Visitor Perceptions and Resource Conditions of Campsites in Two Coastal Alaskan National Parks

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VISITOR PERCEPTIONS AND RESOURCE CONDITIONS OF CAMPSITES IN TWO COASTAL ALASKAN NATIONAL PARKS

by

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ABSTRACT

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Increasing visitation and use-levels in parks and protected areas presents managers with the challenge of providing quality visitor experiences while mitigating ecological impacts from recreation. Adaptive management frameworks often suggest determining desired conditions and establishing thresholds to compare to existing conditions. This research integrates ecological impact assessments of unconfined campsites with social science methods evaluating the acceptability of these impacts in open-water, coastal Alaskan parks. This study completes the dimensions of a management framework in three parts: 1. Establishes thresholds of acceptability regarding crowding and coastal resource conditions as well as cruise ships that detract from the visitors' wilderness experience through a survey in Glacier Bay National Park and Preserve (GLBA); 2. Compares these thresholds to *in situ* observations of the indicators and visual extent of cruise ships in the park, and; 3. Evaluates the longitudinal monitoring efforts of campsites in Kenai Fjords National Park (KEFJ) to explore patterns in changing campsite conditions and determine possible improvements in the efficiency of the current monitoring protocol. Using normative theory, crowding thresholds derived from the survey results suggest that current backcountry group sizes are acceptable to most visitors; however, coastal resource condition results indicate that the number of tent rocks left undispersed on campsites are out of compliance with the established threshold. Additionally, with varying levels of visibility, cruise ships can be observed from two-thirds of the campsites in GLBA and were considered to be a detraction from the backcountry visitors' experience. In KEFJ, patterns in changing campsites were difficult to discern until examined by park region and opportunities to optimize the current monitoring protocol were identified by removing redundant indicator variables. Based on these findings, this research provides the information necessary for park managers to make informed management decisions to maintain quality visitor experiences and protect the natural resource.

(121 pages)

PUBLIC ABSTRACT

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Shannon T. Wesstrom

Increasing visitation in parks and protected areas presents managers with the challenge of providing quality visitor experiences while mitigating ecological impacts from recreation. Successful management strategies often suggest determining desired conditions for visitor experiences and ecological conditions to establish thresholds. These thresholds can then be compared to existing conditions in order to determine if changes in management strategies should be made. By integrating visitor survey results with ecological assessments, this research is a unique coastal Alaskan regional analysis of the three components of a management framework: 1. Establishes visitor determined thresholds of acceptability for crowding and coastal resource conditions in Glacier Bay National Park and Preserve (GLBA); 2. Compares those thresholds to existing conditions, and; 3. Evaluates the monitoring efforts of campsites in Kenai Fjords National Park (KEFJ) to explore patterns in changing campsite conditions. Crowding thresholds derived from the GLBA survey results suggest that current backcountry group sizes are acceptable to most visitors; however, coastal resource condition results indicate that the number of tent rocks left undispersed on campsites exceed the established threshold. Patterns in changing campsites at KEFJ were detected by park region and several statistical analyses proved improvements could be made to the current monitoring protocol. The results from this research support the need for proactive management strategies and provide suggestions for improved ecological monitoring protocols.

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CHAPTER 1

INTRODUCTION AND BACKGROUND

Introduction

Visitation to parks and protected areas (PPAs) has been increasing for the past five decades in the United States and across the globe (National Park Service, 2020; Machlis et al., 2019). By area, Alaska encompasses over half of the United States' National Park designated lands, which have quickly become hot spots for tourism. With a state nickname of "The Last Frontier", Alaska has some of the last remaining undeveloped ecosystems in the world and makes up about 54% of the United States' designated Wilderness (Norris, 2007). Recent social shifts in rural Alaskan communities have occurred as natural resource extraction industries, such as fishing and forestry, decline and amenity-driven activities attract visitors and new residents (Safford et al., 2014).With abundant opportunities for remote scenic landscape and wildlife viewing, solitude, and cultural learning, these Alaskan communities have developed a novel tourism industry that brings millions of visitors to the state. The quality, condition, and appearance of the natural resources maintains the demand for recreation and tourism in these coastal PPAs (Lazarow, 2007).

Increasing visitation and use-levels in PPAs presents land managers with the challenge to protect the integrity of the natural resources while providing visitors opportunities for recreation. With an increase in use, there is an assumption of ecological degradation to natural resources and negative effects on visitor experience (Manning et al., 2010). Balancing these demands to provide quality visitor experiences and opportunities for recreation can be especially contentious and challenging when managing wilderness areas. These primitive areas are protected under the Wilderness Act of 1964 and are defined as "an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain."(pg. 1). They typically have no roads, infrastructure, or development nor do they allow for the operation of mechanized vehicles, including bicycles. Additionally, they provide pristine solitude experiences and primitive recreation opportunities, such as hiking and camping. Balancing demands for public access and protecting the natural resource requires addressing the carrying capacity in these spaces. Carrying capacity is the limit of type and level of use that an environment can handle before unacceptable, potentially irreversible, ecological degradation occurs (Manning, 2011). Contemporary analyses of carrying capacity include three components: resource, social (i.e. experiential), and managerial. Each capacity is individually evaluated through rigorous scientific approaches and then compared and prioritized against the other components to determine an overall carrying capacity (Manning et al., 1996).

Multiple approaches to define appropriate conditions have been devised based on the management agency and achieving specific objectives. For instance, the United States Forest Service produced a procedural framework, Limits of Acceptable Change (LAC) System for Wilderness Planning (Stankey et al., 1985). Rather than define recreational carrying capacities, the primary emphasis is on desired conditions instead of how much the land can tolerate. Similar conceptual frameworks include Visitor Impact Management (VIM) (Graefe et al., 1990) and Visitor Experience and Resource Protection (VERP) (National Park Service, 1997) for use in National Parks and other conservation areas. The Interagency Visitor Use Management Council, a group of federal land management agencies, used concepts from multiple frameworks to develop the Visitor Use

Management (VUM) framework (IVUMC, 2016). By taking the concepts from the original management by objectives frameworks, the VUM applies common language and a sliding scale to create a framework that works across multiple agencies and varying levels of planning. More broad management objectives are set to determine desired social and natural resource conditions. For example, a social wilderness management objective provides opportunities for solitude while a cultural or historical protected site strives to provide opportunities for learning (Hallo et al., 2018). With many PPAs having a variety of recreation resources, the Recreation Opportunity Spectrum (ROS) is a management tool operationalized to provide recreation opportunities to a diverse and changing visitor-base (Clark et al., 1979). ROS allows for a range of opportunities for visitors with varying motivations and intentions to recreate in the same place (McCool et al., 2007). ROS can be applied in the same recreation area or across an entire management agency such as the National Park Service or Forest Service, with broad objectives.

The aforementioned frameworks can be used as tools for adaptive management planning. Walters and Hilborn (1978) and Walters (1997) describe adaptive management as an ongoing learning process by which “management policies can be applied as experimental treatments.” By monitoring the effects of management implementations it is possible to determine the success of the new policy. Managers use adaptive management planning frameworks by first defining desired characteristics that guide the broad objectives. These desired characteristics are explained in an actionable form and expressed quantitatively as indicators and thresholds. Indicators are variables that can be manipulated to serve as proxies for the desired condition. Thresholds then determine the minimum acceptable condition for the indicator variable (Hallo et al., 2018). Managers can compare these thresholds to the existing conditions through monitoring practices to determine management success. This cyclical process of monitoring existing conditions to compare to desired conditions allows for adaptive management changes or continued long-term maintenance (Hammitt et al., 2015). PPA managers and researchers often utilize normative theory to define these thresholds.

Normative Theory

Stemming from the field of social psychology, normative theory is a framework to apply and develop thresholds (formerly “standards”) and desired conditions (Manning et al., 1999). Applying the normative approach to visitor determined thresholds uses Jackson’s (1965) return potential methodology. Shelby et al. (1986) and Vaske et al. (1986) were two of the first to apply these methods to recreation areas. This theory provides directions for how people should make decisions based on group and/or societal judgments, creating normative rules. Normative rules then provide a threshold to compare to people’s actual behavior (Hickson et al., 2014). These thresholds describe human response to a situation using measurable indicators of quality. When used in recreation research, indicators of quality variables must be measurable and manageable to replicate the quality of the natural resources and visitor experience. To interpret the results, thresholds of quality then define the minimum acceptable condition of the indicators of quality variables (Manning et al., 1999; Manning, 2011). Common indicators in park management include counting visitors to measure crowding (Manning et al., 1999), social trails and vegetation loss to measure resource impact (D’Antonio et al., 2013), or animals with varying distances from humans to observe visitor perceptions of safe human-wildlife interactions (Miller et al., 2018; Cerri et al., 2019). These normative judgements produce thresholds of acceptability that often lead to administrative changes to management, public policy, and legislative changes if accepted by a resounding portion of visitors (Manning et al., 2010; Manning, 2007).

People's responses to normative theory questions can be influenced by their past experiences in a place, encounters with others, and personal characteristics (Price et al., 2018; Manning et al., 1999). Additionally, when assessing norms, visitor type (in wilderness vs. developed or maintained PPAs), visitor experience (frequency and duration), and recreation type (hiking, camping, kayaking, etc.) need to be considered (Hallo et al. 2018). Because of these potential biases, questions that rely on visuals are considered more effective when asking questions about ecological or social situations that are difficult to communicate using text or numerical explanations (Manning, 2011; Manning et al., 2010). Images representing specific conditions give the participant the opportunity to focus and observe the impact under consideration rather than imagine their own version of the described situation. Composite visual methods create a more standardized approach to reach judgments and acceptable thresholds across a population.

When respondents look at each visual, they are asked to rate how acceptable they find an image, typically based on a Likert scale. A Likert scale is a rating system in which zero is neutral and the positive and negative numbers correspond to positive or negative reactions to the image. To interpret the results of norm theory questions and determine acceptable thresholds, Manning et al. (1999) suggests creating a social norm curve (Figure 1). The changing variable is on the X axis while the acceptability rating is on the Y. The mean acceptability rating for each variable is plotted and the points are connected with a line. The highest point on the curve is considered the optimal or preferred acceptable condition, while the lowest point is the least acceptable condition. The point where the curve crosses zero along the acceptability rating (Y axis) is considered the minimum acceptable condition. This value indicates where respondents draw the line from feeling neutral about a variable to reacting negatively to it. This value is calculated with the point-slope linear equation. The range of acceptable conditions is each point that remains above the zero on the Y axis. Normative crystallization is the amount of dispersion between points and suggests the level of consensus among respondents, often calculated from the standard deviations of the mean responses. The social norm curve creates an interpretable visualization to better understand thresholds of quality for both resource and social conditions.

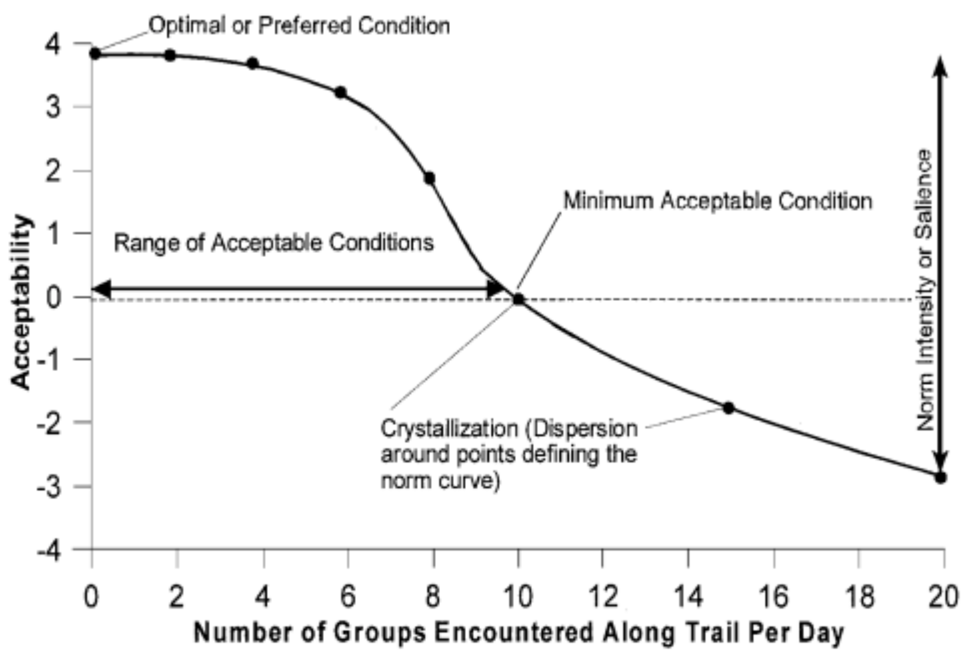

Figure 1. Hypothetical norm curve (Manning et al., 1999). Means of acceptability ratings are plotted for each hypothetical number of groups seen along a trail in one day. The range of groups encountered above zero on the acceptability rating (Y axis) are the acceptable conditions, the value at zero is the minimum acceptable condition, and the values below zero are considered unacceptable. The range in acceptability rating responses for each condition is the crystallization and informs the consensus among respondents.

To better understand the agreement levels between survey responses, Vaske et al. (2006) (corrected Manfredo et al., 2003) devised the Potential for Conflict Index (PCI). This allows for interpretation of the level of consensus between surveyed visitors and their preferred conditions. Results from a PCI elucidate areas of strong or weaker consensus in specific condition levels. The index incorporates how many people responded to each possible answer from the Likert Scale (-3 to 3) and multiplies the number of responses to the corresponding Likert Scale value (Figure 2). In this equation, X_a are the acceptable conditions (responses >0); X_u are the unacceptable conditions (responses <0); and Z is the maximum sum of all scores (Z = 3n). Possible answers to this equation range from 0 to 1. A result of 0 implies complete agreement, whereas 1 implies complete disagreement. A strong consensus in normative results implies a greater confidence in the condition and that it represents the feelings of a large portion of the sample. If agreement is low, it is likely that the threshold is not indicative of the feelings of a larger population. These results may be representative of a small portion of the sampling group (Hallo et al., 2018).

$$\mathrm{PCI} = \left[1 - \left|\frac{\sum_{i=1}^{n_a} |\mathrm{X_a}|}{\mathrm{X}_t} - \frac{\sum_{i=1}^{n_u} |\mathrm{X_u}\,|}{\mathrm{X}_t}\right|\right] \times \frac{\mathrm{X_t}}{\mathrm{Z}}$$

$$\mathrm{X}_t = \sum_{i=1}^{n_a} |\mathrm{X_a}| + \sum_{i=1}^{n_u} |\mathrm{X_u}|$$

Figure 2. The full equation for the Potential for Conflict Index (Vaske et al., 2006).

Ecological Monitoring of Campsites

There are generally two types of techniques recreation ecologists use to examine recreation effects on the environment: experimental studies and monitoring. Using controlled experimental designs, experimental studies examine the causality between recreation type, intensity, and behavior and ecological disturbance or lack thereof. Monitoring and assessment studies provide initial condition evaluations and can model trends of environmental change over time. They also provide evidence of the effectiveness of management strategies and are more commonly used in the field (Hammitt et al., 2015). Trails (Leung et al., 1999b), campsites (Cole et al., 1992; Marion, 1991), human-wildlife interactions (Miller et al., 2017), and recreational water systems (Graham et al., 2009) have all been monitored for recreational impacts. These recreational facilities and resources have individualized monitoring protocols but, the effective systems share four key characteristics (Hammitt et al., 2015):

1. Reliable and sensitive measuring techniques.
2. Meaningful measured variables.
3. Costs remain low so all sites can be evaluated over the length of the study.
4. Measurements are duplicatable and sites can be easily relocated.

Marion (1991), Cole et al. (1992), and Leung et al. (1999a) laid the groundwork of campsite monitoring protocols still used today. All analyze multiple parameters, however Marion (1991) offers a more rapid approach when measuring variables. Campsite area, ground cover disturbances such as vegetation cover loss and soil exposure, tree damage, and evidence of previous use such as litter, human waste, and tent rocks are variables assessed in these multiple parameter systems. How these measurements are taken determines the level of precision the monitoring protocol can obtain. For instance, campsite area measurements captured with Marion's (1995) radial transect protocol requires the perimeter of the campsite to be marked with flags. A technician then stands in the center of the campsite and records the azimuth (i.e. compass bearing from magnetic north) and the distance from the center to each established boundary flag with a high-accuracy GPS unit. This process allows for the determination of parameter points that can be georeferenced and plotted as polygons in geographic information system (GIS) applications after collecting the data. Simpler campsite area measurement techniques define a geometric shape to the campsite and an estimated area ($25m^2$, $50m^2$, or $100m^2$). While faster and still accurate, there is a loss of precision with these types of methods; however, this might be acceptable to PPA managers depending on their objectives with the monitoring study. Other indicator variables such as soil exposure, vegetation cover, and tree damage can be visually estimated and categorized. Tent rocks, trash, trails, and human waste can be counted and used as continuous variables. Condition class rating systems are another measured variable often used in rapid assessments to classify the environmental integrity of a site. The system provides a series of categories based on specific descriptions and delivers an overall assessment of the impacts rather than the individual variable measurements. Frissell (1978) suggests a five-class rating system based on ground cover disturbances (i.e. vegetation cover and soil exposure), tree damage, and root exposure. While helpful as an addition to a multiple parameter system, condition class ratings do not typically stand alone. Sometimes campsites have a particular condition class rating for one variable but a different rating for other variables, making one condition class rating hard to discern.

