Simulations and field data guide development of vegetation monitoring in the Southwest Alaska Network

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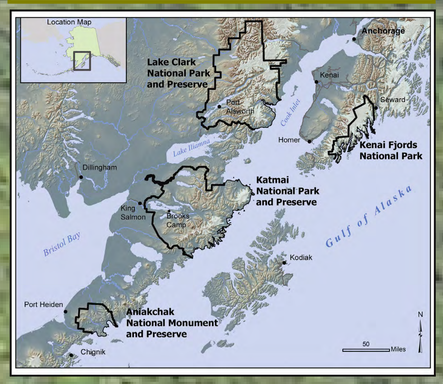
Abstract

The Southwest Alaska Network is using a combination of GIS analysis, field data, and simulations to develop methods for vegetation monitoring. Ground-based monitoring will target changes in vegetation that are too subtle to be detected through remote sensing techniques alone. First, we use a generalized random-tesselation stratified design to select monitoring plots from accessible areas delineated in a GIS. Simulations are used to estimate sample size and frequency, based on assumptions regarding rates of change derived from image time series, field data, and the literature. Unlike conventional power analyses, our simulations provide the sample size and frequency required to detect different magnitudes of change across a range of coefficients of variation (CVs) for a specified time interval. We then compare these simulation results with CVs estimated from field data to establish a realistic sampling design for monitoring.

1 Parks of the Southwest Alaska Network (SWAN): Alagnak Wild River (ALAG); Aniakchak National Monument & Preserve (ANIA); Lake Clark National Park & Preserve (LACL); Katmai National Park & Preserve (KATM); and Kenai National Park (KEFJ). Ground-based monitoring is planned for LACL, KATM, and KEFJ.



Data sources

Satellite imagery & air photos

Landsat TM/ETM+ (**Fig. 2**), IKONOS data and orthorectified air photos (**Fig. 3**) from the 1950s, 1980s, and 1990s (1:24,000-1:63,000) are being used to describe landscape-level changes in the SWAN. Estimated rates of vegetation change have been incorporated into simulations to estimate sample size and frequency.

GIS data

We used a path-distance analysis to develop access layers for LACL & KATM (Mortenson and Miller 2008), with land cover, land ownership, and topography influencing the cost of travel (**Fig. 4**). A similar layer was developed for KEFJ using slope and shoreline features. Barriers to travel include steep slopes, glaciers and major river crossings.

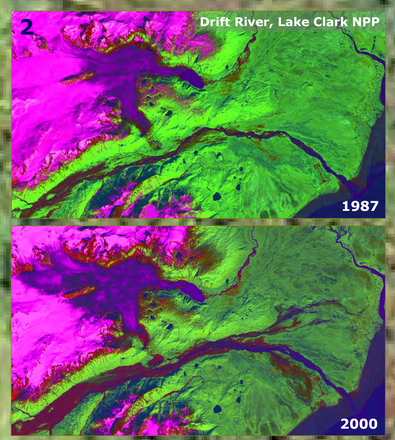
Introduction & Background

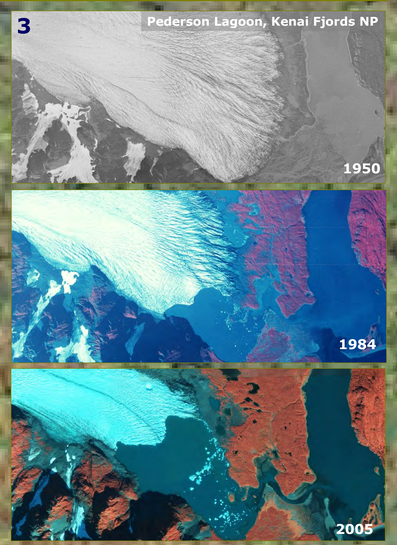
Vegetation is integral to ecosystem function, energy transfer, and element cycling, and serves as a sensitive indicator of environmental change. In the Southwest Alaska Network (SWAN; Fig. 1), vegetation composition and structure will be monitored at a variety of spatial scales.

