosa-Salix* spp./*Carex bigelowii-Ledum decumbens*/feathermosses-lichens (Hanson 1951; Scott 1972)
**Betula nana-Rubus chamaemorus-Ledum decumbens-Vaccinium* spp. (Craighead et al. 1988)

4 Alpine dwarf and prostrate shrub communities (>900 m)

II.D.1.a. Dryas tundra – dwarf scrub

**Dryas octapetala* (Craighead et al. 1988; Drew and Shanks 1965; Hanson 1953; Hettinger and Janz 1974; Johnson et al. 1966; Nodler et al. 1978; Pegau 1968; Viereck 1963)
**Dryas octapetala-Salix arctica-Oxytropis nigricans* (Bos 1967)
Dryas octapetala-Arctostaphylos alpina (Jorgenson 1984, Webber et al. 1978, Young 1974b)
Dryas octapetala-Carex microchaeta (Webber et al. 1978)
Dryas integrifolia (Hettinger and Janz 1974; Komarkova and Webber 1978; Webber and Walker 1975)
Dryas integrifolia-Vaccinium spp. (Drew and Shanks 1965; Jorgenson 1984)
Dryas octapetala-Vaccinium uliginosum-Salix reticulata (Anderson 1974)
Dryas octapetala/Hierochloe alpina (DeVelice et al. 1999)

II.D.1.c. Dryas-lichen tundra – dwarf scrub

**Dryas octopetala*-lichens (Anderson 1974; Brock and Burke 1980; Childs 1969; George et al. 1977; Hanson 1951; Spetzman 1959)
**Dryas octapetala*-lichens-*Oxytropis nigrescens-Salix phlebophylla-Carex microchaeta* (Johnson et al. 1966)
Dryas octopetala-Cetraria spp.-*Cladonia* spp. (Pegau 1968; Viereck 1962)
Dryas octopetala-Empetrum nigrum-Salix arctic-Cetraria spp.-*Cladonia* spp. (Young and Racine 1978)
Dryas integrifolia-lichens (Drew and Shanks 1965; Hanson 1951; Komarkova and Webber 1978; Webber and Walker 1975)

II.D.2.a. Bearberry tundra – dwarf scrub

Arctostaphylos alpina-Vaccinium vitis-idaea (Hanson 1953)
Arctostaphylos alpina-Rhododendron camtschaticum (Pegau 1968)
Arctostaphylos alpina-Vaccinium spp.-*Empetrum nigrum-Cassiope tetragona*-lichens (Jorgenson 1984)

II.D.2.b. Vaccinium tundra – dwarf scrub

Vaccinium vitis-idaea-Dryas octapetala-Empetrum nigrum-Festuca altaica (Scott 1974)

Vaccinium vitis-idaea-Salix phlebophylla-Arctostaphylos alpina (Anderson 1974)
Vaccinium vitis-idaea-Empetrum nigrum-Cladina spp. (Racine and Anderson 1979)
Loiseleuria procumbens-Vaccinium uliginosum-Salix arctica-Ledum decumbens (Griggs 1936)
Ledum decumbens-Vaccinium vitis-idaea-Cetraria spp. (Hanson 1951)
Vaccinium uliginosum-V. vitis-idaea (Hettinger and Janz 1974)
Vaccinium uliginosum-Empetrum nigrum-Ledum decumbens-Cladonia spp. (Steigers et al. 1983)
Vaccinium uliginosum-lichens (Craighead et al. 1988)

II.D.2.c. Crowberry tundra – dwarf scrub

Empetrum nigrum (DeVelice et al. 1999)
Empetrum nigrum-Arctostaphylos alpina (DeVelice et al. 1999, Fries 1977, Bos 1967)
Empetrum nigrum-Vaccinium uliginosum (DeVelice et al. 1999, Hultén 1962)
Empetrum nigrum-Vaccinium spp. (Friedman 1982, Racine and Young 1978, Griggs 1936)
Empetrum nigrum-Carex bigelowii-Arctostaphylos alpina (Bos 1967)
Empetrum nigrum-Salix arctica-Cetraria spp. (Young and Racine 1978)

II.D.3.a. Willow tundra – dwarf scrub

Salix rotundifolia (Komarkova and Webber 1978, White et al. 1975, Klein 1959)
Salix arctica-S. rotundifolia-Empetrum nigrum (Shacklette et al. 1969)
Salix arctica-Empetrum nigrum (DeVelice et al. 1999)
Salix rotundifolia/Carex microchaeta (DeVelice et al. 1999)

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Appendix J: Proposed database design

The proposed database design for the SWAN vegetation monitoring program is based upon a MS Access database developed for the Denali Long Term Ecological Monitoring (LTEM) Program and modified for the Central Alaska Network (CAKN) (Figs. J.1, J.2; Roland et al. 2004). SOPs for data entry and QA/QC will be developed pending development of a structurally similar SQL database for the SWAN.

Three primary types of tables comprise the database:

1. **Reference tables**, which contain attribute data on individual records such as species and are denoted with the prefix "ref_".

2. **Data tables**, into which the actual field data are entered (e.g., cover transects, species composition, tree measurements, etc.) and are denoted by the prefix "tbl_".

3. **Cross-reference tables**, which are the products of combinations of data tables and reference tables, which are denoted by the prefix "xref_" in the database structure.

The database design allows for entry of numerous iterations of observations from a single point in space (the permanent plot). While the CAKN sampling design is founded on a two-stage grid, the SWAN sampling design utilizes a single set of randomized (GRTS) points weighted by elevation and landcover class. As such, CAKN tables referencing the mini-grid or points within a grid will be reduced to a single plot identifier in the SWAN version.

I. Data model

The relational database (Fig. J.1) for this program contains of a variety of tables, queries and forms to handle data entry, validation, export and analysis. The sample event table, *tbl_sample_event*, serves as a focal point in the data model tying 14 separate data tables to appropriate plot identifiers in *tbl_sample_point*. The field *sample_event_num* serves as the primary key for *tbl_sample_event* and as the foreign key in each of the 14 data tables. Values for *sample_event_num* consist of a concatenation of the four-letter park code, four-digit year, two-digit elevation code, and three-digit GRTS code. For example, "LACL_2008_02_016" represents GRTS point 016 in elevation band 2 (450-900 m) sampled in Lake Clark National Park and Preserve (LACL) in 2008. A sample event is defined as a single trip to a single plot in the sample design. Thus this field ties together the spatial and temporal aspects of sampling for the program.

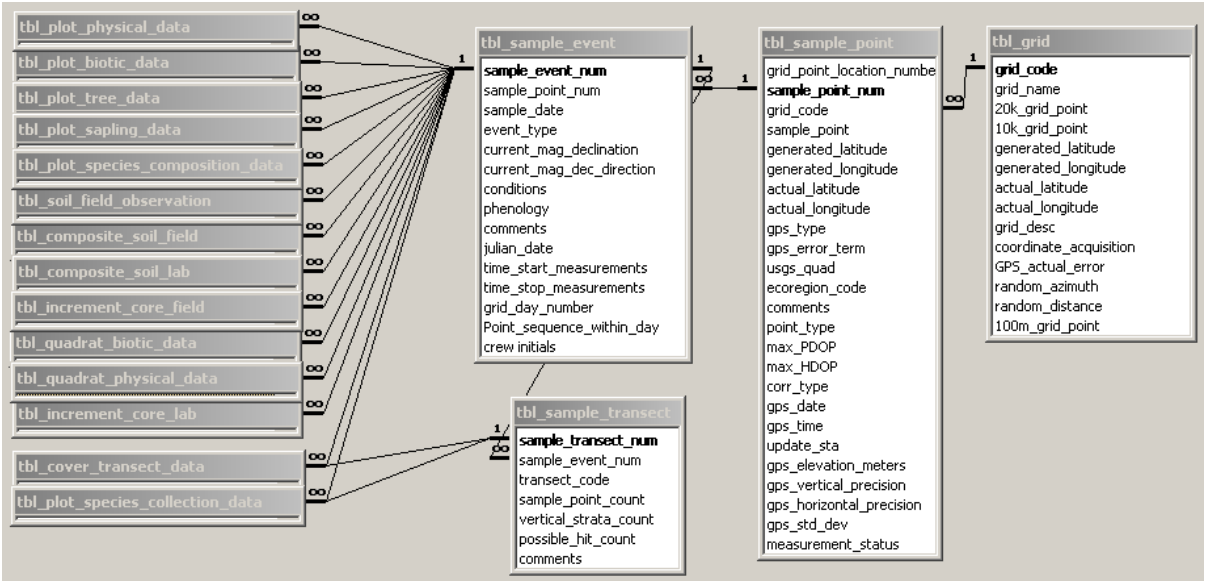

Figure J.1. Simplified database relationship diagram showing primary relationships in the *CAKN_vegetation.MDB* database.