Many monitoring protocols take an extensive amount of time to complete, especially when there are multiple sites to assess. Advanced technologies have opened up monitoring capabilities without the need for intensive field sampling. Remoting sensing and GIS techniques have made it possible to analyze changing ecological conditions and predict future areas of concern (Tomczyk et al., 2013; Tomczyk et al., 2017). These advancements can be costly, especially if it is necessary to collect the data using drones or low-altitude flights, but they can cover a greater percentage of the landscape in a shorter time than field technicians. In certain areas, the US Geological Survey provides open source ecological data that can be assessed and utilized by researchers. Whichever monitoring technique is utilized, these protocols provide managers the data necessary to determine the best applicable visitor management strategy to deliver quality visitor experiences and protect the natural resource.

Thesis Purpose

This thesis combines survey methods and *in situ* observation in Glacier Bay National Park and Preserve (GLBA) with environmental impact assessments of campsites in Kenai Fjords National Park (KEFJ) to provide a unique regional analysis of adaptive management planning frameworks in coastal Alaskan National Parks. Surveys conducted in the summer of 2018 provided the data necessary to establish thresholds of acceptability on crowding and coastal resource conditions of campsites. This research is the first attempt at using tent rocks as both an indicator of natural resource manipulation and evidence of previous use. By determining visitor thresholds of both natural resource conditions and social variables this research aims to optimize the use of variables as indicators within a formal theory. Respondents also described elements of their trip that were a disruption to their wilderness experience. Visitors reported negative perceptions of cruise ship encounters and provided evidence for a new indicator to evaluate. Using the best available data, *in situ* observations were used to compare to the desired conditions. Novel geographic information system (GIS) analyses were conducted to deduce spatial and visibility patterns of campsites where preferred conditions were not met in a quantitative manner. This comparison informs management on whether or not adaptive management strategies should be applied if conditions are less than preferred.

The application of a longitudinal monitoring protocol in KEFJ helps determine the proficiency of the management strategies in place to minimize the environmental impacts of recreational use. The data allowed for an investigation of campsite changes and an exploration of the effectiveness, efficiency, and sensitivity of the current monitoring protocol. By uncovering areas of environmental concern, managers can adapt their management strategies to better protect and restore the environmental integrity of those areas.

Integrating visitor-established thresholds of acceptability with campsite monitoring data informs management objectives on visitor experience and natural resource conditions. While understanding campsite resource conditions is important in the field, exploring how visitors might perceive the current conditions provides objective information that management can use to determine the best course of action. Consistent monitoring then determines the effectiveness of the chosen management strategy and may uncover unexpected issues that occur with changes in use. This study aims to describe and explore the nuances of visitor crowding and coastal resource condition perceptions while investigating environmental changes of campsites due to human use in remote coastal Alaskan National Parks. The significance of these findings supports the need for adaptive management planning frameworks in PPAs, informs management strategies, optimizes future monitoring protocols, and adds to current recreation ecology theory.

Research Questions

1. Is Glacier Bay National Park (GLBA) in compliance with the crowding and coastal campsite resource condition thresholds based on visitor preferences?

2. What proportion of campsites in GLBA have a cruise ship within its viewshed?

2.a Is it possible to produce a threshold based on backcountry visitors' preferences for the amount of cruise ships seen?

3. What is the magnitude of change of the sampled variables over time in camping locations in Kenai Fjords National Park (KEFJ)?

4. How can the monitoring protocol be optimized to reduce indicator redundancy, site observation intervals, and be more efficient in the field?

Thesis Organization

To complete my objectives, this thesis includes three subsequent chapters. The first chapter being this introduction followed by two manuscript style chapters and finally a conclusion. Chapter two is focused on establishing crowding and resource condition thresholds, as well as situational detractions from the visitors' experience in GLBA as evidenced from a survey conducted in the summer of 2018. This chapter provides insight on those thresholds, an observational analysis on existing conditions, and the visual extent of cruise ships at campsites throughout the park.

Chapter three examines a five-year longitudinal monitoring data set from KEFJ. Data collected from 2008 to 2012 observe campsite ecological conditions by reporting variables such as campsite area, vegetation cover loss, social trails, tree damage, etc. This analysis examines patterns of change in campsites and variables and offers a suggested optimized monitoring protocol for the park to utilize in the future.

Finally, the fourth and last chapter is a conclusion of the results tying the two parks together for a regional analysis detailing recreational impacts and implications for the quality of visitor experiences in unconfined recreation settings which is critical for sustainable coastal park management.

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CHAPTER 2

SOCIAL, ECOLOGICAL, AND EXPERIENTIAL THRESHOLDS IN COASTAL WILDERNESS: AN APPLICATION OF NORMATIVE AND VISIBILITY ANALYSIS IN GLACIER BAY NATIONAL PARK, ALASKA USA.

Abstract

Park and protected area (PPA) managers are tasked with balancing recreational opportunities against preserving the ecological integrity of the lands they protect. Managerial adaptive management frameworks often suggest determining desired conditions and setting thresholds to compare to existing conditions. To maintain quality visitor experiences and natural resources in Glacier Bay National Park and Preserve (GLBA), social and ecological thresholds were determined by backcountry visitors using social science survey techniques and normative theory. Experiential disruptions from the visitors' wilderness experience were also established and analyzed from data collected in a summer 2018 survey. Our research examines how well GLBA meets the visitor-established crowding and coastal resource condition thresholds using *in situ* observations and analyzes the relative visibility of cruise ships from visitor campsites that were considered a detraction to visitors' experience. Using group size as an indicator for crowding and tent rocks as an indicator for coastal resource manipulation, visitors responded that a group size with more than 6 individuals and 8 or more tent rocks at a campsite were less preferred conditions. In our observations, GLBA met the group size threshold in 93% of visitor groups in 2018, however, 49% of campsites had more than 8 tent rocks in the most recent site assessment conducted in 2012. With varying levels of visibility, cruise ships can be observed from two-thirds of the campsites in the park. This

research provides evidence indicating the necessity of coastal PPA managers to offer different areas of use to support different recreation types and varying visitor motivations and expectations.

Keywords: Acceptability Thresholds, Visibility Analysis, GPS tracking, Normative Theory

Management Implications

- To avoid perceived crowding, smaller group sizes are the most desired. Group sizes of six individuals are the minimum preferred condition in GLBA.
- Visitors should be reminded to redistribute any rocks used to tie down tents or create fire rings to preserve resource conditions and an atmosphere of solitude for the next visitor.
- Maintaining zones of motorized and nonmotorized use can provide optimal recreation opportunities for visitors who want to avoid crowding and cruise ships.

Introduction

Coastal wilderness areas provide opportunities for solitude, connection to nature, recreation experiences such as open water kayaking or swimming, and marine wildlife viewings not attainable in other protected areas. More specifically, coastal Alaskan wilderness areas provide remote scenic landscape views such as glaciers, wildlife encounters, and cultural learning opportunities that are globally rare. Coastal Alaska also includes some of the most at-risk ecosystems due to climate change and human impacts.

Much of Alaska's landscapes are products of the Little Ice Age. With ice field capacities reaching their peak around 1750 massive deglaciation events have followed during the past several hundred years (Connor et al., 2009). In Glacier Bay National Park & Preserve (GLBA) 120km of ice has retreated in the past 160 years (Mann and Streveler, 2008). These rapid glacial recessions as well as more convenient travel opportunities has brought an increased number of visitors to Alaskan park and protected areas (PPAs) to witness these atypical landscapes.

PPA managers have been tasked with providing outstanding visitor experiences while preserving the integrity of the natural resource they protect. This requires a management framework that establishes desired conditions and compares them to existing conditions through consistent monitoring. While visitor research in PPAs typically focuses on either the visitor experience or the ecological implications of visitors in these areas, management decisions and strategies must be informed by both. To establish thresholds for a quality visitor experience, managers look towards indicator-based planning methods and management frameworks to control for resource and social impacts in their parks and protected areas. Such frameworks include Visitor Impact Management (VIM) (Graefe et al., 1990), Visitor Experience and Resource Protection (VERP) (National Park Service, 1997), Limits of Acceptable Change (LAC) System for Wilderness Planning (Stankey et al., 1985), and Thresholds of Acceptability (Laven et al., 2005). When levels of acceptable change are established using visual methods and are applied to biophysical observations, park management can determine if a) a problem exists and b) what actions to take to minimize undesirable change (D'Antonio et al., 2013; Goonan et al., 2012; Newman et al., 2005). Normative theory (Manning et al., 1999) provides the basis to create these methods used for management planning.

Stemming from the field of social psychology, normative theory is a framework to apply and develop thresholds (formerly "standards") to many facets of daily life (Manning et al., 1999). This theory provides guidance for how people should make decisions based on group and/or societal judgments, creating normative rules. Normative rules then provide a threshold to compare to people's actual behavior (Hickson et al., 2014). These thresholds describe human response to a situation using measurable indicators of quality. When used in recreation research, indicator of quality variables must be measurable and manageable to replicate the quality of the natural resources and visitor experience. To interpret the results, thresholds of quality then define the minimum acceptable condition of the indicators of quality variables (Manning et al., 1999; Manning, 2011). Finally, if the defined thresholds are violated, the carrying capacity of that indicator has been reached. Common indicators in park management include counting visitors to measure crowding (Manning et al., 1999; Cribbs et al., 2019; Bell et al., 2011), social trails and vegetation loss to measure resource impact (D'Antonio et al., 2013), or animals with varying distances from humans to observe visitor perceptions of safe human-wildlife interactions (Miller et al., 2018; Cerri et al., 2019). These normative judgements of indicator conditions produce thresholds of acceptability that often lead to administrative changes to management, public policy, and legislative changes if accepted by a resounding portion of visitors (Manning et al., 2010; Manning, 2007).

Our study was informed by a post-experience survey given to non-motorized independent backcountry visitors (i.e. kayakers) to understand their experience and determine their preferred conditions for social and ecological variables in GLBA (Furr et al., in press). Deciding which indicators to use in the survey came down to situations visitors might be sensitive to, tangible variables that management can control, and conditions with obvious signs of human use and impact (Hammitt et al., 2015). In a previous study, Manning et al. (1996) established a capacity limit for cruise ships, tour vessels, and private boats. GLBA was interested in determining if a cap should be instated on nonmotorized vessels (i.e. kayaks) as well to reduce crowding and maintain the remote backcountry experience visitors want. Current policies limit backcountry group sizes to no more than 12 individuals to limit overcrowding and potentially disturbing other visitors' experiences. For these reasons, the number of people in a backcountry group was chosen as the social indicator to determine crowding thresholds. Vegetation loss is a highly used and effective ecological indicator to convey human impacts on resources conditions (D'Antonio et al., 2013; Goonan et al., 2012). Multiple studies have examined the long-term impacts of human use on campsites in coastal Alaskan Wilderness by examining vegetation cover loss (e.g. Twardock et al., 2010; Monz et al., 2010). While it does serve as an effective indicator in some places, it was not entirely appropriate in this location. Determining impacts as being human caused is more difficult here due to intense winter storms and a semidiurnal tidal swing of up to 7.6 meters. Tent rocks and fire rings are recognizable indicators of previous human use and manipulation of the environment and were chosen to represent coastal resource conditions.

To understand more about the backcountry visitor experience, the survey provided a multi-response question prompting visitors to report if they saw: cruise ships, kayaks, tents on the beach, or other evidence of anthropogenic use and how many they saw during their trip. If they saw one of the variables listed, they were asked to rate how much it bothered them and how that encounter affected the quality of their wilderness experience. Cruise ships were the most bothersome and detracted the most from visitors' wilderness experiences out of all of the variables (Furr et al., in press). In an open-ended question, visitors were asked to denote what detracted most from their trip. Again, cruise ships were noted, un-prompted, as the greatest detractor from the independent backcountry visitors' experience (22.61%). Due to visitor responses to these questions as well as the sizeable income cruise ships provide to the park, we were interested in how many visitors can encounter a cruise ship from their chosen campsite.

With a UNESCO Marine World Heritage designation, half million visitors per year, and an extensive history of visitor experience and ecological monitoring, GLBA made an ideal study site (Manning et al., 1996; Lewis et al., 2007; Goonan et al., 2015). This research focuses on visitor responses to establish thresholds of acceptability regarding crowding and coastal resource conditions as well as situations that detracted from the visitors' wilderness experience. We established these thresholds and compared them to existing conditions while determining the extent of cruise ships visual impact to backcountry visitors on campsites. This site level analysis provides an indicator to the park as to how many campsites violate the established thresholds and determine whether or not this is an issue and for the park to intervene.

Methods

Study Site

Spanning 3.3 million acres in Alaska's southeastern panhandle, GLBA features 8 tidewater glaciers and the Fairweather mountain range with coastal peaks exceeding 10,000 feet. Over 80% of the park, 2.7 million acres, is designated Wilderness with 13% of the waters designated as Marine Wilderness with no motorized boat use in these areas. The park serves as a marine wildlife sanctuary to protect whales, seals, and stellar sea lions. Since 1979, GLBA has been classified as a UNESCO Marine World Heritage (MWH) site, formally naming the park as one of the world's most outstanding natural marine and cultural sites. In a survey conducted by Cerveny et al. (2020), sampling 45 MWH sites, GLBA was 1 of 14 that allows large (1500 – 3499 passengers) and mega-sized (3500+ passengers) cruise ships into the protected area. While there are currently no established criteria or guidelines for cruise ships to travel to these areas sustainably, GLBA has set a standard for them to enter the park safely since the 1970s. The park requires ships to adhere to strict emissions testing, vessel speeds, maintaining distance from wildlife, and no ballast water removal in the sanctuary (Genede et al., 2016). Marine sanctuary managers look to GLBA as an example of how to structure their own management practices. This notion, combined with receiving over half a million visitors per year (National Park Service, 2019), makes the park a unique area for visitor observation and a prime place to study cruise ship encounters with backcountry visitors, who make up one percent of the annual visitors.

Sample Population

There are multiple ways to experience the upper bay of GLBA. We surveyed 822 visitors in the 2018 summer season. Of those surveyed visitors (84.91%) experienced GLBA in a motorized manor either utilizing the park's concessionaire day boat (N=495), a private chartered vessel (N=5), or a tour vessel (N=198). Cruise ship passengers were not surveyed due to feasibility reasons. The focus of this research was informed by the 124 (15.09%) non-motorized independent backcountry visitor responses (Furr et al., in press). Independent backcountry visitors were those that recreated in GLBA wilderness, including kayakers and backpackers. They were the only sample population to stay overnight on land in the backcountry. To tour the upper reaches of the bay, they must travel via personal non-motorized vessels, or ride the day boat to be dropped off at one of two designated locations available each day during the on-season (Sebree, Scidmore, Mt. Wright, Sundew, or Ptarmigan). Sea kayakers either departed from Bartlett Cove, or boarded the day boat to be dropped off with their kayak and gear at one of the designated locations (Figure 1).

