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Developing effective sampling designs for monitoring natural resources in Alaskan national parks: An example using simulations and vegetation data

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ABSTRACT

Monitoring natural resources in Alaskan national parks is challenging because of their remoteness, limited accessibility, and high sampling costs. We describe an iterative, three-phased process for developing sampling designs based on our efforts to establish a vegetation monitoring program in southwest Alaska. In the first phase, we defined a sampling frame based on land ownership and specific vegetated habitats within the park boundaries and used Path Distance analysis tools to create a GIS layer that delineated portions of each park that could be feasibly accessed for ground sampling. In the second phase, we used simulations based on landcover maps to identify size and configuration of the ground sampling units (single plots or grids of plots) and to refine areas to be potentially sampled. In the third phase, we used a second set of simulations to estimate sample size and sampling frequency required to have a reasonable chance of detecting a minimum trend in vegetation cover for a specified time period and level of statistical confidence. Results of the first set of simulations indicated that a spatially balanced random sample of single plots from the most common landcover types yielded the most efficient sampling scheme. Results of the second set of simulations were compared with field data and indicated that we should be able to detect at least a 25% change in vegetation attributes over 31 years by sampling 8 or more plots per year every five years in focal landcover types. This approach would be especially useful in situations where ground sampling is restricted by access.

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1. Introduction

The United States National Park Service (NPS) is charged with protecting or maintaining natural systems within US national parks. As part of this mandate, the NPS Inventory and Monitoring (I&M) Program was developed to collect scientifically sound data on the current status and long-term trends of key components of park ecosystems. Monitoring data, in particular, are expected to promote a better understanding of ecosystem processes, and to provide information used in decision making for resource protection and management, as well as public education and outreach (Fancy et al., 2009). Monitoring data should also serve to document alterations to park ecosystems as a result of climate change and other factors (Lindenmayer and Likens, 2009).

Despite the importance of credible data on the status and trends of key resources, far too many natural resource monitoring programs to date have been ineffective because of inadequate programmatic support, poor planning, and lack of rigorous study design (Legg and Nagy, 2006; Field et al., 2007; Lindenmayer and Likens, 2009). Challenges to developing a rigorous design include the need to maximize spatial balance of a random sample of plots while minimizing sampling effort, the need for sample sizes sufficient to detect change in heterogeneous or highly variable environments, and the long time periods required to detect change. The parks in southwest Alaska are large (0.3–1.7 million ha, each), remote, and generally lack infrastructure for travel (roads, trails). Additional logistical challenges associated with sampling include a limited number of landing areas for planes to access sample areas, inclement weather, and a short summer field season.

Practical considerations, such as accessibility and cost, necessarily limit the sampling design alternatives that can be implemented in remote, roadless parks. Possible sampling approaches include remote-sensing techniques (e.g., change detection using mid- and high-resolution imagery), aerial surveys (e.g., population counts) and/or ground-based sampling (e.g., plot-based sampling). Each approach has technological, budgetary, and/or logistical constraints and addresses monitoring objectives at different temporal and spatial scales. Although remote-sensing data can provide wall-to-wall coverage of park resources at a much lower cost than field

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visits, there are many aspects of resource condition that are too subtle to detect spectrally, or occur at too fine a scale to monitor through remote-sensing techniques alone.

In this paper, we outline an iterative, three-phase process that we used to develop a sampling design, adapted from Woodward et al. (2009), for ground-based monitoring of vegetation in national parks of the Southwest Alaska Network (SWAN; Fig. 1), one of 32 I&M networks nationwide. In Alaska and other northern latitudes, regional warming is expected to contribute to changes in species composition (e.g., Walker et al., 2006; Hudson and Henry, 2009); shifts in species' ranges (e.g., Sturm et al., 2001; Lesica and McCune, 2004); drought stress and reduced tree growth (e.g., Barber et al., 2000); and increasingly severe, large-scale disturbances (e.g., Berg et al., 2006). Our overarching objective was to estimate long-term trends in the composition and structure of late-successional plant communities from three elevation bands (0–450 m; 451–900 m; >900 m) in the three largest SWAN parks. We framed our monitoring objective as a function of elevation because we expected both drivers (environmental) and response variables (vegetation attributes) to vary along an altitudinal gradient. We further separated estimates of vegetation change by park because regional effects (e.g., geography) were also expected to influence variation in vegetation composition and structure.

Our sampling design is intended to capture changes at the level of individual species or plant communities, including changes in species richness and species turnover that could be associated with climate change. We address the challenges outlined above (access; sampling effort; ability to detect change) with a focus on the methods we used to delineate our population of interest, determine sample unit configuration, and estimate sample size and frequency required to detect a change or trend. The sampling design is thus tailored to meet the monitoring objectives of the NPS I&M Program, generally, and to address the logistical challenges of field work in SWAN, specifically.