II. Description of Tables and Fields in the CAKN Vegetation Monitoring Database

The following descriptions of the tables in the database include the linkages between tables (Fig. J.2). To reduce redundancy of the text, all linkages between reference tables (ref_) and data tables (tbl_) are only listed under the reference table heading.

Table Name: ref_azimuth

This is a reference table that contains values for different categories of azimuth for describing the aspect of the vegetation plot – such as "south", "southwest" etc. This info is recorded on the plot data sheet. The code for slope and azimuth is entered in the **Plot Physical Data** entry screen. This table is linked to the table ***tbl_plot_physical_data***.

Field Name	***Field Type***	***Field Size***	***Field Desc***
azimuth_code	Text	50	one or two letter code for azimuth/compass direction
azimuth_desc	Text	255	describes azimuth/compass direction

Table Name: ref_cross_section

This is a reference table that contains values for different categories of slope cross-section for describing the shape of the slope of the vegetation plot – such as "convex" or "concave" etc. The code for slope cross-section is entered in the **Plot Physical Data** entry screen. This table is linked to the table ***tbl_plot_physical_data***.

Field Name	***Field Type***	***Field Size***	***Field Desc***
cross_section_code	Text	50	abbreviated description of cross section
cross_section_desc	Text	255	description of microtopography in cross section

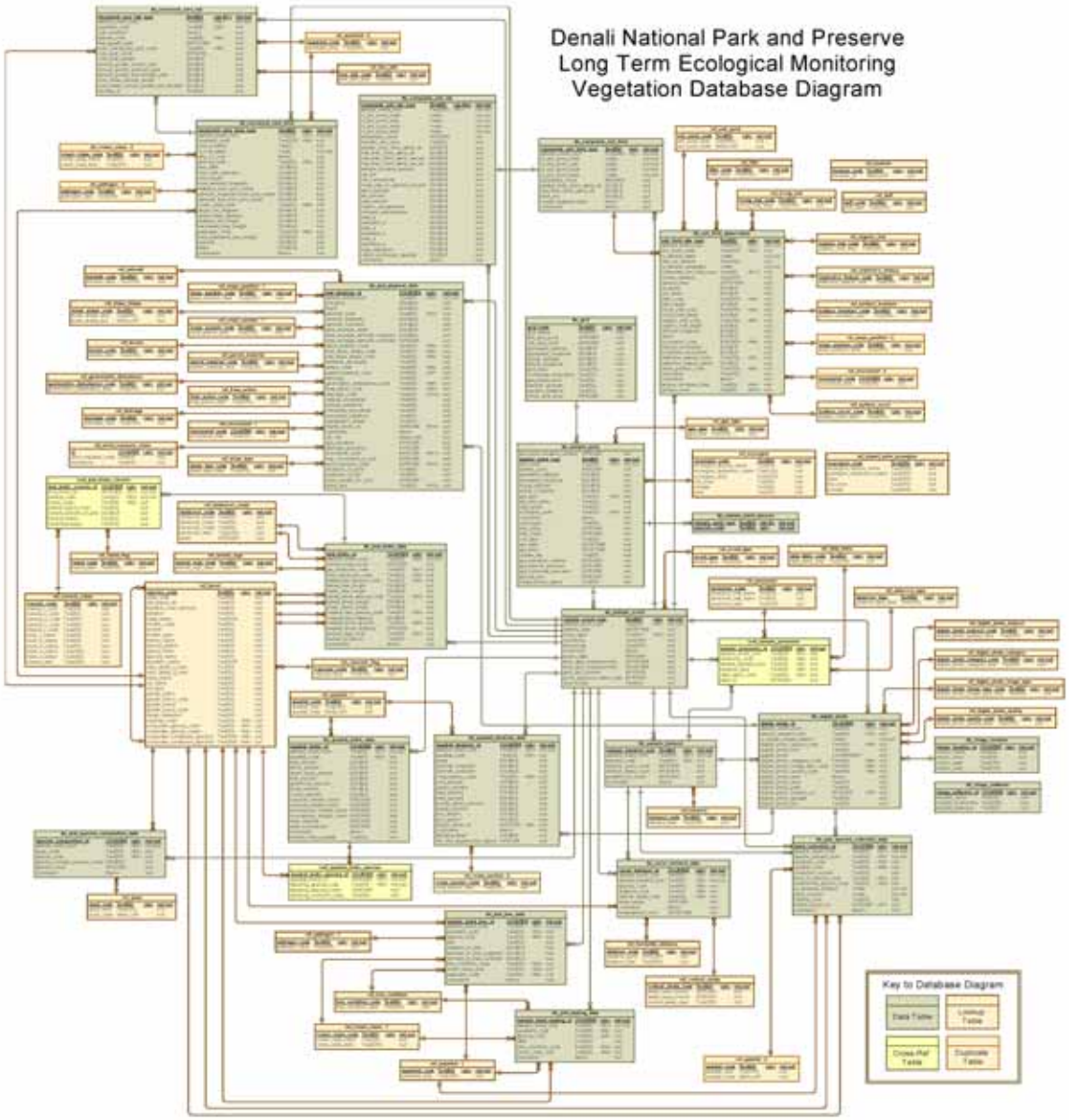

Figure J.2. Diagram of database design developed for CAKN, including tables and relationships among variables.

Table Name: ref_crown_class

This is a reference table that contains values for the canopy position (crown class) of trees observed in the vegetation plots. This information is recorded in the field on the Tree and Sapling data sheet, and the Increment Coring field data sheet. The data are entered into the **Tree and Sampling** entry screen and **Tree Increment Coring** entry screen. This table is linked to the tables ***tbl_plot_tree_data***; ***tbl_plot_sapling_data***; and ***tbl_increment_core_field.***

Field Name	***Field Type***	***Field Size***	***Field Desc***
crown_class_code	Text	50	number assigned to specific crown class

crown_class_name	Text	50	name of specific crown class
crown_class_desc	Text	255	description defining specific crown classes

Table Name: ref_crown_length

This is a reference table that contains values for the length of the live canopy (crown length) of trees observed in the vegetation plots. This information is recorded in the field on the Tree and Sapling data sheet. The data are entered into the **Tree and Sapling** entry screen. This table is linked to the table ***tbl_plot_tree_data*** through the field crown_length_code.

Field Name	***Field Type***	***Field Size***	***Field Desc***
crown_length_code	Text	50	numerical code associated with different percent intervals
crown_length_percent	Text	50	percent of total possible living crown observed

Table Name: ref_digital_photo_image_type

This is a reference table that contains the image type, either single shot or panoramic, for each photo. In the field, these data are recorded in the photo log book. The data are entered in the **Plot Photo Data** screen. This table is linked to the table ***tbl_digital_photo*** through the field digital_photo_image_type_code.

Field Name	***Field Type***	***Field Size***	***Field Desc***
digital_photo_image_type	Text	50	describes type of photo
digital_photo_image_type	Text	50	describes type of photo - panorama or single image

Table Name: ref_digital_photo_quality

This is a reference table that contains the image quality for each photo. Image quality is decided when the photo is saved onto a hard drive from the digital compact flash card. The data are entered in the **Plot Photo Data** screen.

Field Name	***Field Type***	***Field Size***	***Field Desc***
digital_photo_quality_cod	Text	50	assessment of photo quality, same as description
digital_photo_quality_des	Text	255	assessment of photo quality

Table Name: ref_digital_photo_subject

This is a reference table that contains the subject for each photo. Image quality is decided when the photo is saved onto a hard drive from the digital compact flash card. The data are entered in the **Plot Photo Data** screen.

Field Name	***Field Type***	***Field Size***	***Field Desc***
digital_photo_subject_cod	Text	50	abbreviated description of photo subject
digital_photo_subject_des	Text	255	detailed description of photo subject

Table Name: ref_drainage

This is a reference table that describes the type of drainage of the plot. These categories are then used to group the dataset by class for trend analysis. These data are linked to the ***tbl_plot_physical_data*** table by the field drainage_code.