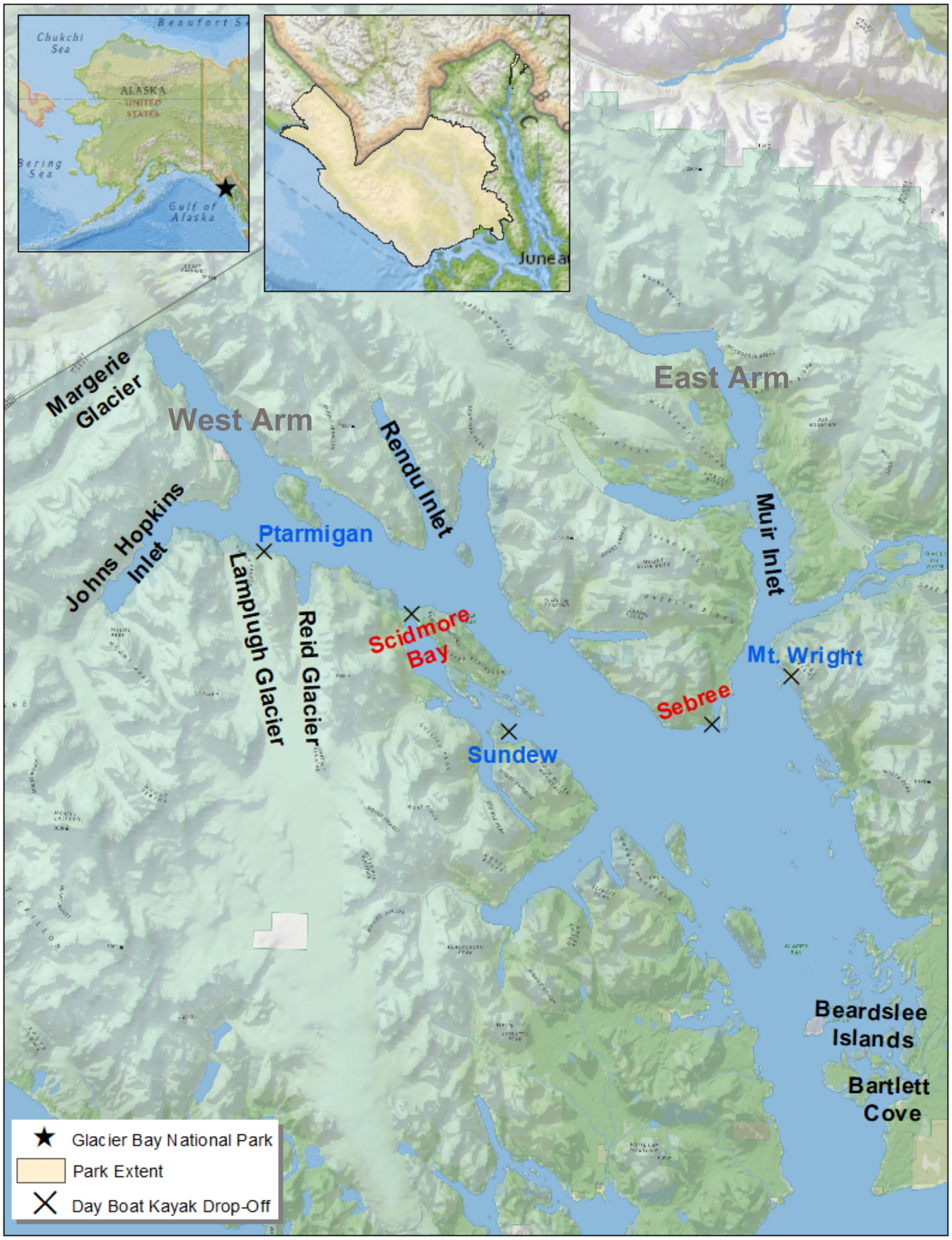


Figure 1. Map of day boat kayaker drop-off and pick-up locations. Scidmore and Sebree were the drop-off locations from May 26, 2018 to July 15, 2018. Sundew, and Mt. Wright were the drop-off locations from July 16, 2018 to September 3, 2018 with Ptarmigan replacing Sundew on Sundays.

Thresholds of Acceptability

We used two methods to determine social and ecological thresholds. First, using an experience-based approach, we asked visitors about specific conditions they encountered during their visit to GLBA. Conditions included encountering other groups, cruise ships and motorized vessels, and anthropogenic ecological impacts. This was followed by a series of questions asking how those conditions affected the visitor's experience. Second, following well-established theoretical methods (Bell et al., 2011, p. 503; Manning, 2007) we used a visual simulation approach to determine visitor thresholds for potential crowding and coastal resource condition variables.

Respondents examined images modified to represent hypothetical situations at a location similar to what could be GLBA, with varying levels of impact. Varying amounts of tandem kayaks and tents on a beach served as indicators to establish crowding thresholds (Figure 2). Each tent and kayak pair represented a pair of people. The image with 0 tents and 0 kayaks represented our control, or no group present. The image with 20 objects, namely 10 tents and 10 kayaks, represented a group of 20 individuals. Tent rocks and the presence of a fire ring were the indicators depicting resource impacts or evidence of previous use. While various stages of vegetation loss have proven to be reliable depictions of resource impacts (D'Antonio et al., 2013, Goonan et al., 2012, Price et al., 2018), this type of ecological change would not serve as an impartial visitor-caused impact in GLBA with frequent winter storms acting as a natural disturbance agent. A tent rock is a moveable rock that visitors use to tie down a tent or tarp in windy conditions. If they are not dispersed after use, they are often considered a visitor disturbance (Goonan et al., 2015). They provide highly visible evidence of resource disturbance and can be somewhat easily modified by management. The inclusion of a fire ring in one of the images exaggerates the evidence of human manipulation of the environment and provides a more visible, but realistic, indication of previous use (Figure 2).

The computer-edited photo series were presented in a random order. Each participant was asked to rate each photograph on a seven-point scale from -3 (very unacceptable) to 3 (very acceptable) in accordance with procedures describe by Manning et al. (1999). The mean acceptance ratings were then plotted in a norm curve to understand the preferred and minimum acceptable conditions and crystallization (i.e. agreement). The point-slope line equation determined minimum preferred condition. Vaske's Potential for Conflict Index (PCI) equation (corrected from Manfredo et al., 2003) was used to measure respondent agreement for each level of impact (Vaske et al., 2006). PCI results range from zero to one. Zero indicates complete agreement among all responses. One indicates complete disagreement among all responses. Respondents completed the survey on paper and responses were then transcribed in the online survey forum, Qualtrics. SPSS and R were used to summarize and conduct statistical analyses (v.25, SPSS, Inc. Chicago, IL; v.1.1.456, R Foundation for Statistical Computing, Vienna, Austria).


Photo 1a (0)


Photo 2a (4)


Photo 3a (8)


Photo 4a (12)


Photo 5a (20)


Photo 1b (0)


Photo 2b (5)


Photo 3b (10)


Photo 4b (15)


Photo 5b (20)

Figure 2. Photo set A is a simulation of crowding. Photo set B is a simulation of coastal ecological conditions. Values in parenthesis are counts of the manipulated variable.

Because cruise ships were noted in an open-ended question as detracting from the backcountry experience (Furr et al., in press), we devised a method to determine a cruise ship visibility threshold the average backcountry visitor would find acceptable to see during their visit. If a visitor saw or heard a cruise ship during their trip, they were asked to report how many and rate on a scale from 1 (not at all) to 5 (extremely) how much it bothered them. We plotted the average number of cruise ships seen for each level of bother category to determine if there was a pattern in the number of cruise ships seen to the level of bother for the backcountry visitor. A separate question allowed for a positive effect in seeing cruise ships in the backcountry. Visitors were asked how the number of cruise ships seen affected the quality of their wilderness experience. On a Likert scale, visitors responded from -2 (detracted greatly) to 2 (added greatly). These results were also plotted as the average number of cruise ships seen for each effect on backcountry experience category.

To reduce the variance and decipher a threshold value of the number of cruise ships visitors would accept seeing during their trip, the same statistics were completed using survey responses from visitors staying in the backcountry for the determined average length of time. In 2018, the range of stay in the backcountry was between 1 and 28 days. Because the length of stay in the backcountry varied considerably among visitors, it was important to understand how the visitors with an average length of stay responded to the level of bother question. With two cruise ships permitted in Glacier Bay daily, the length of the trip affects how many cruise ships you will see. For example, the visitor traveling for 28 days, has the potential of seeing 56 cruise ships throughout their trip, while visitors there for 3 days, may see up to 6. The average length of stay for all visitors surveyed was 5 days. To control for potential variation in responses due to the length of stay, visitor surveys between the first quartile (3 days) and third quartile (7 days) were used for this analysis (N = 68).

Observational Data Analysis

Visitors reported their group size, where they camped, and if they used the concessionaire "Day Boat" service when they returned from their backcountry trip to GLBA park officials. This information was used to spatially identify *in situ* observations exceeding the defined thresholds to determine if there was a pattern in where larger groups camped. A group was considered large if it exceeded the crowding minimum acceptable condition. Additionally, proportions of group size were calculated by dividing group size occurrence, for each group size level (i.e. the number of people in a group), by the total number of groups (N=229). We compared these patterns of use by large groups to ecological data collected by Goonan et al. (2015). In an initiative to monitor campsite ecological integrity, Goonan et al. (2015) recorded tent rocks counts as an indicator of previous use. To determine if there was a spatial relationship between the two thresholds, we plotted campsites that were used by groups with more people and more undispersed tent rocks than the minimum acceptable amount.

The campsite location data was reviewed to determine the relative visibility of a cruise ship from each campsite. In ArcMap (ESRI 2018. ArcMap: Release 10.6. Redlands, CA: Environmental Systems Research Institute), an averaged cruise ship path was created using a total of 67 cruise ship tracks obtained by NPS personnel (Genede, 2018). Establishing areas of high density use from these tracks in a kernel density plot provided an overall route that cruise ships followed. IfSAR Digital Surface Models (DSM) layers from the USGS National Map were imported into the map as a raster layer. These topographic layers were chosen because they show geological elevation and incorporate the height of vegetation. We used the Visibility tool in ArcMap to account for the height of the observer and the height of what is being observed while including topographic variables that can impede visibility (Stamberger et al., 2018; Wing et al., 2001). We included the average height of the cruise ships permitted into the park and the average height of a backcountry visitor determined by the Furr et al. (in press) study. In ArcMap, the frequency analysis outputs how many pixel cell centers can be seen from the observer. Our observer was the cruise ship, but the results are the same for the inverse. Meaning, the relative visibility of the cruise ship to the campsite is the same for the campsite to the cruise ship. The sum of the amount of times an area is seen from that path results in that area's visibility level. Output values were reclassified to include 5 designations of visibility level: no visibility, lowest, low, moderate, high, and highest.

To account for the proportional size of how large the cruise ship appeared based on the distance the visitor could see the cruise ship, we calculated the cruise ship's angular size (or apparent size) from each campsite. Angular size measurements are often used in the field of astronomy to measure the size of cosmic objects (Freedman et al., 2010 pg. 7-9). We measured the closest distance from the cruise ship to each campsite with relative visibility rating above "no visibility" to determine the cruise ship's greatest apparent size from each campsite. In knowing the distance from cruise ship to campsite and the height of the cruise ship we worked with the tangent angle (opposite side/adjacent side) to determine the angular size in degrees of the cruise ship (Figure 3). Cruise ship angular size was calculated for each campsite using the small angle formula:

Angular Size in Degrees = 2*arctan(Height of Cruise Ship/(2*Distance from Campsite to Cruise Ship))

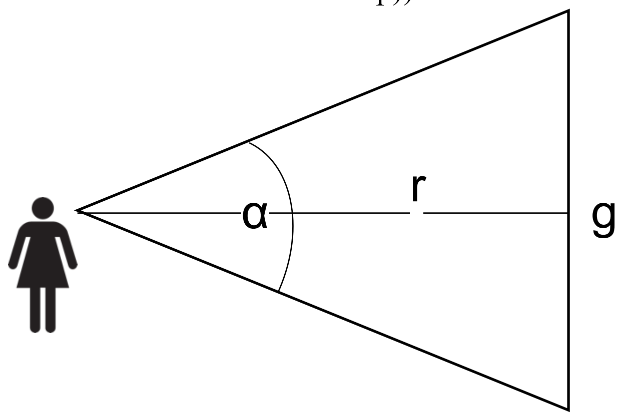


Figure 3. Angular size visualization. A visitor is a distance from the cruise ship (r) and the cruise ship is a set height of 58.8m (g). The small angle formula solves for α.

An angular size of 1° is equivalent to the width of your little finger held at arm's length. A 10° angular size is equivalent to the width of your palm held out at arm's length (Freedman et al., 2010 pg. 8; Kher, *A Handy Guide to Measuring the Sky*).

Results

Thresholds of Acceptability

Of the 124 surveyed backcountry visitors, 114 provided responses to the normative threshold visual simulation questions. Using tents and kayaks to depict the number of people in a group, the norm curve determined the minimum acceptable condition to be 6.2 individuals or 3 tents and 3 kayaks. A group size larger than 6 would be considered less preferred (Figure 4). The PCI results ranged from 0.04 (much agreement) to 0.36 (agreement), suggesting respondents were predominately in agreement regarding crowding conditions. There was a high level of agreement on unacceptable conditions. A total of 93% of the backcountry visitor groups had six or less people in their group (Table 1).

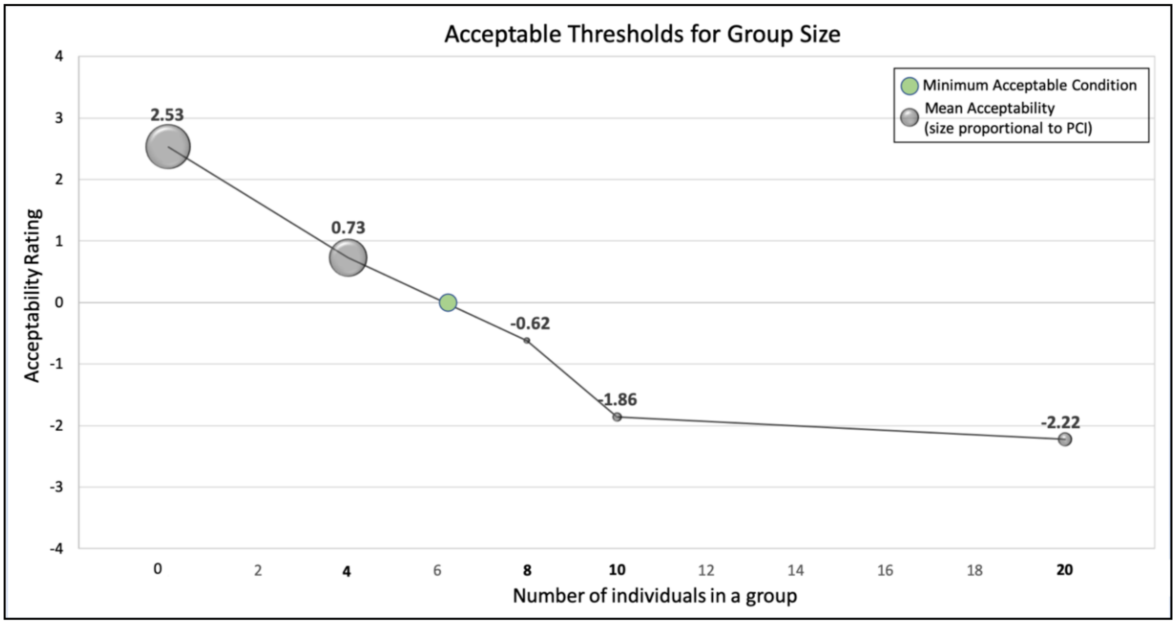


Figure 4. Social norm curve for the number of tents and kayaks on a beach in GLBA. The minimum acceptable condition is 6 tents and kayaks. Larger bubbles indicate less agreement. Smaller bubbles indicate more agreement. Respondent agreement is based on PCI score.

Table 1. Group sizes of backcountry visitors in 2018.

Number of People in Group	Group Size Occurrence	Proportion of Group Size in 2018
27*	1	0.44
12	5	2.18
11	1	0.44
10	3	1.31
9	1	0.44
8	2	0.87
7	4	1.75
6	10	4.37
5	16	6.99
4	23	10.04
3	34	14.85
2	94	41.05
1	35	15.28

N = 229 backcountry groups in the 2018 season.
*A local school group that received special permission.

Results for the resource impact indictor of tent rocks present are illustrated in the norm curve which suggests a minimum acceptable condition of 8 tent rocks, with the assumption of no fire ring. More than 8 tent rocks at a campsite would be considered less preferred (Figure 5). With PCI results ranging from 0.11 (agreement) to 0.55 (some disagreement), respondents agreed more than they disagreed regarding coastal resource condition thresholds, but there were mixed responses. In the 2012 campsite monitoring study, 130 campsites out of 266 sampled (49%), had more than 8 tent rocks. A total of 8 of the 130 campsites also had a fire ring.

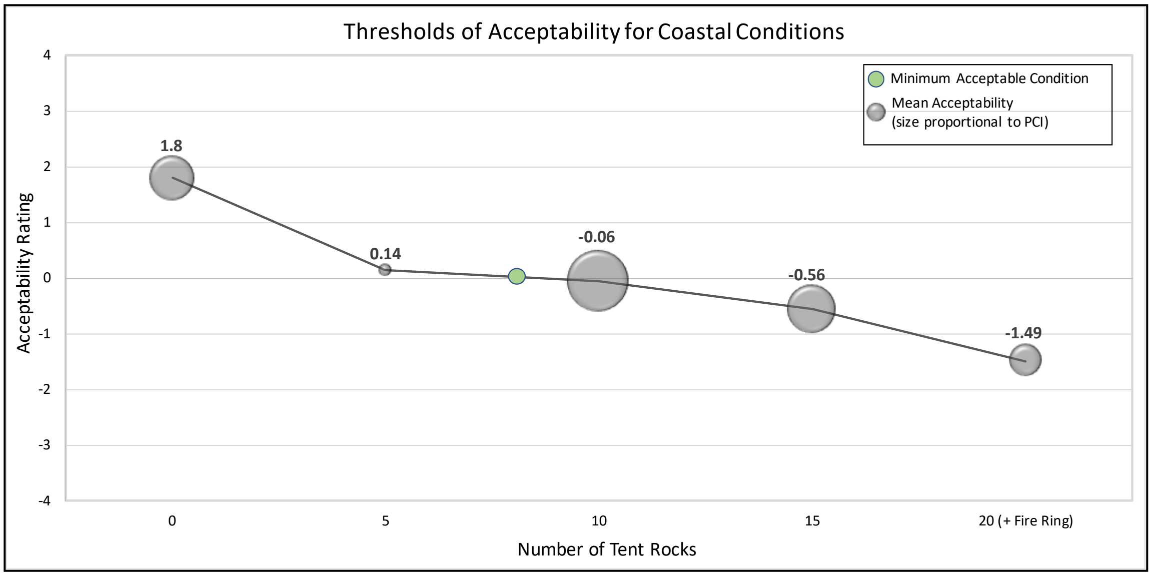


Figure 5. Coastal resource conditions norm curve for coastal resource conditions in GLBA. The minimum acceptable condition is 8 tent rocks. Larger bubbles indicate less agreement. Smaller bubbles indicate more agreement. Respondent agreement is based on PCI scores.