Site access strongly constrains field work in the roadless areas of the SWAN. Landscape-level changes, including glacial retreat and vegetation establishment, can be monitored using remotely sensed data (Figs. 2-3). However, community-level changes, including changes in species richness and turnover, will require ground-based measurements.

Here, we outline a combination of GIS analyses, field data and simulations that are being used to develop methods for ground-based vegetation monitoring.

2-3 (2) Tassel-cap transformed Landsat images showing changes in channel morphology and vegetation cover following the 1989-1990 eruption of Mt. Redoubt (LACL). (3) Orthorectified air photos (1950, 1984) and IKONOS image (2005) showing glacial retreat and shrub establishment at Pederson Lagoon (KEFJ).





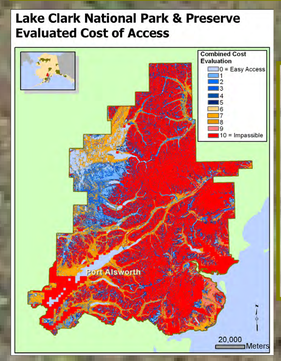
White spruce woodland, Lower Twin Lake (LACL)

Methods - Simulations

Accessible areas were modeled using Path Distance analysis tools in ArcGIS (Fig. 4). An attributed grid of points was generated for each access layer and exported to S-DRAW for the selection of a Generalized Random-Tesselation Stratified (GRTS) sample.

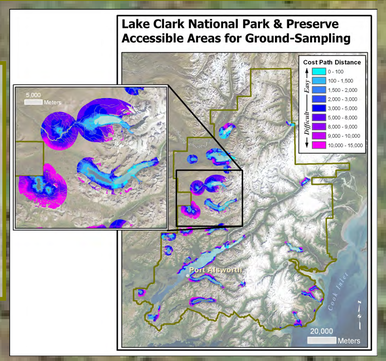
The first set of simulations were run to investigate the minimum level of change that could be detected when 20% or 50% of selected vegetation classes were changed in the existing landcover map, using different spatial arrays of points (2×2 grids, 3×3 grids, and single points). We found that using a GRTS sampling approach across all vegetation classes would result in sufficient replication only for the most frequently occurring classes (e.g., >40% occurrence). Single points had a greater ability to detect change than grids of points with the same level of sampling effort. Based on this finding, we constrained ground-based monitoring to specific vegetation classes in order to optimize sampling effort.

A second set of simulations were run to investigate the minimum level of change that could be detected for populations subjected to different levels of true change (30%, 40%, 50%) over a 31-year period. We varied the number of replicates in each vegetation × elevation class (n = 6, 8, 12, 24) and ran the simulations at two sampling frequencies (5 and 10 years) to estimate coefficients of variation (CVs) required to capture a minimum detectable change (MDC). Estimates of interannual variability in plot variables (2007-2008) and rates of change reported from the literature were used to select a MDC of 20% over 31 years, given a true change of 40%.



4 Development of an access layer for LACL. Maps indicate evaluated cost of access (left) and accessible areas following Path Distance analysis and elimination of null areas (right).

Most of the park is inaccessible due to steep terrain, glaciers, and a limited number of entry points.



Methods – Field data collection

Pilot data were collected from 14 monitoring plots in LACL in 2007-2008 (Fig. 5). Plot variables (cover by species, cover by growth form, species frequency) were summarized across vegetation and elevation classes and CVs calculated for cover and frequency. Calculated CVs were compared with CVs generated from simulations to estimate sample size and sampling frequency, based on a rotating panel design (Table 1). Interannual variability in plot variables was estimated from repeated measurements (2007, 2008) in a subset of plots.

	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					
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

1 Proposed panel design for monitoring vegetation in the SWAN showing a 5-year sampling frequency. A single panel is represented by a single park × elevation band × vegetation class combination. Simulations were run to estimate the number of plots (X) that would need to be sampled in each combination each year. In this scenario, Panel 6 would be sampled for 2 consecutive years during every interval to provide ongoing estimates of interannual variability.