Field Name	***Field Type***	***Field Size***	***Field Desc***
drainage_code	Text	50	abbreviated description of drainage/permeability
drainage_desc	Text	255	description of relative drainage/permeability at site

Table Name: ref_frost_action

This is a reference table that describes the severity of frost action present at each plot. The values in this table are the different levels of frost-action. This table is related to the ***tbl_plot_physical_data*** by the field frost_action_code.

Field Name	Field Type	Field Size	Field Desc
frost_action_code	Text	50	one word code for type of frost action
frost_action_desc	Text	255	describes type of frost action observed at site

Table Name: ref_geomorphic_disturbance

This reference table describes the type of disturbance regimes that may potentially occur at each plot, such as "deglaciation" or "wind scour". This table is related to the ***tbl_plot_physical_data*** by the field geomorphic_disturbance_code.

Field Name	Field Type	Field Size	Field Desc
geomorphic_disturbance_d	Text	255	desc. of type of geomorphic disturbance observed at site
geomorphic_disturbance_c	Text	50	abbreviated description of type of disturbance

Table Name: ref_gps_type

This reference table contains values for the model of GPS used to record data in the field. Currently the standard unit used is the Trimble Geo 3, and in the field it is listed on the Point Data sheet. These data are entered under the **Enter GPS Info for Sample Point** screen on the main data entry menu. The table is linked to the table ***tbl_sample_point*** by the field gps_type.

Field Name	Field Type	Field Size	Field Desc
gps_type	Text	50	abbreviated code for type and make of gps unit
gps_desc	Text	255	describes type and make of gps unit used in field

Table Name: ref_horizontal_distance

This reference table lists the points at which the vegetation is sampled along the cover transects. Data are recorded at each of these points (spaced every 50 cm along the tape) on the Cover Transect data sheet in the field. In the database, these data are entered under the **Transect Cover Data** screen. This reference table is linked to the table ***tbl_cover_transect_data*** by the field distance_code.

Field Name	Field Type	Field Size	Field Desc
distance_code	Text	50	distance along a transect written as number only
distance_point	Long Integer	4	distance along a transect written in centimeters
distance_desc	Text	255	left blank

Table Name: ref_landcover_class

This reference table contains values for the different classes contained in the existing SWAN landcover maps (KEFJ, KATM, LACL). The codes in this table allow both a field determination of land cover class and a GIS determination based on the actual map to be recorded in the ***tbl _plot_biotic_data***. The ***ref_landcover_class*** table is linked to the ***tbl _plot_biotic_data*** through the fields landcover_code and GIS_landcover_code.

Field Name	Field Type	Field Size	Field Desc
landcover_class2	Text	50	describes the second landcover class, if present

sorter	Long Integer	4	number associated with specific landcover class; same as landcover code
landcover_class1	Text	50	describes the landcover class of the plot
landcover_code	Text	50	number associated with specific landcover class
landcover_name	Text	50	describes landcover class category

Table Name: ref_litter

This is a reference table that contains values describing the type of litter that can be present at a site. These data are part of the soils protocol at each cardinal point, and are recorded on the Soils Data sheet. During data entry, these data are entered in the **Soil Field Observations** screen under the field titled Litter_Layer_Kind. The **Soil Field Observations** screen is located under the Soils tab on the main menu. The ***ref_litter*** table is linked to the ***tbl_soil_field_observation*** by the field litter_code.

Field Name	Field Type	Field Size	Field Desc
litter_code	Text	50	same as litter_description
litter_desc	Text	255	describes source of litter

Table Name: ref_living_mat

This is a reference table that contains values describing the type of living (vegetative) mat existent over the soil, which can be present at a site. For example, "dwarf scrub" or "herbaceous". These data are part of the soils protocol at each cardinal point, and are recorded on the Soils Data sheet. During data entry, these data are entered in the **Soil Field Observations** screen under the field titled Living_Mat_Kind. The **Soil Field Observations** screen is located under the Soils tab on the main menu. The ***ref_living_mat*** table is linked to the ***tbl_soil_field_observation*** by the field living_mat_code.

Field Name	Field Type	Field Size	Field Desc
living_mat_code	Text	50	abbreviation of description
living_mat_desc	Text	255	describes general composition of living mat

Table Name: ref_microrelief

This reference table contains values of the types of micro-relief present in the plot, for example, bedrock outcrops or moss hummocks. The table ***ref_microrelief*** is linked to the ***tbl_plot_physical_data*** and the ***tbl_soil_field_observation*** by the field microrelief_code.

Field Name	Field Type	Field Size	Field Desc
microrelief_code	Long Integer	4	unique number for each different category of microrelief
microrelief_desc	Text	255	describes type of microrelief observed

Table Name: ref_organic_mat

This is a reference table that contains values describing the type of organic mat existent over the soil, which can be present at a site. For example, "coniferous leaves" or "fine roots". These data are part of the soils protocol at each cardinal point, and are recorded on the Soils Data sheet. During data entry, these data are entered in the **Soil Field Observations** screen under the field titled Organic_Mat_Kind. The **Soil Field Observations** screen is located under the Soils tab on the main menu. The ***ref_living_mat*** table is linked to the ***tbl_soil_field_observation*** by the field organic_mat_code.

Field Name	Field Type	Field Size	Field Desc
organic_mat_code	Text	50	two letter code for material composing organic mat
organic_mat_desc	Text	255	describes composition of organic mat

Table Name: ref_parent_material

This is a reference table that contains values for broad categories of parent material , such as "alluvium" or "loess". This table is linked to the table ***tbl_plot_physical_data*** by the field parent_material_code.

Field Name	Field Type	Field Size	Field Desc
parent_material_code	Text	50	same as description; describes rock source
parent_material_desc	Text	255	describes source of rock at site

Table Name: ref_pathogen

This reference table contains the types of pathogen infection of trees that may be present in the plots. In the field, these data are entered on both the Tree and Sapling Data sheet (for the trees in the plot) and on the Tree Coring sheet. In the database, these data are recorded the field Pathogen on the **Plot Tree Data** screen under the Plot Tree, Sapling tab in the main data screen. They are also recorded in the field Pathology on the **Tree Cores** data screen. The ***ref_pathogen*** table is linked to the ***tbl_plot_tree_data*** table by the field pathogen_code.

Field Name	Field Type	Field Size	Field Desc
pathogen_code	Text	50	same as pathogen_desc
pathogen_desc	Text	255	describes wounds and pathogens observed in tree

Table Name: ref_personnel

This reference table contains a list of all the individuals who have worked on this project, their initials and the capacity in which they served in the program. In the data entry process, this information is added under the **Enter personnel data** screen in the field Personnel. The ***ref_personnel*** table is linked to the ***xref_sample_personnel*** table by the field personnel_code.

Field Name	Field Type	Field Size	Field Desc
personnel_last_name	Text	50	last name of crew member
personnel_desc	Text	255	official position/capacity of crew member
personnel_first_name	Text	50	first name of crew member
personnel_code	Text	50	initials of crew member

Table Name: ref_quad

This reference table contains values describing the codes corresponding to the quadrats and plot quadrants, and the order they are sampled in. This table is linked to the *tbl_plot_species_composition* table by the field quad_code.

Field Name	Field Type	Field Size	Field Desc
quad_desc	Text	255	written description of quadrat or quadrant
quad_code	Text	50	alphanumeric code for quadrat or quadrant

Table Name: ref_quadrant

This reference table lists the four quadrants of the plots and their corresponding one letter codes.

This table is linked to the following tables by the field quadrant_code: ***tbl_increment_core_field***, ***tbl_plot_sapling_data***, ***tbl_plot_species_collection*** and ***tbl_plot_tree_data.***

Field Name	Field Type	Field Size	Field Desc
quadrant_code	Text	50	one letter code for quadrant – A,B, C, or D.
quadrant_desc	Text	255	written description of quadrant

Table Name: ref_quadrat

This is a reference table that lists the names and codes for the 4 m2 quadrats. It is linked to the following tables by the field quadrat_code: ***tbl_plot_species_collection***, ***tbl_quadrat_biotic_data*** and ***tbl_ quadrat_physical_data***.