Figure 6 highlights known campsites that exceed the visitor-determined minimum acceptable conditions for group sizes and tent rock counts. There is overlap on the northern end of Scidmore Bay, Margerie, Johns Hopkins, Lamplugh, and Reid glaciers. These are notable kayaker drop-off/pick-up locations and scenic points of interest.

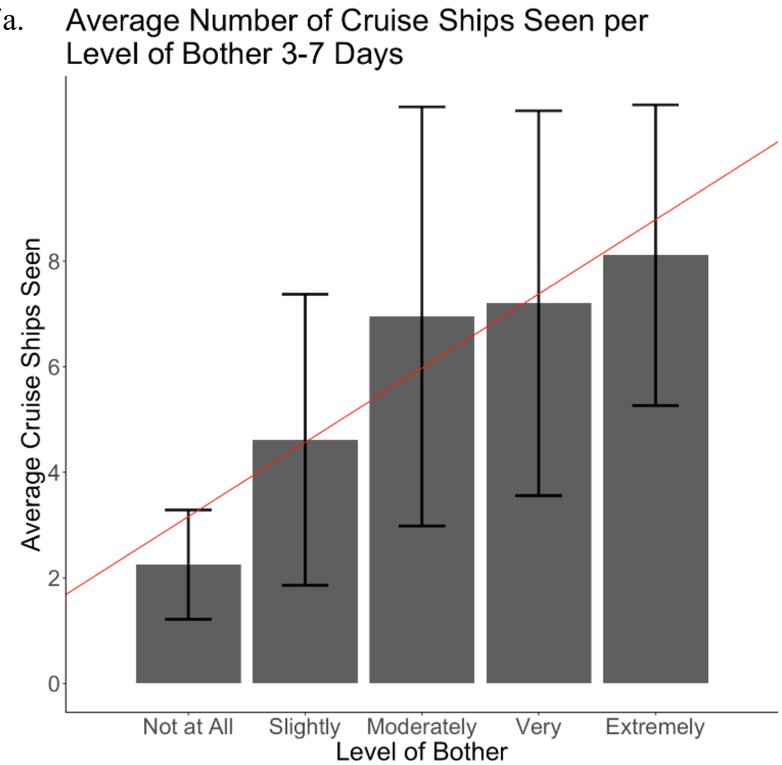
Figure 6. Campsites that exceed the visitor determined minimum acceptable condition for group size and tent rock counts. Red campsites exceed the minimum acceptable condition for the number of people in a group (6 individuals). Blue campsites exceed the number of tent rocks at a site (8 tent rocks).

Cruise Ship Thresholds

All (N = 124) backcountry visitors saw an average of 6.58 cruise ships during the span of their trip. When asked how much the sight of cruise ships bothered them, respondents reported a mean level of bother of 2.70, placing them between slightly and moderately bothered. A total of 66% of respondents (N = 68) who fully completed this question were in the backcountry for the average length of time, 3 to 7 days. On average, visitors were moderately bothered by the sight of cruise ships (mean = 2.98) and saw 6 cruise ships (mean = 6.14) during their backcountry experience. The data indicates a positive linear relationship between the level of bother and the average number of cruise ships seen. As a visitor encountered more cruise ships, they grew increasingly more bothered by them (Table 2). Regression analyses determined that there was a significant effect of the level of bother on the number of cruise ships seen ($p < 0.001$) and an Adjusted R^2 of 0.22 (Figure 7a).

In response to the question "How did the number of cruise ships seen affect the quality of your wilderness experience?" all visitors had a mean response of -1.02 indicating cruise ships somewhat detracted from their wilderness experience (N = 59). Visitors reported a mean level of effect on quality of wilderness at -1.15, placing them between detracted greatly and detracted somewhat. The data indicates a negative linear relationship between the effect on the visitors' wilderness experience and the average number of cruise ships seen. An increase in the number of cruise ships seen increases the negative effect on the quality of wilderness experience for the visitor (Table 3). Regression analyses determined there was a significant effect of effect groups on the number of cruise ships seen ($p < 0.01$) and an Adjusted R^2 of 0.14. (Figure 7b).

7a.



7b.

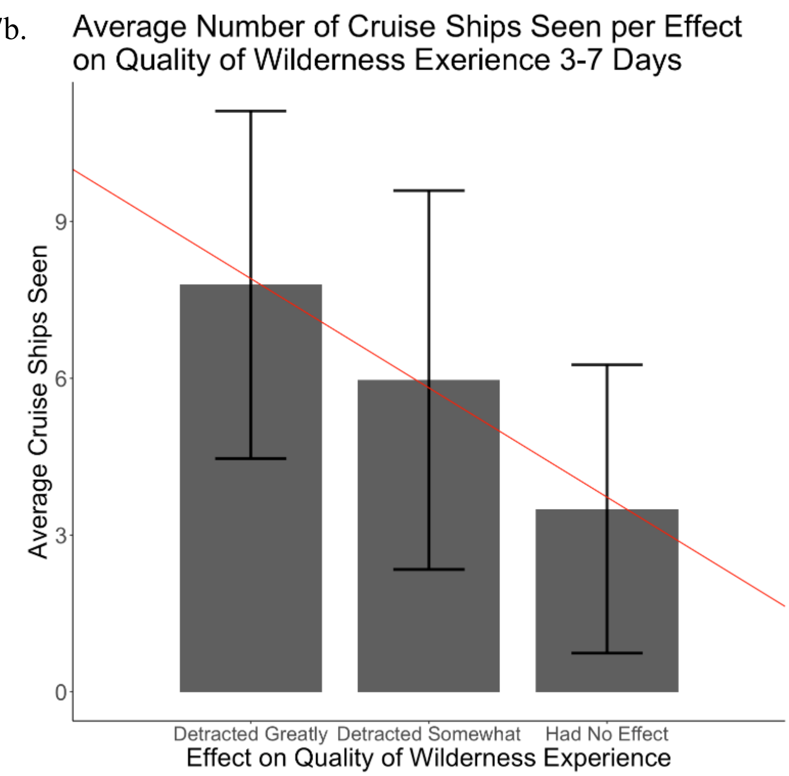


Figure 7. Cruise ship disruption results from visitors staying for the average length of time, 3 to 7 days. a) Average number of cruise ships seen for each level of bother group with standard deviations plotted. Regression line p-value <0.01, Adj. $R^2 = 0.22$ b) Average number of cruise ships seen for each level of effect group with standard deviation plotted. Regression line p-value <0.01, Adj. $R^2 = 0.14$.

Table 2. Level of bother of cruise ships for backcountry visitors.

Level of Bother	Mean Cruise Ships Seen	Standard Deviation	N
All Visitors[1]			
Not at All	3.73	6.02	22
Slightly	4.87	4.43	23
Moderately	7.61	6.73	33
Very	8.79	6.90	14
Extremely	9.18	3.92	11
Visitors staying 3-7 days[2]			
Not at All	2.25	1.04	8
Slightly	4.62	2.75	13
Moderately	7.00	3.97	21
Very	7.20	3.65	10
Extremely	8.11	2.85	9

Includes all complete responses to level of bother question and gave a number of cruise ships seen for visitors staying 3 to 7 days.
[1]N = 103
[2]N = 68

Table 3. Effect of cruise ships on visitors' quality of wilderness experience.

Effect on Quality of Wilderness Experience	Mean Cruise Ships Seen	Standard Deviation	N
All Visitors[1]			
Detracted Greatly	8.00	5.96	28
Detracted Somewhat	6.84	6.23	49
Had No Effect	4.20	6.14	20
Added Somewhat	7.00	7.07	2
Visitors staying 3-7 days[2]			
Detracted Greatly	7.79	3.33	19
Detracted Somewhat	6.00	3.62	30
Had No Effect	3.50	2.76	10

Includes all complete responses to quality of wilderness experience question and gave a number of cruise ships seen.
[1]N = 99
[2]N = 59

Cruise Ship Visibility from Campsites

Out of 876 recorded campsites, 584 allow visitors to see a cruise ship at some point in time during the day (Figure 8, Tables 4 and 5). A total of 292 campsites do not have a cruise ship within their viewshed. These campsites are scattered throughout the bay, but are clustered in inlets of “non-motorized” designation where cruise ships do not go or in the Beardslee Islands where there are a multitude of islands that shield campsites from the outer bay. Visitors at campsites located on the coasts directly facing the outer bay have the cruise ship path in their view for the longest amount of time. Areas of particularly high relative visibility include Rendu Inlet, Sebree, and Ptarmigan Beach.

Campsite distance from the average cruise ship path affects the apparent size of the cruise ship. Cruise ships ranged from 0.12^{o} to 9.74^{o} in apparent size, depending on their distance from a campsite. Intuitively, for campsites closer to the averaged cruise ship path, the cruise ship appeared larger than those campsites further away from the path. This is most obvious for campsites located in the narrow inlets that the cruise ship would travel into (i.e. Johns Hopkins Inlet). Because there are two cruise ships permitted in the bay each day, the length of time in which a cruise ship is visible from a campsite doubles. The first cruise ship of the day enters the park around 6:46am Alaska Daylight Time (AKDT) and leaves at 3:44pm AKDT on average. The second cruise ship typically enters the park at 8:53am AKDT and leaves 6:17pm AKDT. Each cruise ship remains in the park for an average of 9 hours and 10 minutes (Figure 9).

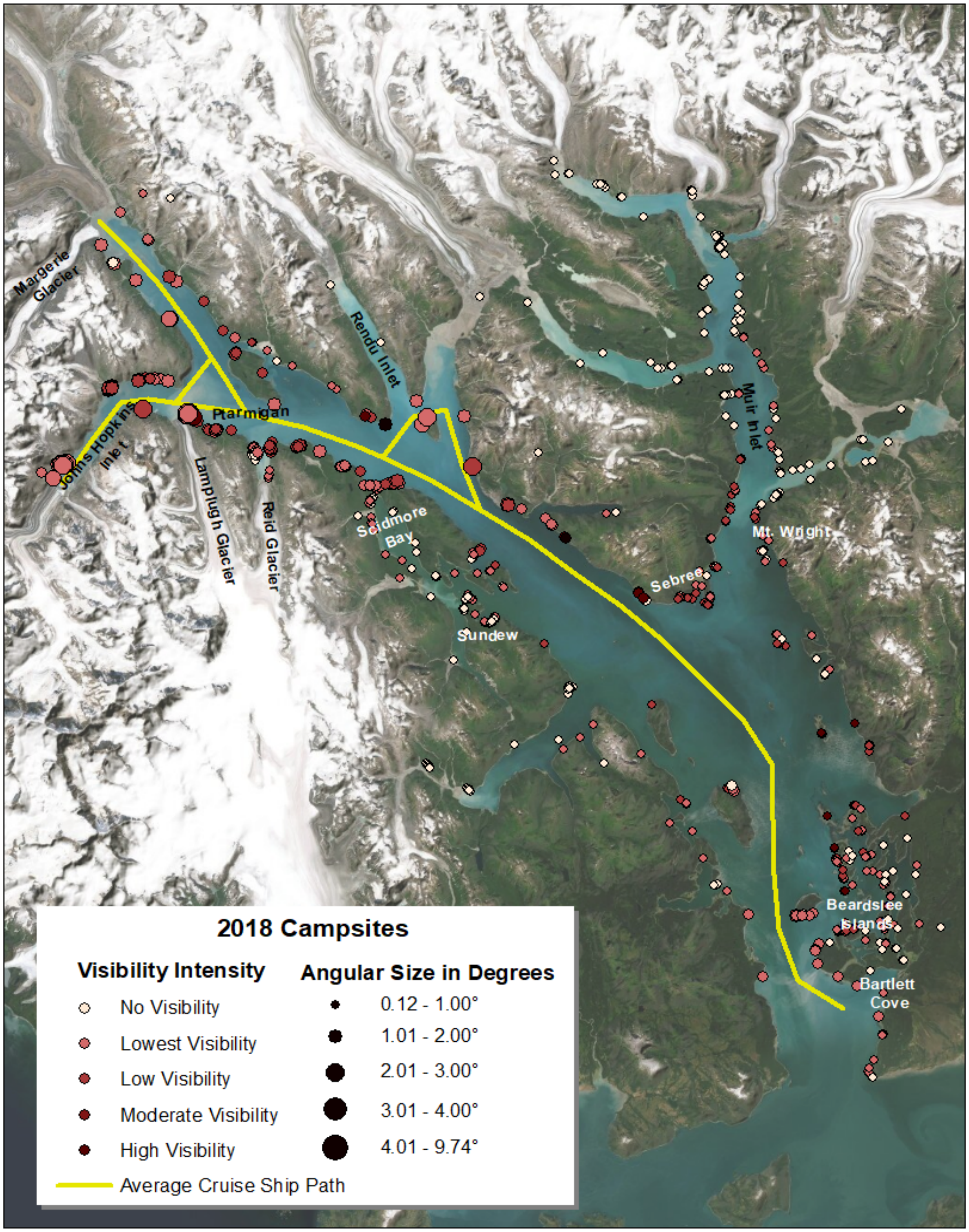


Figure 8. Relative visibility level of the average cruise ship path from campsites. Cruise ships are visible longer for campsites with darker red hues and appear larger to visitors at a campsite with a larger circle.

Table 4. Length of cruise ship relative visibility.

Range of Visibility	Length of Cruise Ship Path Visible[1]	Number of Campsites
No Visibility	0 km	292
Lowest Visibility	13.48 km	352
Low Visibility	41.97 km	206
Moderate Visibility	39.67 km	24
High Visibility	42.01 km	2

N = 876

[1]Values are reported as the total sum of the cruise ship path in each visibility level. Individual campsites see varying portions of their visibility section. Distances are recorded for only one traveling direction.

Table 5. Cruise ship angular size

Cruise Ship Angular Size	Number of Campsites
0.12 – 1.00^{o}	571
1.01 – 2.00^{o}	204
2.01 – 3.00^{o}	54
3.01 – 4.00^{o}	26
4.01 – 9.74^{o}	21

N = 876

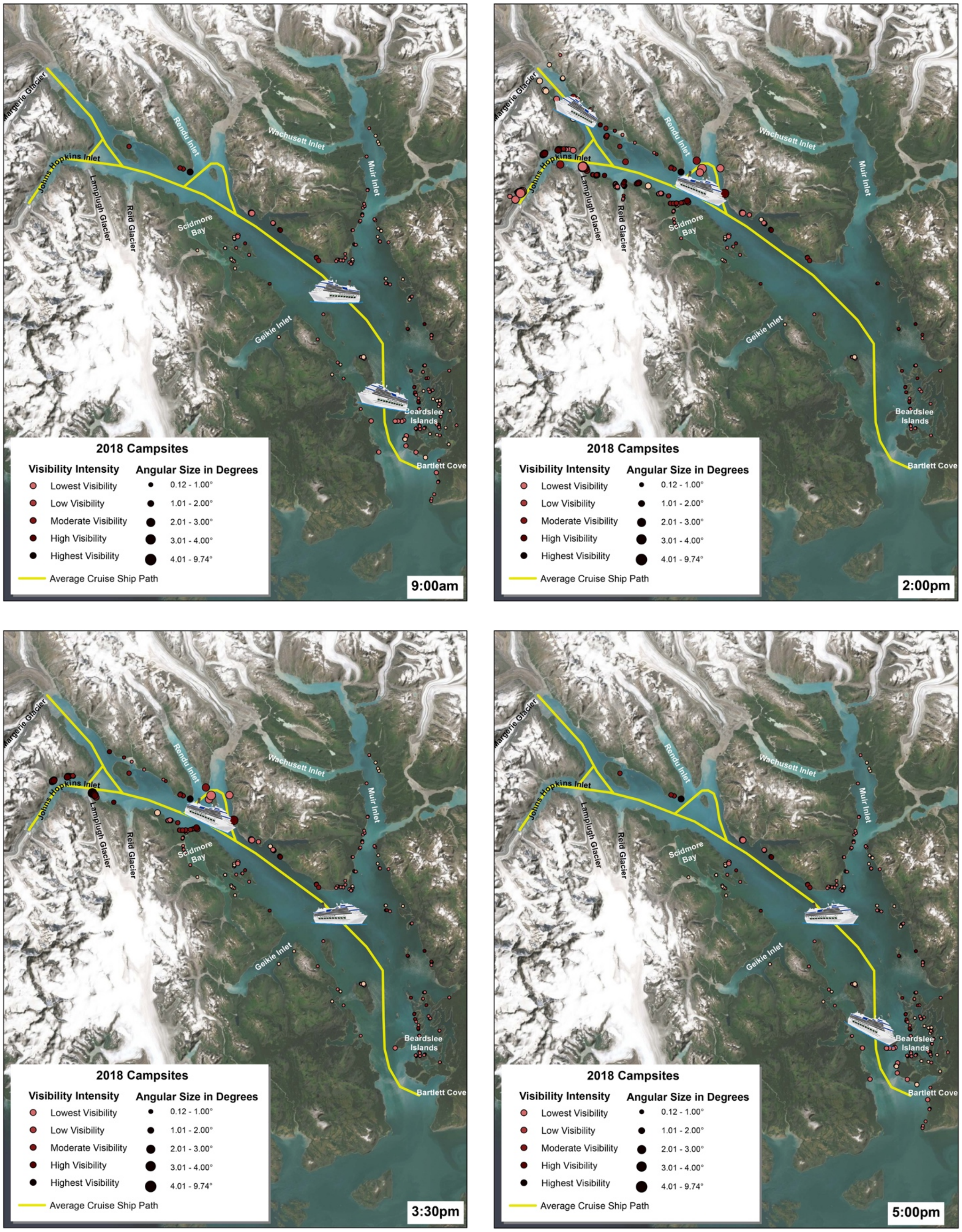


Figure 9. Relative visibility level of cruise ships at four different times of day. Cruise ships are visible longer for campsites with darker red hues and appear larger to visitors at a campsite with a larger circle.