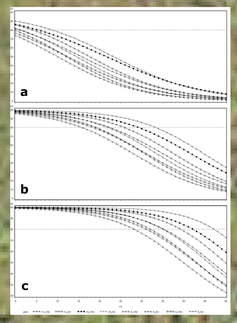
Results

Simulated CVs decreased as sample number and sampling frequency increased (Fig. 6). Coefficients of variation for plot variables were lowest for cover categories (e.g., cover by growth form) and for species that occurred at high frequencies across plots (e.g., common species). CVs increased markedly for rare species, due to high variance in occurrence.

Based on interannual variability in plot variables (2007-2008), rates of change reported from the literature, and CVs estimated from the simulations, we selected a MDC of 20% as a reasonable level of change that could be detected when true change was 40% over the same time period.

Our goal was therefore to detect a +/- 1.3% annual trend (40% mean total change over 31 years) with 95% confidence for selected plot variables (e.g., cover by growth form; cover and frequency of common species). To accomplish this using the panel design shown in Table 1, we would need to sample 12 plots per vegetation × elevation class at a frequency of every 5 years (Table 2) to capture the CVs estimated for plot variables (Table 3).

5 Pilot sampling in LACL. Monitoring plots consisted of three parallel 30-m transects. Species cover was measured by point-intercept at 0.5-m intervals along transects. Species occurrence was measured in nested frequency plots (0.25 m², 1 m², 4 m²) arrayed at 7-m intervals. Tree density, canopy cover, and basal area were quantified within the 30×30 m plot following a modification of FIA protocols. Dwarf birch (right) and white spruce woodland (far right) communities are shown.



6 Chance of recording a MDC of 25% with 95% confidence when the true change is (a) 30%, (b) 40%, or (c) 50%. Response curves are for replicate plots (n=6–24) sampled over 5- and 10-y intervals. CVs are shown on the X-axis. Reference line indicates an 80% chance of detecting the MDC; thus, as MDC<<true change, the CV required to detect MDC decreases.

	Estimated percent (%) chance of detecting the listed or smaller total change given a true average total change of -40%								
CV ($\hat{p}$) (%)	<0%[b]	≥-5%	≥-10%	≥-15%	≥-20%	≥-25%	≥-30%	≥-35%	≥-40%
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

2 Ability to detect different levels of MDC with 95% confidence for a true decline of 40% over 31 years. Simulated CVs are shown for a sample size of n = 12 and a sampling frequency of 5 years.

Vegetation class	Species	Mean cover (%)	CV (%)
Dwarf birch	*Arctostaphylos alpina*	1	63
	Betula glandulosa	26	33
(n=5)	*Ledum palustre* ssp. *decumbens*	22	23
	Lichen	34	18
	Moss	31	24
Spruce woodland	*Picea glauca*	5	22
	Betula glandulosa	16	27
(n=4)	*Vaccinium uliginosum*	16	15
	Empetrum nigrum	27	12
	Lichen	38	22
	Moss	38	21

3 CVs estimated for species cover in two mid-elevation vegetation types sampled in LACL (2007-2008). Common species typically had CVs of 15-40%. Uncommon species (e.g., *Arctostaphylos*) had higher CVs that may preclude detection of significant trends in cover.

Discussion

Simulation results paired with estimates of variance from the field have yielded a sampling design that should enable estimation of long-term vegetation change in accessible areas of the SWAN. Simulations provide an estimate of the magnitude of change that may occur in representative vegetation classes, whereas traditional power analysis provides the sampling effort required to detect a change (MDC >0). By considering a range of MDCs >0%, we were able to evaluate sampling designs that could provide biologically meaningful estimates of change through time.

Changes in vegetation detected by the proposed design may include the following:
- Changes in species occurrence, cover, and height (common species)
- Changes in species richness and diversity
- Changes in cover by growth form
- Changes in seedling, sapling, and tree density

Dwarf birch community, Square Lake (LACL)

Literature Cited

Mortenson DC, Miller AE (2008) Path-distance analysis to determine accessibility for long-term vegetation monitoring program, Lake Clark National Park and Preserve. Natural Resource Technical Report NPS/SWAN/NRTR-2008/126, National Park Service, Ft. Collins, CO.