Field Name	Field Type	Field Size	Field Desc
quadrat_desc	Text	255	written description of quadrat
quadrat_code	Text	50	alphanumeric code for quadrat

Table Name: ref_restrictive_feature

This is a reference table that contains values describing restrictive features that prevent the technician from coring a complete sample of soil at a point. At the plot, this data is recorded on the Soils Data sheet. In the database, these data are recorded in the field Res_feature on the **Soil Field Observations** screen under the Soils tab on the main screen. This table is linked to the table ***tbl_soil_field_observation*** by the field restrictive_feature.

Field Name	Field Type	Field Size	Field Desc
restrictive_feature_desc	Text	255	describes type of restrictive feature of soil depth
restrictive_feature_code	Text	50	same as description

Table Name: ref_slope_position

This is a reference table containing the values describing the location of the plot relative to its position on a slope, e.g. "upper 1/3 slope" or "toe slope". This table is linked to the ***tbl_soil_field_observation*** table and the ***tbl_plot_physical_data*** table by the field slope_position_code.

Field Name	Field Type	Field Size	Field Desc
slope_position_code	Text	50	same as description
slope_position_desc	Text	255	describes relative position of plot on slope

Table Name: ref_slope_shape

This reference table contains values describing the water reception index (from -3 to +3) for the site relative to the surrounding topography. This table is linked to the ***tbl_plot_physical_data*** table by the field slope_shape_code.

Field Name	Field Type	Field Size	Field Desc
slope_shape_sort	Integer	2	used to sort the entries
slope_shape_code	Text	50	unique number associated with degree of concavity or convexity
slope_shape_desc	Text	255	describes degree of convexity or concavity of slope

Table Name: ref_slope_type

This reference table contains the values “simple” and “convex”, which are used to describe the overall type of slope the plot is located on.

Field Name	Field Type	Field Size	Field Desc
slope_type_code	Text	50	same as description
slope_type_desc	Text	255	describes slope as "simple" or "convex"

Table Name: ref_soil_point

This is a reference table that contains the 4 cardinal directions at which soils are sampled for the plot. These data are entered in the field Soil_Point on the **Soils** entry screen. This table is linked to the ***tbl_soil_field_observation*** table by the field soil_point_code.

Field Name	Field Type	Field Size	Field Desc
soil_point_code	Text	50	one letter code standing for cardinal direction
soil_point_desc	Text	255	describes cardinal direction of soil point

Table Name: ref_surface_cover

This reference table contains values for cover of the surface of the soil at the sampling point, for example, “bare ground” or “living moss”. In the field, they are recorded on the Soils Data sheet. In the database they are entered in the field Surface_Cover_Kind on the **Soils** entry screen.

Field Name	Field Type	Field Size	Field Desc
surface_cover_code	Text	50	one or two letter code for each type category
surface_cover_desc	Text	255	describes what type of material is covering land surface

Table Name: ref_surface_moisture

This table contains values for surface moisture of the surface of the soil at the sampling point. In the field, they are recorded on the Soils Data sheet. In the database they are entered in the field Surface_Moisture on the **Soils** entry screen.

Field Name	Field Type	Field Size	Field Desc
surface_moisture_code	Text	50	describes relative moisture of land surface; one word
surface_moisture_desc	Text	255	describes relative moisture of land surface

Table Name: ref_taxon

This reference table is a foundation of this database. This table contains a record for each plant taxon (both vascular and non-vascular) that has been observed in the sample plots for this program. This table contains a variety of attributes of each plant taxon including details about the growth form, life history, conservation status among other attributes. These attribute fields are used to combine species (form pools) or to summarize different attributes of the vegetation. This is a critical table for analysis of the monitoring data. This reference table is linked to all of the data tables in the database that contain species information (through the species_code field) including ***tbl_transect_cover_data, tbl_plotspecies_composition_data, tbl_tree_and_sapling_data*** etc.

Field Name	Field Type	Field Size	Field Desc
growth_form2	Text	50	a list modifier of growth form classes
vasc_aknhp_g_rank	Text	50	AKNHP global rank
species_code	Text	50	CAKN code for taxon of interest -
inf_name	Text	50	infraspeciofic name for taxon

inf_rank	Text	50	infraspecific_rank of taxon
growth_form1	Text	50	primary growth form of taxon
growth_form2_code	Text	50	code for modifier of growth form classes
scientific_name	Text	200	scientific_name is of ref_taxon
range_category1	Text	50	distribution category of taxon, CP=circumpolar, AB=amphiberingian, etc...
vascular_code	Text	50	this field identifies whether the taxon is a vascular or a nonvascular plant
composite_species_code1	Text	50	code for the group in which this species_code is lumped
composite_species_code2	Text	50	additional code for the group in which this species_code is lumped
composite_constituent_spe	Text	255	list of species codes that make up the composite species code
composite_constituent_spe	Text	255	additional list of species codes that make up the composite species code
growth_form1_code	Text	50	code for primary growth form of taxon
endem_code	Text	50	code for type of endemic - Ak, Beringia , etc
usda_code	Text	50	USDA Plants database acronym for taxon
diff_plants_DB	Text	50	Is USDA accepted name different than Denali accepted synonym - yes or no
transect_cover_element	Text	50	transect cover element class for taxon - vascular plant, lichen, bryophyte,
infra_author	Text	50	authors for infraspecific name (where applicable)
usda_name	Text	200	Plants database synonym for taxon - full scientic name with authorities
vasc_aknhp_s_rank	Text	50	AKNHP state rank
endem	Text	50	is the taxon an endemic one? 1= yes, 0 = no
endem_type	Text	50	what endemic category is taxon; endemic_type is
family_name	Text	50	family taxon belongs to
species_author	Text	50	authors for species name
genus_name	Text	50	genus_name of taxon
species_name	Text	50	species_name of taxon
duration	Text	50	is taxon perennial (=PE) annual (=AN) biennial (=BI) or facultatively all of

Table Name: ref_terrain

This is a reference table that describes the terrain. It is linked to the ***tbl_plot_physical_data*** table by the terrain_code field.

Field Name	Field Type	Field Size	Field Desc
terrain_code	Text	50	one word description of terrain, same as terrain_desc
terrain_desc	Text	255	describes terrain (foothills, mountainous, etc)

Table Name: ref_transect

This table contains the values for the three transects, 16, 6a and 6b. In the database these are entered in the transect field on the main data entry screen. ***Ref_transect*** is linked to ***tbl_sample_transect*** by the transect_code field.

Field Name	Field Type	Field Size	Field Desc
transect_code	Text	50	unique code for each of the 3 transect types
transect_desc	Text	255	describes which transect is being sampled

Table Name: ref_tree_condition

This reference table contains values for tree condition, either “live” or “dead”. These data are recorded on the Tree and Sapling datasheet for both trees and saplings in the field. In the database, they are entered into the field Tree Condition on the **Plot Tree Data** screen under the Plot Tree, Sapling tab on the main menu. This table is linked to the ***tbl_plot_tree_data*** and the

tbl_plot_sapling_data tables by the tree_condition_code field.

Field Name	Field Type	Field Size	Field Desc
tree_condition_desc	Text	255	identifies whether tree is alive or dead
tree_condition_code	Text	50	code is simply either "alive" or "dead"

Table Name: ref_vertical_strata

This reference table contains the point categories at which the vertical strata of vegetation are measured during the point transect sampling procedure. In the database, these data are entered in the **Transect Cover Data** screen in the field Vertical Strata. This table is linked to the ***tbl_cover_transect_data*** table by the vertical_strata_code.

Field Name	Field Type	Field Size	Field Desc
vertical_strata_code	Text	50	identifies strata interval between lower and upper boundaries.
strata_lower_bound	Long Integer	4	identifies the value of the lower boundary of each strata;
strata_upper_bound	Long Integer	4	identifies the value of the upper boundary of each strata;

Table Name: ref_viereck_class

This reference table contains information concerning all of the Viereck vegetation classes that have been observed in the vegetation monitoring program. In this way, it is similar to the ***ref_taxo***n table that contains information on species attributes. In the field, the Viereck class data are recorded on the Point Data sheet. In the database, they are entered in the Viereck field on the **Plot Biotic Viereck Classes** screen, which is located through the **Plot Biotic Data** screen. This table is linked to the ***xref_plot_biotic_viereck*** table by the viereck_code field.