Discussion

Using indicators to define preferred conditions and set acceptability thresholds based on the indicator variables is the first element of a visitor use management framework. Comparing these established thresholds to existing conditions through monitoring practices determines management success. This cyclical process of monitoring existing conditions to compare to desired conditions allows for adaptive management changes or continued long-term maintenance (Hammitt et al., 2015). In our study, the integration of social science surveys, *in situ* observations, and GIS analysis provides context for park management and determines if current management strategies should be altered. We were able to establish normative thresholds for crowding and campsite resource conditions, determine patterns of violated thresholds, and suggest zoning locations based on visitor trip motivations.

Surveyed backcountry visitors reported that six individuals per group as the minimum acceptable condition. Group sizes with more than six individuals was considered less preferred. Our results follow the crowding norm curve as established by Manning et al. (1999) and other crowding norm threshold work (Cribbs et al., 2019; Bell et al., 2011). In the 2018 summer season, of the 229 groups of backcountry visitors to receive a permit from the park, only 7.42% of groups contained more than six individuals (Table 1). This implies that GLBA meets the minimum visitor established social norm thresholds and indicates that the park is doing an adequate job of maintaining smaller group sizes. While there was overwhelming agreement that more than six individuals in a group would be less preferred, respondents disagreed the most on the situation with no tents or kayaks on the beach. This may suggest that some visitors may prefer to see other visitors, perhaps for safety or to know where it is appropriate to camp. Regardless, maintaining smaller group sizes promotes a solitude experience and has added ecological benefits. Marion and Farrell (2002) found that limiting campsite group sizes minimized campsite area thus reducing ecological impacts. Respondents also reported eight tent rocks as the minimum acceptable condition on campsites. Based on the low response agreement from visitors, tent rocks may be more of an issue management is concerned about rather than visitors. However, in our observational studies, nearly half of the sampled campsites had more than 8 tent rocks. To keep the park in compliance with the visitors' preferred conditions, we do suggest that the park be more forthcoming in requesting that visitors disperse these rocks after use. This can be done in the visitor orientation every backcountry visitor goes through as part of the permitting process. Providing low ecological impact education programs have proven successful in the past (Marion and Reid, 2007).

In terms of crowding, all visitor groups dispersed broadly throughout the park. Supporting similar findings from Lewis et al. (2007), there are clusters of campsites in highly sought out regions of the park (i.e. near tidewater glaciers, day boat drop-off locations, suitable kayak landings and campsite areas). When examining patterns of use for groups that exceed the threshold of six individuals, the west arm region of the park, again near the tidewater glaciers and day boat drop-off locations, has more use. The east arm of the park and Beardslee Islands have limited use by these groups in comparison (Figure 6). With the logic of larger groups having more tents and thus require more tent rocks, we did expect to see more spatial overlap in areas where larger groups camped and more tent rocks could be found. However, we could not identify enough of a pattern to determine a correlation between the two conditions. The different locations of less preferred group sizes and tent rock conditions might suggest visitor use intensity may have changed. Perhaps larger groups camped closer to Mt. Wright and Sebree in 2012, which would explain the number of campsites there with more tent rocks. This may have been an effect of where the day boat drop-off locations were that year. In the future, to avoid congested areas, management might suggest that visitors camp on separate beaches from other groups, maintaining a more remote appearance for visitors.

The survey data suggested a new and different experiential indicator to test after respondents reported a high level of disruption from their wilderness experience when they encountered cruise ships. From our experimental attempt of establishing a quantitative cruise ship visibility threshold, we concluded that an increase in cruise ship sightings increases the level of disruption to the visitors' wilderness experience. Because the number of cruise ships permitted into the park is confined to two per day, our results suggest visitors with a longer trip have a lower tolerance for encountering them, at least as their trip continues. Our innovative attempt to spatially operationalize where visitors camp also determined how long and often they see a cruise ship. With two-thirds of campsites having cruise ships within their viewshed, there are regions of the park with no to very limited cruise ship visibility (east arm and non-motorized areas). Campsites that have a higher relative visibility of the cruise ship coincide with the highly sought out regions of the park (west arm). With these results, our models support the creation of recommended backcountry travel paths for visitors who desire a wilderness experience with fewer views of cruise ships and interactions with other visitors. Campsites in the east arm of the bay or beyond the mouth of Rendu inlet, would be ideal for this type of visitor. Routes to these campsites would require more time and flexibility during a trip as they are located further from the day boat drop-off locations.

Finally, the best course of action for GLBA to maintain positive visitor experiences is to maintain their recreation opportunity spectrum (ROS) framework by keeping the motorized and non-motorized zoning. Currently, the east arm and Beardslee Islands are off limits to motorized crafts for extended portions of the year, with cruise ships never accessing these areas. A ROS framework provides opportunities for a larger variety of recreationalists to participate in different activities in different settings and have their desired experience within the same protected area (Hammitt et al., 2015). Within GLBA's established non-motorized zones, there are clear patterns of use with less crowding, less undisbursed tent rocks, and limited cruise ship visibility. This zone offers the opportunity for a recreationalist most interested in finding solitude and a connection to nature without anthropogenic disturbances. Our study supports GLBA management decisions as they are with the caveat of promoting different regions of the park to different types of visitors based on their desired conditions. We believe that our findings can be extended to other coastal Alaskan protected areas such as Prince William Sound and Kenai Fjords National Park given the similar visitor demographics (Harpers Ferry Center Interpretive Planning, 2009), ecological systems, and management strategies. The conclusions from this research can also be extended to public land campsites, off of a road system, in temperate coastal rainforests.

Conclusion

GLBA is a unique park, not only for its tidewater glacier viewing opportunities, wilderness experiences, or wildlife encounters but in how the park is managed, funded, traveled to, and visited. While less than one percent of visitors venture out into the open waters of the park, managers strive to maintain a positive visitor experience. Our results suggest that for backcountry visitors, optimal conditions include group sizes with no more than 6 individuals, no more than 8 tent rocks undispersed from campsites, and limited cruise ship encounters. *In situ* observations suggest that current backcountry group sizes are acceptable to most visitors but visitors could be reminded to redistribute rocks used to tie down tents or create fire rings. This will preserve resource conditions and an atmosphere of solitude for the next visitor. While GLBA remains an example of how to provide sustainable cruise tourism, our research informs managers that for backcountry visitors, cruise ships do detract from their experience. Continuing to zone regions of the park where cruise ships and motorized vessels cannot access provides backcountry visitors opportunities for solitude and the connection to nature they seek while in the park. Further research into the soundscape of the park when backcountry visitors encounter motorized vessels or planes overhead would enhance the understanding of the quality of the visitor experience. Additionally, investigating spatial and temporal relationships between visitors and cruise ships could provide open water paddlers an improved experience.

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CHAPTER 3

BACKCOUNTRY CAMPSITE ENVIRONMENTAL CHANGES AND EFFECTIVE MONITORING PRACTICES: A CASE STUDY IN KENAI FJORDS NATIONAL PARK

Abstract

Monitoring the ecological condition of natural resources in parks and protected areas is an effective means of identifying areas of environmental concern and analyzing the effectiveness of management strategies. However, many monitoring programs require sizeable financial, time, and crew investments. This research examines existing backcountry campsites resource conditions over a five-year period in Kenai Fjords National Park, Alaska. Using campsite ecological monitoring techniques, 101 campsites were assessed for area size, vegetation cover loss, condition class assessments, and other ecological indicator variable measurements. We utilized parametric, nonparametric, robust linear regression, and principal component analysis statistical approaches to explore patterns in changing campsite conditions and to determine possible improvements in the efficiency of the current monitoring protocol. Patterns in changing campsites were difficult to discern until examined by park region. Tree damage, mineral soil exposure, and root exposure were indicator variables sensitive to change while campsite area displayed changes in some locations. To streamline the sampling initiative, future monitoring protocols should replace the rapid and complete assessments with one comprehensive protocol that reduces the number of indicator variables to include: rapid campsite area measurements, tree damage, vegetation cover loss, tent rock counts, trail

counts, condition class ratings, and ghost tree damage. Campsite assessments should be conducted at a three to five-year sampling interval and revised if large significant changes occur or there is a significant change in the level of visitor use. As parks and protected areas continue to see increases in visitation and overnight use, the potential for recreational impacts increases without the appropriate management strategies. Our conclusions provide evidence to determine suitable management approaches and can be applied to future monitoring protocols to ease the burden of time intensive and expensive sampling.

Introduction

Monitoring natural resource conditions is fundamental to park and protected area (PPA) management (Manning, 2011). Preserving the integrity of natural resources is the responsibility of PPA managers. With increasing demand for outdoor recreation (Machlis et al., 2019), limiting the amount of ecological impact associated with increased visitation rates to recreation sites has grown more challenging. An effective and commonly used practice to evaluate recreational impacts, is to set up longitudinal monitoring programs. These programs assess changes in conditions and determine areas of concern based on the level of anthropogenic impacts. Study areas are commonly confined to popular visitor areas such as trails and campsites (Leung et al., 2000).

Multiple studies have been conducted that suggest some generalizations of campsite effects on the environment (e.g. Twardock et al., 2010; Arredondo et al., 2018; Cole et al., 1992). Cole et al. (1992) discovered that even with increases in campsite size, vegetation cover remained consistent over an 11-year study period in Eagle Cap Wilderness, Oregon. Monz et al. (2010) summarized this phenomenon by explaining that on established sites, changes in areal extent or surface area were more obvious than the changes in the impact intensity. Increases in site numbers (which imply increases in surface area disturbances) over time may be more of a concern for managers than the degradation at the individual site level. This type of impact opens up a popular discussion for managers in terms of planning strategies. More confined “designated camping areas” limit the formation of new sites and allow for more desirable well-maintained sites, which work well in locations with high volumes of visitors (Brame et al., 2011; Leung et al., 1999). Conversely, Cole et al. (2008) found in a study of Grand Canyon National Park that, over 20 years, informal sites were created even under a functioning confinement campsite plan, resulting in an increase in total disturbed area. These results led managers to believe that a more dispersed campsite strategy plan works in areas where visitor campsite demand is low.

Dispersing or concentrating visitors to certain areas are not the only management strategies to reduce the amount of anthropogenic impacts. Hammitt et al. (2011) present type of recreational use, visitor behavior, timing of use, site hardening or shielding, and recreational site location as factors that can be manipulated by managers to reduce ecological impacts. When considering the composition of the recreational site location, vegetation morphology may be a better predictor of the resilience of a location than the amount of use (Cole, 1995a; 1995b; Shrader-Frechette et al., 1995). Numerous studies suggest that in terms of vegetation, the most resilient landscapes are those with rocky surfaces and grasses. Vegetation that is flexible, with rapid growth, and few stems tend to be the most resilient (Monz et al., 2013; Cole, 1995a; 1995b). Given that the ecological composition of the coastal camping locations in our study site are rocky, it is possible that there is little landcover disturbance caused by campers.

Kenai Fjords National Park (KEFJ) is in the unique position of offering experiences with receding tidewater glaciers, endangered wildlife, and backcountry adventures within a three hour drive of Anchorage, Alaska. Given the dispersal of overnight backcountry visitors in KEFJ, our study aims to investigate the potential ecological changes of campsites over a five-year sampling period. Determining the extent of ecological changes due to recreational influences in KEFJ helps managers improve backcountry experiences and may change how visitors are educated on Leave No Trace Principles to minimize damage. Additionally, while long term monitoring practices are vital to understanding the conditions of natural resources and how they might change due to certain management strategies, they are often expensive and time intensive. The original protocol for this project was designed to examine the ecological changes at campsites in KEFJ to a high degree of accuracy and precision. However, data collection often exceeded the time and resource expectations managers prepared for. Therefore, our study objectives were to inform managers of potential areas of concern in the backcountry landscape and how best to assess campsite conditions in the future. By analyzing a five-year dataset of coastal campsite assessments, we addressed the following questions:

1. What is the magnitude of change of the sampled ecological variables over time in camping locations in Kenai Fjords National Park (KEFJ)?
2. How can the monitoring protocol be optimized to reduce indicator redundancy, site observation intervals, and be more efficient in the field?

The implications of our research test the applicability of Leung and Marion's (1999) multiple-indicator monitoring system in a coastal Alaskan setting and are relevant to all campsite monitoring protocols. By investigating the rate and presence of ecological change and comparing the extent of change to each location we have a better understanding of appropriate monitoring intervals for park managers and the relationships between the variables at each campsite. Understanding visitor influence on the environment is integral for park managers to better establish guidelines to reduce the anthropogenic impacts on the environment. This analysis optimizes future monitoring programs by suggesting alternative data collection frequencies and establishing key indicators for observation to reduce cost and staffing needs.

Methods

Study Site

Located in south central coastal Alaska, KEFJ provides a sanctuary for marine and terrestrial wildlife, a productive environment for colorful flora, and a dynamic geological landscape. Spanning 1,685km^2, KEFJ is less remote than other protected areas of Alaska. The Seward visitor center is less than a three hour drive from the city of Anchorage, making it more accessible to visitors because of the road system layout of the state. Unlike other protected areas of the state, visitors do not have to charter a plane or a boat to get to KEFJ once they are on the main Alaskan road system. Nearly 51% of the park is covered in ice with 14 named glaciers within the park boundary (Nagorski et al., 2010). The dynamic landscape receives 203 to 381 centimeters of precipitation each year, establishing it as part of the temperate rainforest biome. Sitka spruce (*Picea sitchensis*) and Mountain hemlock (*Tsuga mertensiana*) are the dominant tree species in the region.

While a majority of the tree species are coniferous, there are a few deciduous species including: black cottonwoods (*Populus trichocarpa),* Sitka alder (*Alnus viridis ssp. sinuate*), and several willow (*Salix sp.*) species (NPS, 2018, Boggs et al., 2008).

With harsh weather conditions from September to April, visitor use is typically confined to the summer months. Overnight visitors arrive at their campsites via kayak, motorized boats, or, on the rare occasion, sea planes. With the exception of the walk-in campground near Exit Glacier, there are no formal or designated campsites in the park. Most camping is confined to 15 beaches dispersed in the most popular three bays of KEFJ: Northwestern Fjord, Aialik Bay, and Resurrection Bay (Figure 1). These are the three most accessible bays due to their proximity to Seward and where most backcountry visitors camp and recreate in the park. Campsite substrate types on these beaches are classified as sand, soil, cobble, or some combination of the three. Soil/sandy beaches occur near a source of sediment deposition: rivers, eroding sea cliffs, and sand transported by wind or from the ocean shelf (Ritter, 1986). Above the high tide line, where visitors camp, the beach is dominated by grasses, forbs, and ferns. Species include: American dunegrass (*Leymus mollis*), beach pea (*Lathyrus maritimus*), lady fern (*Athyrium filix*), and alpine buckler fern (*Dryopteris expansa*). Further beyond the high tide line common graminoid vegetation species include: *Hordeum bracteosum*, *Poa eminens*, *Festuca rubra*, *Deschampsia spp*., and others. The graywacke (cobble) beaches are a result of erosion on rocky shorelines and cliffs and are often the remains of deglaciation. With exposure to wave action and storm swells common resilient species on these beaches include: American dune grass (*Leymus mollis*) and beach pea (*Lathyrus maritimus*), sea sandwort (*Honckenya peploides*), mountain hemlock (*Tsuga* *mertensiana*), Scottish licorice-root (*Ligusticum scoticum*), villous cinquefoil (*Potentilla villosa*), and lupine (*Lupinus nootkatensis*) (Boggs et al., 2008).