2. Materials and methods

The initial steps of defining program goals and objectives, compiling and summarizing existing information, developing conceptual models, and prioritizing and selecting indicators (cf. Fancy et al., 2009), were precursors to the development of an overall sampling design for SWAN and are not addressed in this paper. In the following sections, we describe the process we used to develop a ground-based sampling design for monitoring vegetation in national parks in southwest Alaska.

2.1. Phase I: Defining a target population, sampling frame and sampled population

An important step in developing a sampling design for some geographical area is to define the spatial units containing the complete collection of plants, animals, or other natural resources of interest. The collection of all possible point locations or spatial units within this area of interest comprises the target population (Fig. 2). That is, one may define the target population as all point locations within an area where some spatial unit (e.g., plot) is associated with a selected point, or as a non-overlapping collection of spatial units that cover the area of interest. In our target population, we subdivide the area of interest into non-overlapping spatial units, or sampling units (e.g., plots), that do not occur within bodies of water, marine mudflats, airstrips, trails, cabins, campsites, and non-NPS lands within a given SWAN park. The natural resource of interest, such as a plant, is an attribute measured on the

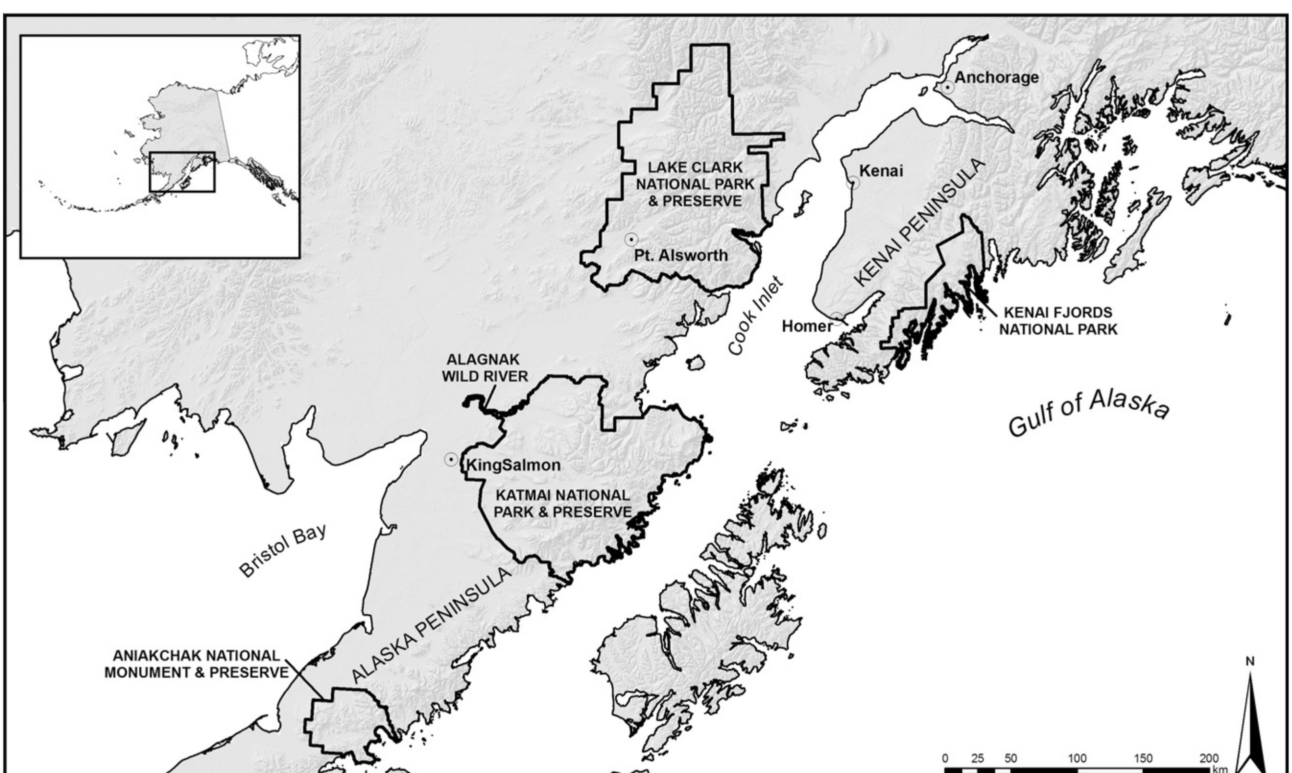

Fig. 1. The Southwest Alaska Network (SWAN) includes Alagnak Wild River, Aniakchak National Monument and Preserve, Katmai National Park and Preserve, Lake Clark National Park and Preserve and Kenai Fjords National Park. Collectively, these units sum to 3.8 million ha, or 11.6% of the land managed by the US National Park Service (figure from Bennett et al. (2006)).