Field Name	Field Type	Field Size	Field Desc
level_ii_name	Text	50	Viereck vegetation class level_ii_name
viereck_iv_code	Text	50	Viereck vegetation class level _iv_code
viereck_desc	Text	255	Name of viereck class
level_v_name	Text	200	Viereck vegetation class level_v_name
level_iv_name	Text	100	Viereck vegetation class level_iv_name
level_iii_name	Text	50	Viereck vegetation class level_iii_name
viereck_v_code	Text	50	Viereck vegetation class viereck_v_code
viereck_iii_code	Text	50	Viereck vegetation class viereck_iii_code
viereck_ii_code	Text	50	Viereck vegetation class viereck_ii_code
viereck_i_code	Text	50	Viereck vegetation class _i_code
viereck_code	Text	50	Viereck vegetation class
level_i_name	Text	50	level_i_name

Table Name: ref_wind_exposure_class

This reference table contains values for the relative exposure of the site to wind. In the field, these data are recorded on the Point Data sheet. In the database, they are recorded on the **Plot Physical Data** screen in the Wind expose field. This table is linked to the ***tbl_plot_physical_data*** table by the field ID.

Field Name	Field Type	Field Size	Field Desc
Description	Text	50	describes relative exposure to wind
ID	Long Integer	4	unique number associated with each code
wind_exposure_code	Text	50	description of wind exposure abbreviated to one word

Table Name: tbl_composite_soil_field

This data table stores data about the soil samples taken in the field. This table is linked to the table ***tbl_soil_field_observation*** through the field ***composite_soil_field_num***, and through the sample event field to ***tbl_sample_event***. These data are recorded in the field on the Soils Data sheet.

Field Name	Field Type	Field Size	Field Desc
subsample_count	Long Integer	4	number of samples taken from plot and combined into one
comments	Memo	0	any additional observations recorded in the field or on data entry
coarse_fragment_desc	Memo	0	description of the course fragment of the soil
field_pH	Double	8	pH of sample determined in the field using field pH meter
less_than_2mm_samp_wt	Double	8	wt. of soil fraction of size class < 2mm,
greater_than_2mm_samp_wt	Double	8	wt. of soil fraction of size class > 2mm,
is_soil_point_south	Boolean	1	was a soil sample taken at the south point? (yes or no)
is_soil_point_east	Boolean	1	was a soil sample taken at the east point? (yes or no)
is_soil_point_north	Boolean	1	was a soil sample taken at the north point? (yes or no)
composite_soil_field_num	Text	50	Unique ID describing which samples have been combined.
is_soil_point_west	Boolean	1	was a soil sample taken at the west point? (yes or no)
sample_event_num	Text	50	plot identifier (park, year, elevation, GRTS point)

Table Name: tbl_composite_soil_lab

This data table stores information about soil samples collected for the vegetation monitoring program derived from laboratory analyses of these samples. This table is linked to the tables ***tbl_soil_field_observation***, and ***tbl_composite_soil_field*** through the sample event field to ***tbl_sample_event***. These data are not recorded onto specific data sheets, but are recorded onto a spreadsheet by lab personnel. Each line on this spreadsheet corresponds to an individual soil sample, taken in the field (and field attributes are recorded on the soils data sheet).

Field Name	Field Type	Field Size	Field Desc
comments	Memo	0	
sand_percent	Double	8	percent of sand in sample
silt_percent	Double	8	percent of silt in sample
clay_percent	Double	8	percent of clay in sample
carbon_autoanalyzer	Double	8	Percent carbon of sample – by ignition loss
nitrogen_autoanalyzer	Double	8	Percent nitrogen of sample – by ignition loss
total_p	Double	8	Total phosphorus of sample
available_p	Double	8	Dissolved phosphorus not bound within the chemical
cation_exchange_capacity	Double	8	capacity of soil sample for cation exchange
mass_loss_on_ignition_pe	Double	8	percent loss of mass on ignition
sample_event_num	Text	50	plot identifier (park, year, elevation, GRTS point)
munsell_soil_color	Text	50	description of soil color based on Munsell color chart
greater_than_2mm_samp_wt	Double	8	weight (g) of particles of sample that are > 2mm diameter
less_than_2mm_samp_wt	Double	8	weight (g) of particles in sample that are <2 mm diameter
less_than_2mm_samp_wet	Double	8	field wet weight of fraction of sample <2 mm diameter
less_than_2mm_samp_dry	Double	8	lab dried weight of fraction of sample >2 mm diameter
lab_pH	Double	8	ph of sample, measured in the lab

Table Name: tbl_cover_transect_data

This data table stores all of the observations acquired on the cover transects (recorded in the field on the cover transect data sheet). Each record in this table consists of a single "hit" observed along the vegetation cover transects. A record joins four attributes – 1) a specific sample event; 2) a specific location along a specific transect; 3) a specific vertical stratum; and 4) a specific taxon (or other cover element such as moss, lichen, down wood, etc…). This table is linked to

the ***tbl_sample_event*** table through the field sample_event_num.

Field Name	Field Type	Field Size	Field Desc
cover_transect_id	Long Integer	4	this field is a unique number for each record in the database
distance_point	Long Integer	4	the distance along the transect, written only as a number
comments	Memo	0	any comments on data entry at this point, or notes from the field
slope_angle	Long Integer	4	slope_angle is slope of tape
strata_lower_bound	Long Integer	4	the lower number of a given interval
vertical_strata_code	Text	50	the interval along the vertical strata in centimeters,
distance_code	Text	50	the distance along the transect in centimeters
species_code	Text	50	6 letter code linked to "ref_taxon" for transect element encountered
sample_transect_num	Text	50	identifies plot, and which transect was sampled
sample_event_num	Text	50	plot identifier (park, year, elevation, GRTS point)
entryDateSort_num	Date	8	field to sort records based on system date and time

Table Name: tbl_digital_photo

This data table stores all of the data attached to each photo taken for the project. This table is linked to the table ***tbl_sample_event*** by the sample_event_num field and *tbl_sample_transect* by the field sample_transect_num. It is linked to the ***tbl_image_location*** table by the field digital_photo_location_id. It is linked to the following tables by the field digital_photo_id: ***tbl_plot_species_collection_data***, ***tbl_quadrat_physical_data***, and ***tbl_plot_physical_data***.

Field Name	Field Type	Field Size	Field Desc
digital_photo_image_type	Text	50	code describing type of photo taken
digital_photo_subpath	Text	50	subpath to location where the file is stored
digital_photo_location_id	Long Integer	4	randomly generated number
digital_photo_desc	Memo	0	more elaborate description of photo subject, from photo log
digital_photo_drive	Text	50	computer drive that photo is located on
digital_photo_file	Text	50	the photo's file name on the computer, written as "number_img.jpg"
digital_photo_quality_cod	Text	50	assessment of relative quality of image, linked to ref_photo_quality_code
digital_photo_num	Text	50	unique number generated by camera
digital_photo_subject_cod	Text	50	written description of photo subject, linked to ref_digital_photo_subject
is_digital_image_present	Boolean	1	is digital photo present? (yes/no)
sample_transect_num	Text	50	unique number identifying the transect the image is from
sample_event_num	Text	50	plot identifier (park, year, elevation, GRTS point)
digital_photo_id	Long Integer	4	randomly generated unique number
digital_photo_path	Text	50	computer pathway to locate photo
digital_photo_category_co	Text	50	code describing general category of photo subject, linked

Table Name: tbl_image_location

This data table stores information about the location of stored digital images that are viewed within the image window on the Plot_photos tab located on the **Main Data Entry** screen. The path of each image is noted in this table, which is linked to the ***tbl_digital_photo*** by the field digital_photo_location_id.

Field Name	Field Type	Field Size	Field Desc
image_location_id	Long Integer	4	randomly generated unique number
sample_event_num	Text	50	plot identifier (park, year, elevation, GRTS point)
imgloc_drive	Text	50	computer drive where images are located
imgloc_path	Text	255	computer pathway to find where images are located

imgloc_desc	Text	255	description of subject of images

Table Name: tbl_image_software

This table contains the values for the types of software used for this program, and the location of each program on the computer's hard drive.

Field Name	Field Type	Field Size	Field Desc
image_software_id	Long Integer	4	
imgsoft_extension	Text	50	type of extension at end of file name, indicating type of image
imgsoft_name	Text	50	type of software used to organize/manipulate images
imgsoft_locationfile	Text	255	computer pathway to locate where images are filed

Table Name: tbl_increment_core_field

This data table contains information on the spruce trees that are cored for this program, and on the cores that are taken from these trees. These data are recorded onto the Increment Core data sheet in the field, and entered into the **Increment Core Field Observations** screen in the database. This table is linked to the tables ***tbl_sample_event*** and ***tbl_increment_core_lab*** by the field sample_event_num.