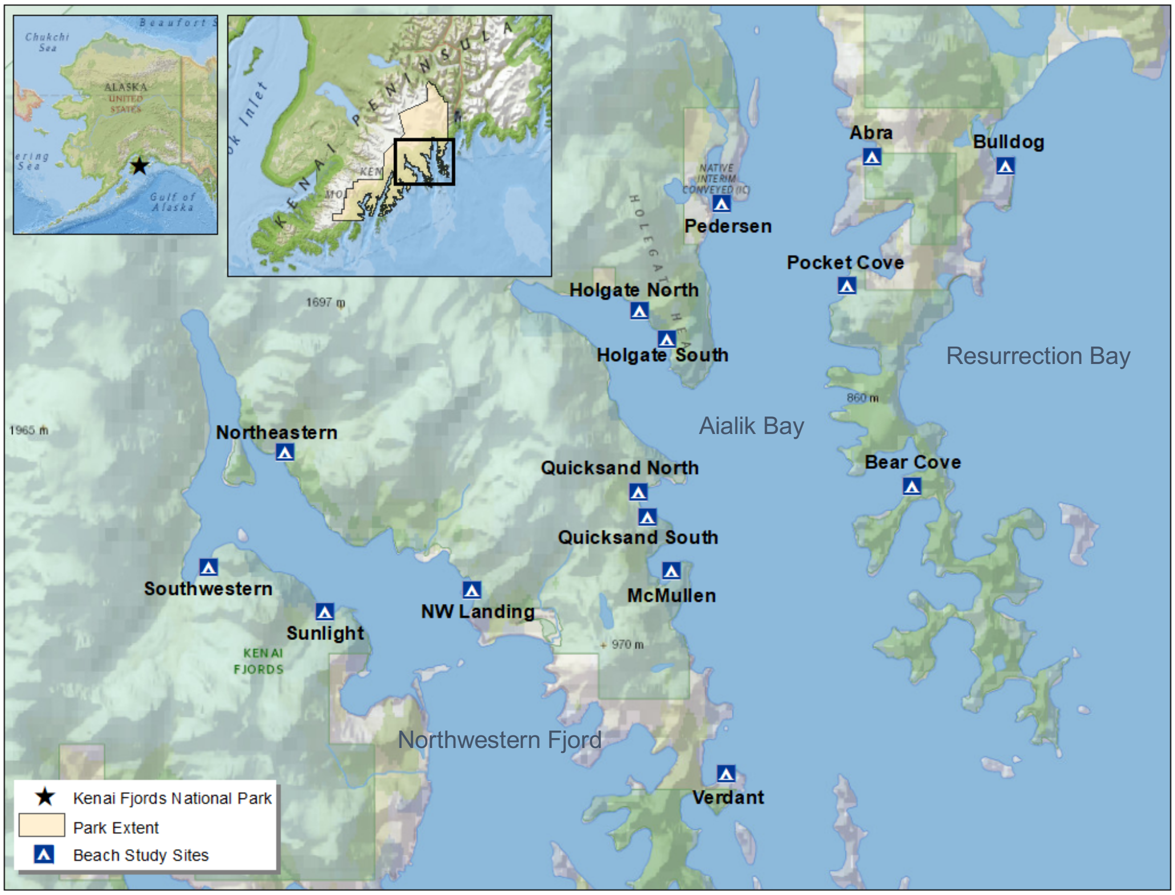

Figure 1. Beach locations of campsite study areas.

Data Collection

Monz et al. (2011) developed an Alaskan coast specific monitoring protocol following well established procedures created by Marion (1995), Leung et al. (1999), Newsome et al. (2001), and previous work done by Monz et al. (2010). Data collection occurred from 2008 to 2012, with a sampling of 101 total observed campsites. To discern potential campsites, entire beaches feasible for camping were searched to find locations of flattened vegetation, surface layers, or soil disturbances that may indicate human influences. These search techniques occurred on the limited number of beaches able to accommodate camping. Combined with regular ranger patrols in most areas, this technique, provided a reasonable assurance that most camping locations were found and assessed.

Two types of campsite assessments were conducted as part of a long-term monitoring program for KEFJ: Rapid and Complete. Rapid assessments were designed to be done by one person and take approximately five minutes to complete per campsite. These quick assessments were intended to discover new sites not previously recorded and to check in on campsites the monitoring program was already aware of for large scale damages and severe ecological degradation. These assessments were planned to be performed in between regular monitoring field seasons to reduce the sampling burden (Monz et al., 2011). However, due to staff changes and the desire to acquire a more comprehensive data set, rapid assessments only occurred in 2008 with complete assessments taking place in 2009 through 2012. Complete assessments were designed for two to three technicians to complete in about fifteen to twenty minutes. Using a Trimble Global Positioning System (GPS) unit, several observations of the campsite were noted and recorded (Tables 1 and 2). Campsite area measurements were captured following Marion's (1995) radial transect protocol (Monz et al., 2011 pg. 39). The perimeter of the campsite was flagged and a metal center point marker with a unique identification number was buried in the center of the campsite. With a technician standing on the center point, the azimuth, or compass bearing from magnetic north, was recorded and the distance from the center point to each established boundary flag was measured. This process allowed for the determination of parameter points that could be georeferenced and plotted as polygons in real space after the data was collected. Photographs were also taken of the exact location to assist with the identification of the campsite in the following sampling years. All data were then uploaded, stored, and analyzed in GPS Pathfinder Office to be reviewed and evaluated later (Marion, 1995; Monz et al., 2011). While the intentions and requirements were straightforward for each assessment protocol, technicians in the field found the protocols to be more cumbersome than expected. Relocating the metal campsite center point pins proved to be the most difficult and time intensive. Combined with setting up the boundary flags and establishing the compass bearings, complete assessments took 30 minutes per campsite.

Table 1. Impact assessment indicator variables, methods, and measurement scale.

Site Attribute	Method	Measurement Scale

Campsite Area	Radial transect	Square Meters
Distance from high tide	Measurement of campsite distance from high tide line marked by vegetation	Meters
Landing and campsite substrate type	Observation	Sand, Sand/Cobble, Cobble, Soil/Cobble, Soil, Bedrock
Tree Canopy	Observation	Presence/Absence
Vegetation cover onsite/control and mineral soil exposure onsite	Ocular estimation	Six level scale: 0-5%, 6-25%, 26-50%, 51-75%, 76-95%, 96-100%
Tree and ghost tree[1] damage and root exposure onsite	Ocular estimation	Four level scale: N/A, None/Slight, Moderate, Severe
Tree and ghost tree[1] stumps, fire rings, and trails	Counts	Total number present
Tent Rocks	Ocular estimation	Four level scale: 0, 1-5, 6-15, 16+
Trash	Ocular estimation	Three level scale: None to a handful, more than a handful to a gallon, greater than a gallon
Human Waste	Ocular estimation	Two level scale: None and Some
Condition Class	Ocular estimation	Six level classification scale

[1]Ghost trees are the dead standing tree stumps left behind from the 1964 Good Friday earthquake. All tree variables including root exposure, should only be assessed if trees are present.

Table 2. Campsite condition class definitions.

Class	Description
Class 0:	• Describes a previously established site that has re-grown and is not showing current, observable disturbance. This class can only be used for re-measurement of an established site • Recreation site barely distinguishable • None or minimal disturbance of vegetation and/or organic liter • No observable vegetation loss in campsite as compared to off site
Class 1:	• Recreation site barely distinguishable • Slight loss of vegetation cover and/or minimal disturbance of organic liter • 6-25% vegetation loss in campsite as compared to off site
Class 2:	• Recreation site obvious • Vegetation cover lost and/or organic litter pulverized in primary use areas • 26-50% vegetation loss in campsite as compared to off site
Class 3:	• Vegetation cover lost and/or organic litter pulverized on much of the site • Some bare soil exposed in primary use areas • 51-75% vegetation loss in campsite as compared to off site
Class 4:	• Nearly complete or total loss of vegetation cover and organic liter • Bare soil widespread • 76-95% vegetation loss in campsite as compared to off site
Class 5:	• Soil erosion obvious, indicated by exposed tree roots and rocks and/or gullies formed • 96-100% vegetation loss in campsite as compared to off site

Monz et al. 2011, pg. 29.

Data processing and GIS Analysis

Polygons created from the radial transect measurements were imported into Esri's ArcMap 10.6.1 (2019, Environmental Systems Research Institute (ESRI), Redlands, CA, USA) and depicted campsite areas in meters squared. Center points, located in the center of each polygon, detailed the list of recorded variables (Monz et al., 2011). The polygons and center points were sorted by year of data collection and cleaned. Center points and polygons with notes indicating they were the new identification number for a center point marker that could not be found in the field were paired with the old center point marker number. For analysis purposes, campsites on beaches Verdant South and Verdant were combined due to their proximity to each other and to increase the sample size for a more accurate statistical analysis. Holgate Mid campsites were combined with Holgate South campsites for the same reason. While the majority of the indicator variables were recorded as numerical values or categories, vegetation cover loss needed to be calculated post hoc using vegetation cover estimates and the following equation (Monz et al., 2010):

$$\text{Vegetation Cover Loss} = 1 - \frac{\text{\% cover in campsite}}{\text{\% cover in control plot}} \text{ X } 100\%$$

Statistical Analysis

Using a combination of parametric and non-parametric statistical analysis techniques, we determined which campsites, beaches, and regions had the most change during the study period, if there was redundancy in the observed indicator variables, and calculated more reasonable sampling intervals. A random coefficients model was used to estimate campsite ecological change by campsite, beach, and region over time. The random coefficients model allowed us to examine the relationship between each ecological variable's repeated measure across time without a fixed interval. Campsites within a beach and beaches within a region were considered to be replicates. Each campsite, beach, and region was analyzed separately for each variable using a random coefficients model to estimate change per year as the linear slope coefficient. Random intercepts incorporated variance among campsites, however, there were too few repeated measures on campsites to estimate random slopes. (Harrison et al., 2018). There were some limitations in definitively describing change by campsites due to smaller sample size, however, estimates for annual change were calculated. Since categorical variables used in this analysis were ordinal, they were recoded as integers. To determine which beach had the most ecological change, all estimated slopes for each indicator variable were ordered from most improved (negative integers) to most static (zero) or degrading (positive integers) and ranked. The data collection process was designed so each increase in category indicated progressive wear on the site. Positive values for change represented increased degradation and negative values for change indicated more recovery. Each variable ranking was added together to create one value to represent change rank amount for each beach. Each indictor held the same weight when being ranked to distinguish dynamic versus static beaches. This means, for example, campsite area had the same amount of pull in determining which beaches changed more as the amount of trash found on campsites.

Exploratory principal component analyses were conducted to visualize change occurring at campsites that were sampled more than once during the sampling period, using the estimated slopes data. Factor loadings were determined using varimax rotation and the results of the first two factors that describe the most variance were ordinated to illustrate patterns of change. A principal component analysis was used again using the cleaned raw data from each site, at each sampling year to determine if there was redundancy when measuring the independent indicator variables. This was an effort to determine if there were superfluous variables that could be excluded for a more efficient monitoring protocol (Monz and Twardock, 2010; Leung and Marion, 1999). Condition class rating assessments were not included in this analysis because of the covariance between these ratings and the other indicator variables. Condition class ratings were determined and provided as a generalization of all other indicator variables combined. The data collection protocol specified intensive sampling measurements every other year at each campsite. The actual data collection sampling periods occurred more sporadically. Most sites were sampled in three-year increments (intensive sampling was completed three years apart). This proved to be beneficial for our study, because it allowed us to determine a more appropriate intensive sampling interval. Paired student's T-tests were run on continuous variables, while Pearson's Chi-square tests were run for categorical data to determine which variables changed significantly over time (Twardock et al., 2010). Change significance of each indicator variable was conducted by interval sample group. Each campsite was assigned to one of four groups based on the time difference between its first sample and last. For example, if a site was first observed in 2008 and its last sample observation was in 2010, that site would be in the year 2 group. The sample number is often different for groups for each variable because there was missing data for some variables during sampling, but not all variables. By identifying when significant changes occurred for the variables, we determined a more efficient sampling interval.

Finally, to provide a more efficient method of measuring campsite area in the field, we compared the campsite area sizes that resulted from the radial transect method to estimated ellipses drawn around the polygons established by the radial transect method. To calculate the ellipse area, a major (a) and minor (b) axis of the campsite were drawn over the campsite polygon in ArcMap. The longest section from vertex to vertex was drawn as the major axis and the shortest section from vertex to vertex was drawn as the minor axis. Each axis aimed to cut the polygon in half trying to maintain equal parts on both sides (Figure 2). The estimated area was then calculated using the ellipse area equation:

$$Area = \pi \frac{ab}{2}$$

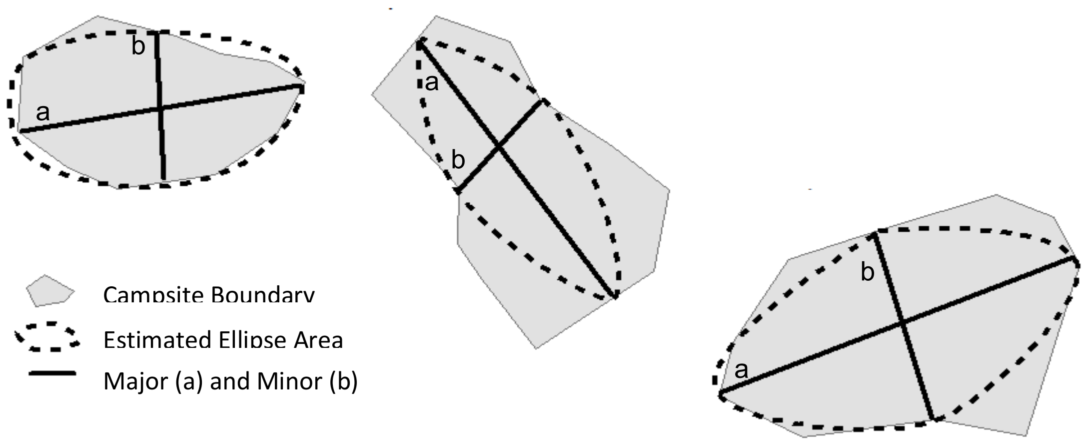

Figure 2. Drawn major and minor axes over theoretical campsite boundaries to create ellipse area estimations.

All 54 of the campsites measured in 2012 were used in the sample to determine if there was a significant difference in areas from the radial transect and ellipse methods. We calculated the means and standard deviations of both area measurements and compared the two with a paired T-Test to examine significant differences in the means. A simple linear regression analysis was also conducted in order to determine how well the ellipse areas could predict the true area determined by the radial transect. SPSS and R were used to summarize and conduct statistical analyses (v.25, IBM Corp., Armonk, NY, USA; v.1.1.456, R Foundation for Statistical Computing, Vienna, Austria).

Results

Descriptive Statistics

Over the five-year study period, measurable impacts were found on 101 campsites. Based on the data collect from every campsite for each year sampled, the mean area for campsites in KEFJ was 31.46m^2 (median = 19.52m^2). The mean condition class for all of the sites and their observations was two, indicating obvious recreational use. Vegetation loss and mineral soil exposure were both around 50%. There was a mean of 8.47 tent rocks found at each site (Table 3). It is possible that tent rock numbers were inflated, because tent rocks were not counted individually but rather in categories.

Table 3. Indicator variable summary for all sites in KEFJ. Values are mean ± SD for continuous variables and median ± range for ordinal variables.

Site Attribute	KEFJ Study Area	N
<u>*Continuous Measures*</u>		
Area (m^2)	31.46 ± 41.85	208
Vegetation Loss (%)	55.66 ± 39.22	216
Mineral Soil Exposure (%)	58.56 ± 37.15	213
Tent Rocks	8.47 ± 5.98	221
Trails	2.19 ± 1.63	230
Fire Rings	0.18 ± 0.44	230
Tree Stumps	0.19 ± 0.66	230
Ghost Trees	0.19 ± 0.86	230
<u>*Ordinal Measures*</u>		
Condition Class	2 ± 4	226
Tree Damage*	1 ± 2	170
Ghost Tree Damage*	1 ± 2	61
Root Exposure*	1 ± 2	173
Trash**	1 ± 2	229
Human Waste***	0 + 1	229

*Categorical Variables: 0 = None/Slight, 1 = Moderate, 2 = Severe, NA = Not Applicable.
**Trash Variable: 0 = None to a handful 1 = Handful to a gallon, 2 = Greater than a gallon.
***Human Waste Variable: 0 = None and 1 = Some.

Campsite Changes by Ecological Variable

A majority of variables were improving or remained static for each campsite. Trails and vegetation cover loss were the variables most likely to experience degradation. Number of tree stumps, fire rings, ghost tree damage, trash, and human waste predominately remained static. For these variables, if there was change, it was mostly improving. Campsites 93 (Pedersen) and 27 (Quicksand North) were the only two sampled sites that were degrading by four variables (area, vegetation loss, tent rocks, and mineral soil exposure), with the other variables remaining static. All other campsites either had a combination of recovering and static variables or a combination of recovering, static, and degrading variables (Tables 4a and 4b). Overall, 15 campsites recovered with no identifiable indication of recent visitor use and 14 new sites were found by the final year of sampling and no beaches experienced campsite proliferation.