Field Name	Field Type	Field Size	Field Desc
sample_event_num	Text	50	plot identifier (park, year, elevation, GRTS point)
quadrant_code	Text	255	1 letter code for which Quadrant is associated with core
core_modifier	Text	1	modifier informing what number a core is when there is
species_code	Text	50	6 letter species code from ref_taxon
tree_DBH	Double	8	diameter of tree at breast height, measured in centimeters
tree_core_diameter	Double	8	diameter of tree at core height, measured in centimeters
distance_from_plot_center	Double	8	distance from plot center to cored tree, in meters
field_estimated_tree_height	Double	8	height of tree if it is measured in the field
core_height	Double	8	distance from the ground at which core was taken (cm)
azimuth	Double	8	specific azimuth of the cored tree on its slope
pathogen_code	Text	255	shortened code for pathogens observed in cored tree
calculated_tree_height	Double	8	tree height - result of formula calculating tree height based on angles and distance
distance_for_height	Double	8	distance from tree in meters at which angles were observed
angle_base_degrees	Double	8	angle to the bottom of the cored tree, measured in degrees with a clinometer
angle_top_degrees	Double	8	angle to the top of the cored tree, measured in degrees with a clinometer
crown_class_code	Text	50	code describing relative position to other trees, linked to ref_crown_class
azimuth_true_from_plot_ce	Double	8	corrected azimuth from plot center to tree, calculated post-field
azimuth_magnetic_from_pl	Double	8	magnetic azimuth from plot center to cored tree
slope	Double	8	slope in immediate vicinity of cored tree, measured in degrees

Table Name: tbl_increment_core_lab

This data table contains information on the lab results for the cores from spruce trees that are taken for this program. These data are entered into the **Increment Core Lab Observations** screen in the database. This table is linked to the tables ***tbl_sample_event*** and ***tbl_increment_core_field*** by the field sample_event_num.

Field Name	Field Type	Field Size	Field Desc
species_code	Text	50	6- letter code for species

core_total_growth	Double	8	# of millimeters shown in core
decade_id	Text	50	ID number for decade for decade growth (value shown in previous field)
core_mean_annual_growth	Double	8	millimeters of growth in the last decade before core
core_mean_annual_growth	Double	8	total growth/number of years
annual_growth_penultimat	Double	8	# millimeters growth in year two years previous to core being taken
annual_growth_previous_	Double	8	# millimeters growth in year previous to core being taken
annual_growth_current_ye	Double	8	# millimeters growth in year core taken
increment_core_lab_num	Text	50	identifier number of the core assigned in the lab
last_growth_year	Date	8	#millimeters growth in current year
core_modifier	Text	1	gives core a unique identifier for when multiple cores are from same tree.
quadrant_code	Text	50	code of the quadrant the tree was cored in, A, B, C or D
sample_event_num	Text	50	Concatenation of site number and sampling iteration
core_year_count	Long Integer	4	number of annual growth rings
core_insects_tree_pith_cod	Text	50	code for any insect infestations present in the core

Table Name: tbl_plot_biotic_data

This table contains all the general data describing the biotic aspects of each plot. This table is linked to the ***tbl_sample_event*** table by the field sample_event_num, and to the ***xref_plot_biotic_viereck*** table by the plot_biotic_id field.

Field Name	Field Type	Field Size	Field Desc
nearest_tree_species_code	Text	50	6 letter species code from ref_taxon for tree nearest to plot center
nearest_tree_distance	Double	8	distance of nearest tree from plot center, in meters
animal_sign_code	Text	50	code for sign of animals in plot
comments	Memo	0	anything noteworthy about site recorded in the field, or comments on data
nearest_shrub_species	Text	50	6 letter species code from ref_taxon for shrub nearest to plot center
gis_landcover_code	Text	50	linked to ref_landcover_class, DENA landcover description
tallest_shrub_height	Double	8	height of tallest shrub, in meters
Human_evidence	Text	50	evidence of human activity in the vicinity of the plot
tallest_tree_height	Double	8	height of tallest tree in plot, in meters
field_landcover_code	Text	50	linked to ref_landcover_class, DENA landcover description
nearest_shrub_distance	Long Integer	4	distance of nearest shrub from center, in meters
viereck_class_count	Long Integer	4	total number of Viereck classes in plot
sample_event_num	Text	50	plot identifier (park, year, elevation, GRTS point)
tallest_tree_species_code	Text	50	6 letter species code from ref_taxon for tallest tree in plot
plot_biotic_id	Long Integer	4	unique identifier, randomly generated number
tallest_shrub_species_code	Text	50	6 letter species code from ref_taxon for tallest shrub in plot

Table Name: tbl_plot_physical_data

This table contains all the general data describing the physical aspects of each plot. This table is linked to the ***tbl_sample_event*** table and to the ***tbl_digital_photo*** table by the field sample_event_num.

Field Name	Field Type	Field Size	Field Desc
comments	Memo	0	any additional noteworthy information recorded at site
vert_slope_shape_code	Text	50	code for vertical shape of ground in plot
max_microrelief_in_plot	Long Integer	4	maximum microrelief observed in plot, in decimeters
microrelief_code	Long Integer	4	description of dominant microrelief in plot, linked to ref_microrelief
altimeter_elevation	Long Integer	4	elevation of plot read from altimeter
off_180	Integer	2	absolute value in degrees of true aspect minus 180, which

			yield degrees
wind_exposure_class	Long Integer	4	description of relative exposure to wind at plot, linked to
digital_photo_id	Long Integer	4	database assigned ID for digital photo
gps_elevation	Long Integer	4	elevation of plot in meters calculated by gps unit in field
horz_slope_shape_code	Text	50	horizontal shape of ground in plot
slope_position_code	Text	50	choice of 8 codes from ref_ slope_position
area_average_azimuth_mag	Double	8	prevailing aspect of land surface within 100 meters of plot
evidence_of_wind	Text	50	written description of type of wind evidence observed, if any
evidence_of_fire	Text	50	written description of type of fire evidence observed, if any
slope_length_for _plot	Long Integer	4	slope length, from ridge to foot, on which plot is located .
slope_type	Text	50	enter "simple" or "complex" from field data sheet
landform_descriptor	Text	50	description of landform of the plot area
area_average_azimuth_corre	Long Integer	4	prevailing aspect corrected to match current declination
azimuth_magnetic	Double	8	magnetic aspect of the plot's slope
plot_physical_id	Long Integer	4	randomly generated unique number
elevation	Double	8	elevation of plot, derived from gps, in meters
sample_event_num	Text	50	plot identifier (park, year, elevation, GRTS point)
azimuth_code	Text	50	links to ref_azimuth, letter code describing plot aspect
azimuth_corrected	Double	8	magnetic aspect for plot corrected to match current declination
area_average_slope	Double	8	average slope angle in within 100 meters of the plot, in degrees
horizontal_microrelief	Text	50	amount of horizontal microrelief in the plot
lithology	Text	50	type of rock at plot, if known
geomorphic_disturbance_c	Text	50	disturbance regimes assessed at site
frost_action_code	Text	50	code describing frost action observed at plot
drainage_code	Text	50	describes relative impediment of water at plot
vertical_microrelief	Text	50	vertical microrelief in plot
parent_material_code	Text	50	source and composition of rock
slope	Double	8	the slope angle of the plot measured with a clinometer

Table Name: tbl_plot_sapling_data

This table contains the data for tree saplings, which are recorded in the field on the Tree and Sapling data sheet. In the database, these data are entered in the **Plot Sapling Data** screen under the Plot Tree, Sapling tab on the **Main Data Entry** screen. This table is linked to the ***tbl_sample_event*** table by the field sample_event_num.

Field Name	***Field Type***	***Field Size***	***Field Desc***
comments	Memo	0	any additional noteworthy information recorded at plot
tree_condition_code	Text	50	describes whether tree is alive or dead
DBH	Text	50	diameter of sapling at breast height, in centimeters
species_code	Text	50	6 letter species code linked to ref_taxon
quadrant_code	Text	50	1 letter code describing quadrant, linked to ref_quadrant
sample_event_num	Text	50	plot identifier (park, year, elevation, GRTS point)
crown_class_code	Text	50	numerical code describing relative dominance
sample_point_sapling_id	Long Integer	4	randomly generated unique number

Table Name: tbl_plot_species_collection_data

This table contains data for each plant collection made for the project. In the field these data are entered in the field notebook belonging to the lead technician for either vascular or non-vascular plants. This table is linked to the ***tbl_sample_event*** table by the sample_event_num field, to the ***tbl_digital_photo*** table by the field digital_photo_id, to the ***tbl_sample_transect*** table by the sample_transect_num field.

Field Name	***Field Type***	***Field Size***	***Field Desc***
quadrant_code	Text	50	linked to ref_quadrant_code

sample_transect_num	Text	50	number identifying transect species was collected from
comments	Memo	0	comments made in field notes or during data entry
digital_photo_id	Long Integer	4	unique value assigned by the database
catalog_num	Text	50	ANCS+ NPS catalog number
have_voucher	Boolean	1	is voucher present? yes/no
determined_species_code	Text	50	code from ref_taxon positively identifying voucher
field_id_species_code	Text	50	6 letter code from ref_taxon describing tentative field ID
plant_collection_id	Long Integer	4	randomly generated unique number
quadrat_code	Text	50	linked to ref_quadrat code, identifies which quadrat species was collected
sample_event_num	Text	50	plot identifier (park, year, elevation, GRTS point)
collection_number	Text	50	collector's initials and unique collection number

Table Name: tbl_plot_species_composition

This table contains records for all species documented in the plots. In the field, these data are recorded on the Point Transect and Quadrat Species Composition data sheets. In the database, these data are entered into the screens located under the **Transect Cover Data** and **Quadrat Data Sheet** tabs in the **Main Data Entry** screen. This table is linked to the ***tbl_sample_event*** table by the sample_event_num field.

Field Name	Field Type	Field Size	Field Desc
sample_event_num	Text	50	plot identifier (park, year, elevation, GRTS point)
comments	Memo	0	any observation recorded in field, often regarding phenology
species_nonvasc_percent_c	Double	8	the percent cover of the species in question within the 4m quadrat
quad_code	Text	50	alpha numeric code for quadrat, linked to ref_quad
species_composition_id	Long Integer	4	randomly generated unique number
species_code	Text	50	six letter code for taxon observed, linked to ref_taxon

Table Name: tbl_plot_tree_data

This data table contains all field observations of trees made within the 200 m^2 permanent plots that are of diameter greater than 12 cm at breast height (137 cm). These observations are recorded on the Tree and Sapling data sheet, and are entered into the **Plot Tree Data** screen under the Plot Tree, Sapling tab on the **Main Data Entry** screen. It is linked to the table ***tbl_sample_event*** by the sample_event_num field.

Field Name	Field Type	Field Size	Field Desc
tree_condition_code	Text	50	description of whether tree is alive or dead
quadrant_code	Text	50	one letter code linked to ref_quadrant describing which quadrant trees are from
comments	Memo	0	any additional observations written on field data sheet or regarding data
pathogen_code	Text	50	describes any pathogens or wounds
crown_length_code	Text	50	code describing percent of potential crown which is living
crown_class_code	Text	50	description of relative height/dominance of tree in plot
sample_event_num	Text	50	plot identifier (park, year, elevation, GRTS point)
azimuth_to_tree_magnetic	Double	8	azimuth from plot center to tree, measured in field with no declination
distance_to_tree	Double	8	distance in meters from plot center to tree
species_code	Text	50	6 letter code linked to ref_taxon describing tree species
azimuth_to_tree_corrected	Double	8	azimuth from plot center to tree, corrected in office to fit current declination
sample_point_tree_id	Long Integer	4	sample_point_tree_id identifies tbl_plot_tree_data
dbh	Text	50	diameter of tree at breast height, in centimeters

Table Name: tbl_quadrat_biotic_data

This table contains the percent cover data of the biotic categories for each quadrat in the plots. In the field these data are recorded on the Quadrat Data sheet, and in the database are entered into the **Quadrat Biotic Parameters** screen under the Quadrat Data tab. This table is linked to the table ***tbl_sample_event*** by the sample_event_num field.

Field Name	***Field Type***	***Field Size***	***Field Desc***
forb_percent	Double	8	percent cover of all forbs observed in quadrat
dwarf_shrub_percent	Double	8	percent cover of all dwarf shrubs observed in quadrat
shrub_percent	Double	8	percent cover of shrubs observed in quadrat
tree_percent	Double	8	percent cover of all trees observed in quadrat
sample_event_num	Text	50	plot identifier (park, year, elevation, GRTS point)
quadrat_biotic_id	Long Integer	4	randomly generated unique number
graminoid_percent	Double	8	percent cover of all graminoids observed in quadrat
quadrat_code	Text	50	alphanumeric code linked to ref_quadrat
lichen_percent	Double	8	percent cover of all lichen observed in quadrat
viereck_class_quadrat	Text	50	describes Viereck class specifically of quadrat
comments	Memo	0	any observations written on field data sheet or regarding data entry
moss_percent	Double	8	percent cover of all moss observed in quadrat

Table Name: tbl_quadrat_physical_data

This table contains the percent cover data of the physical categories for each quadrat in the plots. In the field these data are recorded on the Quadrat Data sheet, and in the database are entered into the **Quadrat Physical Parameters** screen under the Quadrat Data tab. This table is linked to the table ***tbl_sample_event*** by the sample_event_num field and to the table ***tbl_digital_photo*** by the field digital_photo_id.

Field Name	***Field Type***	***Field Size***	***Field Desc***
off_180_degrees_true_aspe	Long Integer	4	absolute value of aspect difference from 180 degrees (off of due south)
soil_depth1	Double	8	soil depth in centimeters from NE corner of quadrat
soil_depth2	Double	8	soil depth in centimeters from SW corner of quadrat
digital_photo_id	Long Integer	4	the database assigned unique value for the digital photo
woody_debris_percent	Double	8	percent cover of all woody debris observed in quadrat
standing dead	Double	8	percent cover of all standing dead observed in quadrat
azimuth_corrected	Double	8	magnetic aspect corrected in office to match current declination
comments	Memo	0	any additional observations recorded on field data sheet or regarding data
litter_percent	Double	8	percent cover of all litter observed in quadrat
bare_percent	Double	8	percent cover of all bare ground observed in quadrat
gravel_percent	Double	8	percent cover of all gravel observed in quadrat
cross_section_code	Text	50	one word code describing microtopography
azimuth_magnetic	Double	8	aspect of quadrat measured in field with no declination
slope	Double	8	percent slope of quadrat measured with a clinometer
quadrat_code	Text	50	alphanumeric code linked to ref_quadrat
sample_event_num	Text	50	plot identifier (park, year, elevation, GRTS point)
quadrat_physical_id	Long Integer	4	randomly generated unique number
rock_percent	Double	8	percent cover of all rock observed in quadrat

Table Name: tbl_sample_event

This data table is a primary foundation table within this database. It links the place where sampling occurred with a specific sampling instance. Each time measurements are made according to the protocols of this program at one of the sampling locations, we call it a "sample event" and it will have a unique identifier that consists of the place and date of sampling, or the entry in the sample_event_num field. This table is linked to all of the data tables within the database through this

field. It is linked to the table ***tbl_sample_point*** through the ***sample_point_num*** field.

Field Name	Field Type	Field Size	Field Desc
phenology	Text	255	desc. of overall phenology at plot at the time of sample event
sample_event_num	Text	50	plot identifier (park, year, elevation, GRTS point)
sample_date	Date	8	date of sample event
event_type	Text	50	code describing type and iteration of sample
current_mag_declination	Double	8	mag declination unique to each sampling event
crew initials	Text	50	initials of everyone present for sampling event
conditions	Text	255	the weather at time of sample event
Point_sequence_within_day	Long Integer	4	number describing chronological order of sample event within the day
comments	Memo	0	comments on data entry or describing plot
julian_date	Long Integer	4	Julian date of sample event
time_start_measurements	Date	8	time that sampling of plot began
time_stop_measurements	Date	8	time that sampling of plot ceased
current_mag_dec_direction	Text	50	E or W

Table Name: tbl_sample_point

This table contains data pertaining to the physical location of each plot monument (plot SW corner). Most of these data are written on the Point Data sheet in the field and are imported into the database from the .dbf file downloaded from the Trimble GPS unit. The data for generated longitude and latitude of the center point are generated by Arcview. This table is linked to the ***tbl_sample_event*** table by the field sample_event_num, and to the ***tbl_sample_point_species*** table by the sample_point_num field.