At the beach level, by summing all ranked values for each variable Bulldog, Holgate South and North, and Quicksand South recovered the most. NW Landing experienced the most degradation, followed by Pedersen and McMullen (Table 5). This was the same pattern for fully recovered campsites. NW Landing was the only beach to experience, on average, an increase in area size. While all remaining beaches had a reduction in campsite area, on average, campsites on Bear Cove, Bulldog, Holgate North and South, Northeastern, Pedersen, Pocket Cove, Quicksand South, Sunlight, and Verdant had the most significant area decreases (Figure 3). Sunlight beach was not included in this ranked analysis at the beach level because only one campsite was sampled more than once over the course of the sampling period. Beaches in Aialik Bay had the most recovering campsites. Northwestern Fjord had less recovery and was the location for the most new sites found at the end of the study period. Bulldog beach was ranked the highest in terms of recovery but is the only beach sampled in Resurrection Bay. While we were able to rank the amount of change at each sampling level, change was still somewhat marginal for most variables. Change values for each indicator variable can be found by campsite and by region in the Appendix.

Table 4a. Indicator variable baseline (intercept) and annual change (slope) estimates by beach.

Beach	Area (m^2)	Condition Class	Vegetation Loss (%)	Tent Rocks	Trails	Ghost Tree Damage	Trash	Human Waste
Abra	29.16	3.48	-64.06	16.80	1.88	0.00	0.00	0.00
	(-2.41)	(-0.27)*	(7.78)	(-0.91)	(0.04)	(0.00)	(0.00)	(0.00)
Bear Cove	117.99	3.97	-40.29	8.05	3.82	1.22	-0.03	0.00
	(-19.27)*	(-0.42)**	(1.60)	(0.10)	(-0.29)	(0.00)	(0.25)**	(0.00)
Bulldog	78.36	3.57	-44.10	13.72	1.52	0.105	0.37	0.00
	(-12.78)*	(-0.52)*	(-7.62)	(-1.22)	(0.03)	(-0.01)	(0.26)*	(0.00)
Holgate North	53.59	4.09	-29.47	19.09	4.17	0.18	-0.10	0.00
	(-8.71)	(-0.78)**	(-7.33)*	(-3.15)*	(-0.83)**	(-0.04)	(0.26)**	(0.00)
Holgate South	51.96	5.14	-13.26	7.02	1.89	0.42	0.00	0.00
	(-9.90)*	(-0.90)*	(-4.08)	(-0.75)	(-0.23)	(0.00)	(0.00)	(0.00)
McMullen	26.48	1.54	-67.63	1.14	0.60	0.92	-0.11	0.28
	(-2.99)	(0.04)	(0.00)	(2.85)	(0.13)	(-0.13)	(0.25)**	(-0.06)
Northeastern	99.82	2.92	-78.13	12.47	1.86	0.00	0.00	0.00
	(-10.35)*	(-0.13)	(6.25)	(-0.75)	(0.21)*	(0.00)	(0.00)	(0.00)
NW Landing	14.89	0.25	-70.03	6.75	1.00	0.00	0.00	0.00
	(2.22)	(0.75)	(-1.77)	(-0.25)	(0.75)	(0.00)	(0.00)	(0.00)
Pedersen	63.74	2.42	-57.68	4.22	2.79	0.64	0.00	0.00
	(-9.84)	(-0.04)	(0.23)	(-0.23)	(0.24)	(-0.11)	(0.00)	(0.00)
Pocket Cove	62.30	4.16	-40.05	14.76	-0.55	1.39	0.00	0.00
	(-9.36)	(-0.58)	(7.83)	(-0.88)	(0.32)	(-0.17)	(0.00)	(0.00)
Quicksand North	30.82	3.13	-40.17	0.56	3.50	0.63	0.00	0.00
	(-2.01)	(-0.13)	(6.75)	(0.56)	(-0.25)	(-0.13)	(0.00)	(0.00)
Quicksand South	45.98	4.65	-45.99	14.05	3.25	1.79	0.00	0.00
	(-7.69)*	(-0.80)**	(5.07)	(-2.33)*	(-0.37)	(-0.36)*	(0.00)	(0.00)
Southwestern	14.12	2.02	-43.42	14.30	0.07	0.00	0.00	0.00
	(-0.76)	(0.00)	(5.74)	(0.06)	(0.31)	(0.00)	(0.00)	(0.00)
Verdant	59.19	3.77	-18.48	17.08	1.19	1.41	0.00	-0.14
	(-9.19)*	(-0.58)*	(1.65)	(-2.07)*	(0.01)	(-0.15)	(0.00)	(0.05)

Variable baseline of predicted 2008 value (Yearly Change). For all variables, a negative yearly change indicates improvement, 0 is no change, positive yearly change indicates degradation.

*P-value < 0.05

**P-value <0.001

Table 4b. Indicator variable baseline (intercept) and annual change (slope) estimates by beach.

Beach	Mineral Soil Exposure (%)	Fire Rings	Tree Stumps	Tree Damage	Root Exposure	# of Sites
Abra	67.53	0.00	0.00	1.05	0.84	7
	(-0.43)	(0.00)	(0.00)	(-0.17)	(-0.12)	
Bear Cove	65.63	0.11	0.69	1.00	1.06	6
	(-2.96)	(0.00)	(-0.08)	(0.00)	(0.00)	
Bulldog	82.62	0.68	0.00	1.53	1.52	5
	(-7.18)	(-0.10)	(0.00)	(-0.19)	(-0.25)*	
Holgate North	70.66	0.00	0.00	0.26	0.25	6
	(-4.26)	(0.00)	(0.00)	(0.01)	(0.12)	
Holgate South	124.29	0.00	0.00	1.30	1.30	3
	(-18.04)*	(0.00)	(0.00)	(-0.13)	(-0.13)	
McMullen	98.00	0.07	0.00	0.09	0.00	4
	(0.00)	(0.13)	(0.00)	(0.00)	(0.00)	
Northeastern	66.76	0.13	-0.08	1.68	1.47	11
	(-3.54)*	(0.00)	(0.03)	(-0.23)*	(-0.19)**	
NW Landing	-0.13	0.75	3.75	0.75	0.75	4
	(8.88)	(-0.25)	(-1.25)	(0.25)	(0.25)	
Pedersen	-11.08	0.29	-0.12	0.84	1.59	13
	(7.50)*	(0.01)	(0.21)*	(0.11)*	(0.03)	
Pocket Cove	93.92	0.50	-0.35	-0.35	0.33	2
	(-0.27)	(0.00)	(0.17)	(0.17)	(0.02)	
Quicksand North	66.63	0.00	0.00	1.00	1.00	4
	(1.50)	(0.00)	(0.00)	(0.00)	(0.00)	
Quicksand South	87.32	0.00	0.00	1.36	0.64	7
	(-3.34)	(0.00)	(0.00)	(-0.07)	(0.07)	
Southwestern	95.50	0.00	0.00	1.58	1.58	6
	(0.00)	(0.00)	(0.00)	(-0.24)*	(-0.24)*	
Verdant	94.72	0.51	0.38	1.22	0.69	7
	(-0.60)	(-0.05)	(-0.01)	(-0.07)	(0.06)	

Variable baseline of predicted 2008 value (Yearly Change). For all variables, a negative yearly change indicates improvement, 0 is no change, positive yearly change indicates degradation.

*P-value < 0.05

**P-value <0.001

Table 5. Ranks of all indicator variables change by beach.

Beach	Change Rank
Bulldog	1
Holgate South	2
Holgate North	3
Quicksand South	4
Verdant	5
Bear Cove	6
Northeastern	7
Abra	8
Pocket Cove	9
Southwestern	10
Quicksand North	11
McMullen	12
Pedersen	13
NW Landing	14

Change ranks are based on the amount of change occurring for each variable and their sum total. By beach, each variable is ranked from most recovery to most degradation and all variable rank scores are summed.

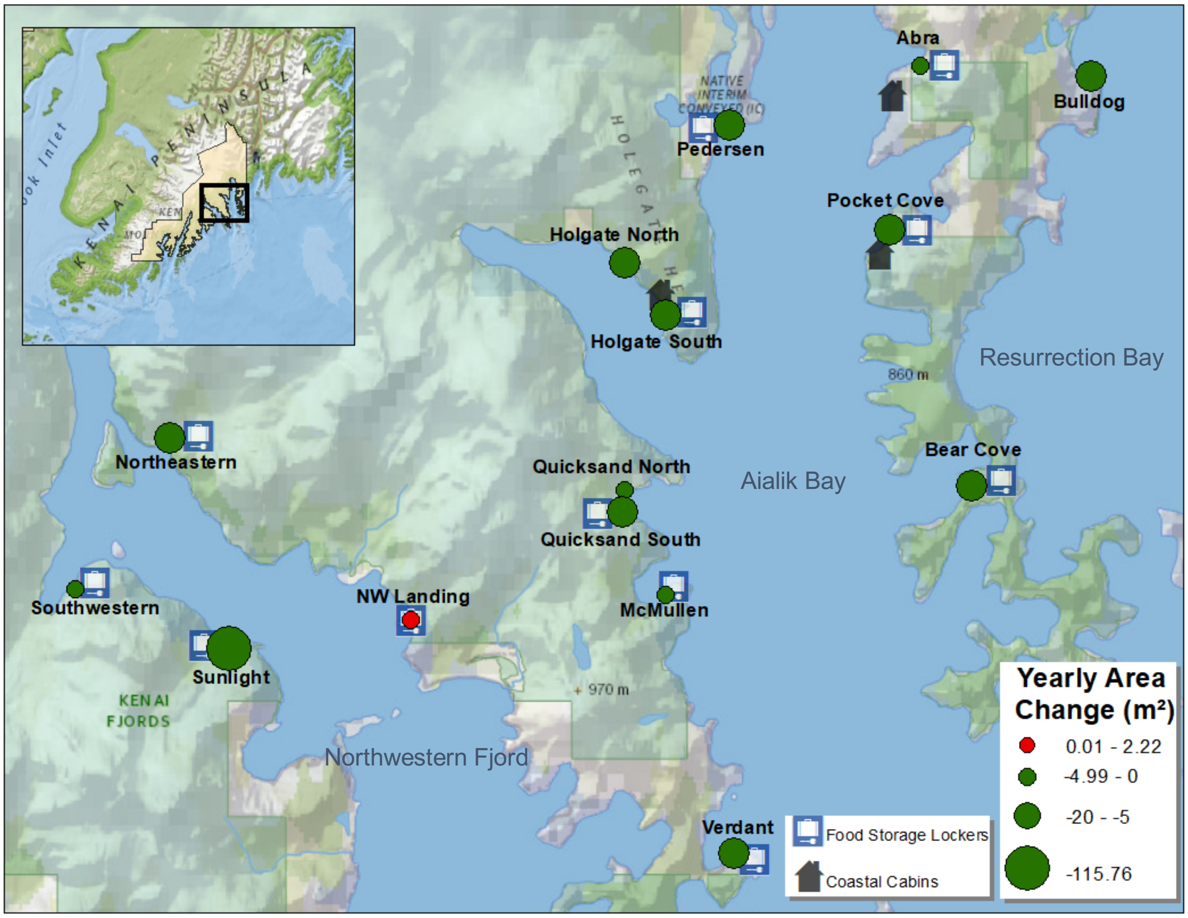

Figure 3. Yearly campsite area change by beach. Red campsite areas (NW Landing) depict area increases. Larger green circles depict greater area reductions.

Ecological Variable Change

Campsite area, tree damage, and root exposure are the most sensitive to change of all indicator variables. The data for this analysis includes the 70 campsites with at least two observation sample periods and no missing data. The exploratory principal component analysis revealed five factors that explained 64.6% of the variation in the change data. Campsite area, tree damage, and root exposure influence the first factor the most and account for 16.3% of the variance. The second factor explains 13.9% of the variability and includes variables: condition class, mineral soil exposure, trails, and trash (Table 6). For ease of interpretation, factor loadings between -0.4 and 0.4 are not listed.

Factor loadings are reported as positive or negative because change occurs in either direction.

Table 6. Factor analysis of indicator variable's change of campsites in KEFJ.

Variable	Rotated Factor Loadings[a]				
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Campsite Area	-.650				
Tree Damage	.887				
Root Exposure	.851				
Condition Class		.755			
Mineral Soil Exposure		.462			
Trails		.708			
Trash		.654			
Vegetation Cover Loss			-.708		
Fire Rings			.764		
Tree Stumps			.768		
Tent Rocks				-.769	
Human Waste				.788	
Ghost Tree Damage					.926
Cumulative Variation Explanation (Percent)	16.3	30.2	43.9	56.2	64.6

[a]Principal components extraction results with varimax rotation. Factors loadings above 0.4 are presented for ease of interpretation. N = 70.

The ordination visualizes which campsites are changing differently from other campsites, based on the variables that loaded the highest in factor one and two. There appears to be no pattern of a specific beach experiencing more exaggerated change than others (Figure 4). Campsite 66, the only campsite on Sunlight beach with more than one year of data, is varying from the clustering of campsites for the factor one variables. This particular campsite did experience a decrease in area size between sampling periods. Where a majority of campsites were observed to have a $10m^2$ or less difference in area size per year, campsite 66 decreased in size by $115.76m^2$ annually. Additionally, most campsites do not exhibit much change in tree damage or root exposure from year to year, but for this site, severity for both variables increased. Campsite 47 also presented itself as an outlier in the ordination plot. This site stood out as different from other sites because of its annual 10.25m^2 area growth, where the majority of sites were declining in size. Similar to campsite 66, this site's change in tree damage and root exposure changes drastically from year to year. For most sites, if there was a change in these variables, it is incremental. Unlike campsite 66, campsite 47 had severe tree damage and root exposure in the first year of sampling and improved by the final sample (Tables 11a and 11b in Appendix).

Factor two scores indicated some patterns by beach as all campsites on Bear Cove and Bulldog beach fell below zero on the Y axis while all of NW Landing and the majority of Pedersen campsites were above zero. This indicates there was a greater magnitude of change at these beaches for the variables condition class, mineral soil exposure, trails, and trash. Bear Cove and Bulldog campsites recovered more for all variables, while NW Landing and Pedersen campsites were degrading. This is evidenced when comparing Bulldog campsite 80 to NW Landing campsites 48 and 49. Campsite 80 improves by one condition class rating and decreases mineral soil exposure by 25% annually, ultimately recovering by the end of sampling. Both campsites 48 and 49 degraded by one condition class rating and gained a trail each year. Mineral soil exposure and trash observations remained static (Tables 11a and 11b in Appendix).

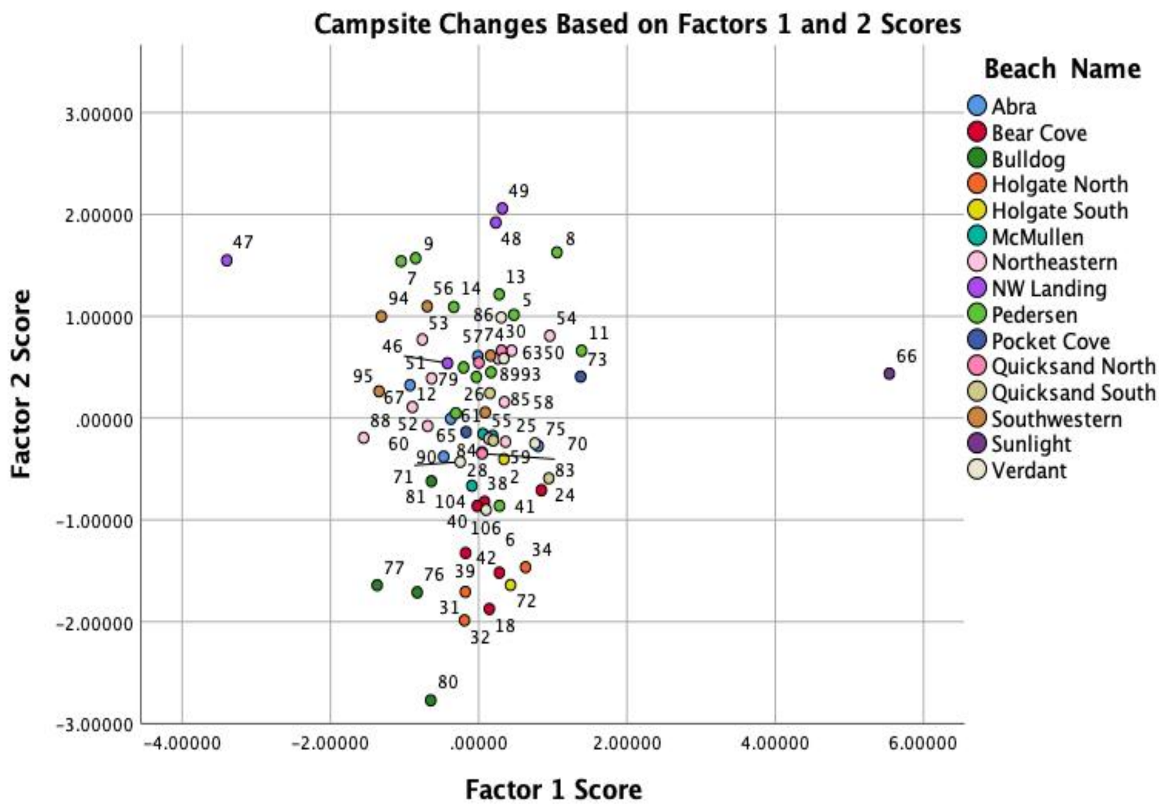

Figure 4. Ordination of campsites based on amount of change of variables in Factors 1 and 2. **Factor 1:** Area, Tree Damage, and Root Exposure. **Factor 2:** Condition Class, Mineral Soil Exposure, Trails, and Trash.