Field Name	Field Type	Field Size	Field Desc
max_HDOP	Long Integer	4	maximum hdop recorded on field gps unit
actual_latitude	Double	8	latitude of sample point measured in the field with a gps unit
gps_date	Date	8	date recorded from gps unit at point
point_type	Text	50	was the point gps'd at the center point or elsewhere?
comments	Memo	0	comments from the field or on data entry
usgs_quad	Text	50	name of usgs quad map in which point is located
gps_error_term	Text	50	for error distance on GPS point for non-Trimble units
max_PDOP	Long Integer	4	maximum pdop recorded on field gps unit
actual_longitude	Double	8	longitude of sample point measured in the field with a gps
corr_type	Text	50	was gps data differentially corrected?
generated_longitude	Double	8	arcview generated longitude of sample point
generated_latitude	Double	8	arcview generated latitude of sample point
sample_event_num	Text	50	plot identifier (park, year, elevation, GRTS point)
gps_type	Text	50	type of gps unit used, linked to ref_gps_type
measurement_status	Text	50	was point sampled - if not, why not!
gps_time	Date	8	time recorded from gps unit at point
gps_elevation_meters	Long Integer	4	elevation in meters read from gps unit at point
gps_vertical_precision	Long Integer	4	vertical precision of gps information
gps_horizontal_precision	Long Integer	4	horizontal precision of gps information
gps_std_dev	Long Integer	4	standard deviation of gps information

Table Name: tbl_sample_point_species

This data table contains the complete species data set for each plot. This table is linked to the ***tbl_sample_point*** table by the field sample_point_num. In the database, these data are entered into the screens located under the **Transect Cover Data** and **Quadrat Data Sheet** tabs in the **Main Data Entry** screen.

Field Name	Field Type	Field Size	Field Desc
sample_event_num	Text	50	plot identifier (park, year, elevation, GRTS point)
species_code	Text	50	six letter code linked to ref_taxon

Table Name: tbl_sample_transect

This table contains data relating a particular transect to a particular sampling event. These data are entered into the Sample_Transect fields on the **Main Data Entry** screen in the database. This table is linked to the following tables by the field sample_transect_num: ***tbl_cover_transect_data***, ***tbl_digital_photo***, ***tbl_plot_species_collection***, and ***xref_sample_personnel***.

Field Name	Field Type	Field Size	Field Desc
comments	Memo	0	comments from the field or on data entry
sample_transect_num	Text	50	concatenation of sample event number and transect code
sample_event_num	Text	50	plot identifier (park, year, elevation, GRTS point)
transect_code	Text	50	identifies which transect is being sampled
sample_point_count	Long Integer	4	the number of sample points for each transect
vertical_strata_count	Long Integer	4	the number of vertical strata

Table Name: tbl_soil_field_observation

This data table contains soils observation data from the field. These data are entered on the Soils data sheet and in the database are entered into the **Soil Field Observations** screen. This table is linked to the ***tbl_sample_event*** table and to the ***tbl_composite_soil_field*** table through the field sample_event_num.

Field Name	Field Type	Field Size	Field Desc
is_sample_integrated	Boolean	1	was sample integrated with other samples from point? yes/no
litter_code	Text	255	linked to ref_litter, identifies type(s) of litter at sample point
restrictive_feature_code	Text	255	identifies whether rock or permafrost is restrictive
horizontal_microrelief	Double	8	numerical value in centimeters of maximum horizontal microrelief at point
vertical_microrelief	Double	8	numerical value in centimeters of maximum vertical microrelief at point
microrelief_code	Long Integer	4	linked to ref_microrelief, describes type of microrelief at sample point
slope	Double	8	slope in degrees at soil sample point
azimuth_magnetic	Double	8	magnetic aspect of slope at soil sample point
organic_mat_depth	Double	8	depth in centimeters of organic mat
organic_mat_code	Text	255	identifies composition of organic mat
living_mat_depth	Double	8	depth in centimeters of living mat
current_weather	Text	255	weather at time of sample event
litter_depth	Double	8	depth in centimeters of litter
anomalies	Text	255	notes on any anomalies observed at point
soil_temp	Double	8	soil temperature in Celsius at sample point
air_temp	Double	8	air temperature in Celsius at sample point
sample_time	Date	8	time that sample was taken
composite_soil_field_num	Text	50	concatenation of sample event num and all soil point codes
why_no_sample	Text	255	if no sample was taken, explain why.
is_sample_taken	Boolean	1	was sample taken? yes/no
soil_point_code	Text	255	one letter code identifying cardinal direction of soil pt
sample_event_num	Text	50	plot identifier (park, year, elevation, GRTS point)
soil_field_obs_num	Text	50	concatenation of sample event number and soil point code
living_mat_code	Text	255	identifies growth form(s) of living mat at point
comments	Memo	0	comments from the field or on data entry
surface_moisture_class	Text	50	describes surface moisture at point

surface_cover	Text	50	describes type of material on surface of plot
slope_position_code	Text	255	describes relative position of sample point
restrictive_feature_depth	Double	8	depth in centimeters of restrictive feature

Table Name: xref_plot_biotic_viereck

This cross- reference table relates the plot Viereck classification to the ***tbl_plot_biotic_data*** table by the field plot_biotic_id. This table functions as a cross-reference table because there can be multiple Viereck classes within a single plot.

Field Name	Field Type	Field Size	Field Desc
viereck_polygon	Text	50	viereck_polygon is of xref_plot_biotic_viereck
plot_biotic_viereck_id	Long Integer	4	plot_biotic_viereck_id identifies xref_plot_biotic_viereck
plot_biotic_id	Long Integer	4	plot_biotic_id identifies xref_plot_biotic_viereck
viereck_code	Text	50	viereck_code partly identifies xref_plot_biotic_viereck
viereck_inplot_code	Text	50	partly identifies xref_plot_biotic_viereck
viereck_percent_of_plot	Double	8	viereck_percent_of_plot is of xref_plot_biotic_viereck
viereck_extent	Text	50	viereck_extent is of xref_plot_biotic_viereck

Table Name: xref_quadrat_biotic_species

This cross-reference table contains data quantifying the count and species of seedlings in each quadrat. It functions as a cross-reference table because there can be more than one species of seedlings in a quadrat. This table links to the ***tbl_quadrat_biotic_data*** table by the field quadrat_biotic_id.

Field Name	Field Type	Field Size	Field Desc
seedling_condition_class	Text	50	seedlings counted are live or dead?
seedling_species_count	Long Integer	4	of xref_quadrat_biotic_species
seedling_species_code	Text	50	partly identifies xref_quadrat_biotic_species
quadrat_biotic_specied_id	Long Integer	4	identifies xref_quadrat_biotic_species
quadrat_biotic_id	Long Integer	4	quadrat_biotic_id identifies xref_quadrat_biotic_species

Table Name: xref_sample_personnel

This cross reference table contains data about the personnel working on the project. It allows the database to recognize that a technician can perform multiple duties, for instance, a technician can be both a reader and a recorder for data on the point transects. This table is linked to the ***tbl_sample_event*** table and the ***tbl_sample_transect*** table by the code sample_event_num.

Field Name	Field Type	Field Size	Field Desc
data_id	Long Integer	4	data_id is of xref_sample_personnel
sample_personnel_id	Long Integer	4	sample_transect_id identifies xref_sample_personnel
sample_event_num	Text	50	sample_event_num identifies xref_sample_personnel
personnel_code	Text	50	personnel_code is of xref_sample_personnel
sample_transect_num	Text	50	sample_transect_num is of xref_sample_personnel
observer_type	Text	50	observer_type is of xref_sample_personnel
data_table_code	Text	50	data_table is of xref_sample_personnel

III. Literature cited

Roland, C., Oakley, K., Debevec, E.M., and P. Loomis. 2004. Monitoring vegetation structure and composition at multiple spatial scales in the Central Alaska Network (Version 1.0). National Park Service, Inventory & Monitoring Program, Alaska Region, Anchorage, Alaska, 50 pp.

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