Optimizing the Monitoring Protocol

Redundant Ecological Variables

The data for this analysis included all 186 observations from the 101 campsites. Since this was the cleaned raw data, it included each sample made from all sampling periods for each campsite. Six equations were created to explain 74.1% of the variation in the data (Table 7). Variables loading similarly on the same factor accounted for similar characteristics in the data set. By eliminating one of the variables per factor, most of the variance could still be identified with less measurements. For example, factor two was most influenced by vegetation cover loss, mineral soil exposure, and tent rocks. A future protocol might suggest only measuring vegetation cover loss instead of mineral soil exposure, because it is easier to properly identify vegetation than it is mineral soil exposure with limited training. The elimination of the excessive variable measurement would still account for most of the variation in the data. Additionally, these results also suggest that removing trash, campsite area, and tent rocks as measured variables would yield a new protocol that would still capture 53.7% of the variance in the data.

Table 7. Factor analysis of indicator variables campsites in KEFJ.

Site Attribute	Rotated Factor Loadings[a]					
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
Tree Damage	.940					
Root Exposure	.935					
Vegetation Cover Loss		.841				
Mineral Soil Exposure		.890				
Tent Rocks		.437			.643	
Trails				.655		
Fire Rings				.756		
Tree Stumps				.502		
Ghost Tree Stumps			.858			
Ghost Tree Damage			.760			
Campsite Area					.799	
Trash						.882
Cumulative Variation Explanation (Percent)	16.6	31.5	42.7	53.7	64.0	74.1

[a]Principal components extraction results with varimax rotation. Factors loadings above 0.4 are presented for ease of interpretation. N = 186.

Sampling Interval

To determine a more appropriate sampling interval, paired Student's T-tests were run to compare the value of the first sample of the measured variable to the last and test for a significant change (Table 8). Our results indicated very little observable change occurred within one year. Significant changes did occur after at least two years. For the categorical variables root exposure, trash, and human waste there was no change detected between sampling years so, they were not included in Table 8. Because ghost tree stumps are evidence of the 1964 Good Friday earthquake, the number of stumps at a campsite should not change as the stumps remain stationary. For this reason, the change in the number of ghost tree stumps was not evaluated, as there was no change. However, in campsites with ghost trees present, the level of damage to them was evaluated because this variable serves as an assessment of human impact when the damage can clearly be identified as human caused. Increased signs of damage such as scratches or cuts provided evidence of increased or irresponsible use.

Table 8. Indicator variable change significance by sampling interval.

Continuous Variables	**Mean Difference**	**p-value**	**N**
Area (m^2)			
1 Year	-18.638	0.384	6
2 Years*	-10.695	<0.001	30
3 Years*	-20.96	<0.001	36
4 Years	-64.452	0.078	6
Condition Class			
1 Year	-0.429	0.120	7
2 Years*	0.786	<0.001	28
3 Years*	0.686	<0.001	35
4 Years*	2.364	<0.001	11
Vegetation Loss			
1 Year	26.112	0.232	9
2 Years	-6.994	0.142	25
3 Years	-9.911	0.057	32
4 Years	0.500	0.965	12
Mineral Soil Exposure			
1 Year	-1.857	0.736	7
2 Years	-5.614	0.297	22
3 Years	3.455	0.462	33
4 Years	14.500	0.287	8
Tent Rocks			
1 Year	0.143	0.928	7
2 Years*	2.815	0.024	27

3 Years*	1.280	0.042	34
4 Years	3.100	0.451	10
Trails			
1 Year*	-0.571	0.030	7
2 Years	0.179	0.510	28
3 Years	-0.400	0.124	35
4 Years*	1.400	0.022	15
Fire Rings			
1 Year	0.143	0.356	7
2 Years	-0.072	0.161	28
3 Years	0.057	0.624	35
4 Years	-0.133	0.164	15
Tree Stumps			
1 Year	0.714	0.253	7
2 Years	0	1.000	28
3 Years	-0.229	0.147	35
4 Years	0.133	0.719	15
Categorical Variables	$\chi 2$	**p-value**	**N**
Tree Damage			
1 Year	3.080	0.2144	7
2 Years*	16.741	0.002	24
3 Years	2.954	0.566	33
4 Years*	11.123	<0.001	6
Ghost Tree Damage			
1 Year	N/A	N/A	0
2 Years*	6.412	0.041	11
3 Years*	11.074	0.004	9
4 Years	5.799	0.055	8

* Significant p-value <0.05

Ellipse Area Measurement

In 2012, campsite areas measured with the radial transect method were, on average, 20.58 m^2. One average, the same campsites measured using the ellipse estimation method were larger by a small margin at 21.02m^2 (Table 9). Radial transect and estimated area measurements were strongly and positively correlated ($r = 0.971$, $p < 0.001$). There was no significant difference between radial transect and estimated area measurements ($t_{53} = -0.93$, $p = 0.357$). On average, radial transect area measurements were $0.45m^2$ smaller than estimated measurements (95% CI [-1.42, 0.52], Table 10). A simple linear regression analysis supported these results, explaining 94% of the variation across the two measures (Figure 5).

Table 9. Descriptive statistics of different campsite area measurement methods.

	Mean	Standard Deviation
Radial Area (m^2)	20.58	14.66
Estimated Area (m^2)	21.02	14.57

N = 54

Table 10. Paired samples correlations of radial versus estimated campsite area measurement methods.

	Mean	Standard Deviation	Lower (95%)	Upper (95%)	t	df	Significance (2-tailed)
Radial - Estimated	-0.45	3.55	-1.42	0.52	-0.93	53	0.357

N = 54

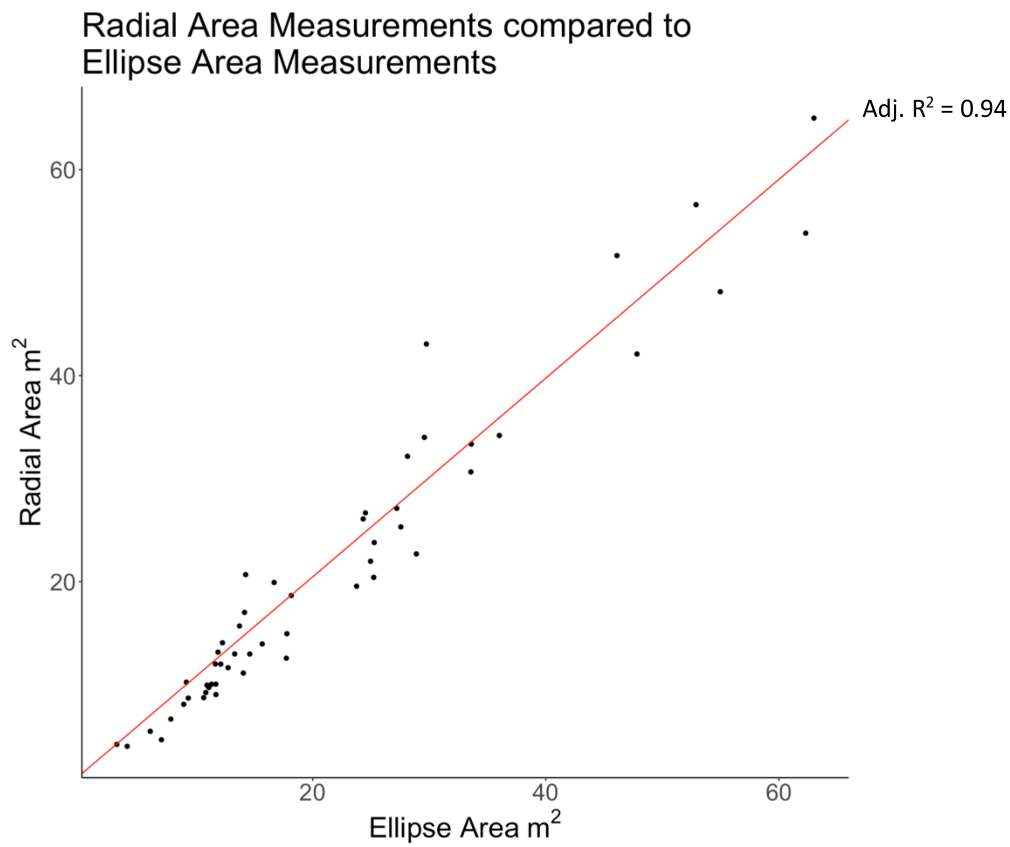

Figure 5. Simple linear regression model comparing radial area measurements to ellipse estimated area measurements. Regression line p-value <0.01, R2 = 0.94.

Discussion

This assessment of campsite changes and the efficiency of current monitoring procedures is an important step in determining best natural resource management practices. Visitors notice ecological impacts on campsites (Farrell et al., 2001). Results from monitoring the conditions of visitor use areas provides the biophysical evidence to bridge the gap of what visitors find acceptable in terms of ecological impact and the reality of the condition they are in (D'Antonio et al., 2013; Goonan et al., 2012). Additionally, results from these assessments provide land managers evidence to justify restoration strategies if determined necessary. Confining visitors to certain designated camping areas (Reid and Marion, 2004), dispersing visitors to different areas (Cole et al.

2008), and closing campsites completely for restoration (Cole et al., 1992) are proven management strategies that have protected the natural resource (Hammitt et al., 2015).

Based on the results of our investigation, for our first objective, we have concluded that the majority of sites indicated recovery or remained static, but there was no spatial pattern in changing campsites at the individual or beach level. However, some spatial patterns were seen by park region. Resurrection Bay exhibited the most recovery, but only consisted of Bulldog beach. Given that Bulldog beach is exposed to high surf and weather from the Gulf of Alaska it is more dangerous to land a vessel there and may suggest fewer visitation levels. NW Landing beach, located in Northwestern Fjord, was a region of some concern. It was the only beach where campsites, on average, increased in size and variables were degrading more than recovering. Pedersen and McMullen beaches had slightly more degrading tendencies than other beaches as well and should continue to be monitored because of the new sites located in the later years of sampling. The same could be said for Abra, Sunlight, Southwestern, and Northeastern beaches. These are areas where new sites were discovered in the last two years of complete sampling assessments and there was little evidence of full recovery on older campsites. In comparison to the work by Twardock et al. (2010) in Prince William Sound, overall KEFJ campsites exhibited more recovery but appear to experience more degradation in terms of mineral soil exposure. While Twardock et al. (2010) presented findings that visitors were using multiple locations with less intensity, our results suggest a change in the overall pattern of use intensity. Visitors appear to be camping in completely different beach locations over time, allowing some beaches to recover while focusing use in other locations. Bulldog may have once been a popular destination, but Northwestern Fjord and areas of Aialik Bay seem to experience more use currently.

Our second conclusion, is that while campsite area did change and is an important measure of campsite impact (Monz and Twardock, 2010; Cole and Hall, 1992), it did not account for much of the variation in the data (Table 7). These mixed results indicate that area change occurs in some places and remains static in others. The precise nature of conducting a radial transect area measurement allowed for determining more sensitive changes in area (Table 6), even though most changes in area were quite small. This suggests that perhaps future monitoring protocols may not require the precision that radial transect measurements offer. While exact campsite areas may be helpful to capture sensitive changes in the data they can be quite cumbersome in the field. A revised protocol might include a more rapid area measurements such as our suggested ellipse area calculation. With no significant difference in the areas calculated from the radial transect method compared to the ellipse estimation and with 94% of the variance accounted for, the ellipse measurements still offer accurate area measurements with just slightly less precision. In the field, the campsite boundary would still be established, however only the length of the major and minor axis would be measured. With this type of measurement, managers will still be able to identify areas of concern and determine sites that are increasing in size at an alarming rate.

Finally, our results suggest a few modifications to the current rapid and complete assessment (Monz et al., 2011) techniques are necessary. With very little change occurring in one year and by campsite, change seems to occur more broadly by only a subset of campsites, and after at least two years. Based on the paired Student's T-test and

Pearson Chi-Square results, suitable monitoring assessments could be completed at a three to five-year sampling interval. Simultaneously considering all our statistical analysis approaches, the high priority variables would include: tree damage, vegetation cover on and offsite, tent rocks, trails, condition class ratings, ghost tree damage, and campsite area. Mineral soil exposure, vegetation cover loss, and root exposure all loaded fairly high in the principal component analysis and accounted for most of the variance in the data. As these variables were correlated, vegetation cover loss was chosen as the most effective indicator variable. Identifying percent vegetation cover on the campsite and at a control plot requires less training than identifying percent mineral soil exposure accurately. Mineral soil exposure can be a complicated variable to measure. It requires correctly identifying mineral soil substances as opposed to the more commonly seen organic soil layer. Root exposure was thought to be less universally applicable because a tree would need to be present on the campsite. Properly identifying an appropriate control plot to compare to the amount of vegetation found on the campsite is imperative to the vegetation cover loss variable. Technicians should be trained on locating control plots within five meters of the campsites perimeter with the same substrate type. Since the variables trash and human waste occurred so infrequently and with the exception of severe cases, are fairly ephemeral, they do not need their own category to classify during each observation. However, they are important indicators of previous use and deviations from Leave No Trace principles, so they should be noted if found. Campsite substrate and high tide line measurements should also be taken for future analysis purposes that may shed light on the causation of some campsite changes. Changes in the high tide line may displace current campsites causing visitors to move inland to find appropriate campsites.

Additionally, campsite substrates have an influence on other variables. For instance, campsites on cobblestone typically have less vegetation growth. This is important to note when finding a control plot to calculate vegetation loss and then again when relocating the campsite for remeasurement (Monz et al., 2011). Henceforth, our optimal monitoring protocol would replace the need for separate rapid and complete campsite assessments, opting for one streamlined comprehensive sampling program that provides a consistent set of variables measured each time. Campsite assessments would occur every three to five years and include: rapid campsite area measurements, tree damage (noting N/A if there are no trees), percent vegetation onsite and at a control plot, tent rock counts, trail counts, condition class ratings, ghost tree damage (noting N/A if there are no ghost trees), campsite substrate type, high tide measurements (meters), and noting any campsite abnormalities such as trash or human waste. Sampling intervals should be adjusted if large amounts of change are occurring or if visitor use levels change significantly. In these instances, a shorter interval period may be necessary.

A successful monitoring protocol inevitably comes down to feasibility. Some of the limitations in our study were brought on because not all campsites could be sampled more than twice in the five year study period. Our variable model predictions would be more robust if each campsite had more samples. Additionally, because these are results from observations taken a decade ago, it might be in the best interest of the park to conduct another round of monitoring using the original protocol to compare to these results. If large scale changes have not occurred, the monitoring interval could be extended beyond the suggested three to five years. Important logistics to consider when determining an appropriate monitoring protocol depends on finances, time, and crew availability. Locating the metal pins used as the site identifiers seems to be the most time consuming part of the assessment process. The investment in sub-decimeter high accuracy GPS units could potentially mitigate this issue. By collecting center point data at each site with a higher degree of precision, returning to that exact location should be much easier in years to come. Considering the geographical location of Alaska and the effect of the magnetic field in KEFJ, a sub-decimeter level of GPS precision when relocating the campsites center point pin may not be achievable. With this in mind, having photographs of the campsites with the center points clearly identified with permeant landmarks in the photographs may cut done on the search time for the center point. Efforts to relocate the metal center points with a high accuracy GPS unit and reference photos should not exceed five to seven minutes. A new center point using a technicians best judgement should be created if the search time exceeds seven minutes. More thoughtfully organized record keeping protocols could also decrease assessment times. This would include providing drop down menus to select from a short list of options to reduce sampling times for variables such as substrate type, percent vegetation cover, and tree and ghost tree damage. Taking counts of most variables as opposed to ordinal ocular estimations for variables such as tent rocks and trails would also provide more precise results. Additionally, understanding intensity of use or tracking where visitors camp would improve this analysis. Future research might include providing visitors with a GPS unit to track their trip or asking visitors to document which beaches they camped on after returning from their trip (D’Antonio et al., 2013; Stamberger et al., 2018).

Results from research such as this, provide park managers the information they need to determine how best to mitigate recreation ecological damage and maintain a wilderness experience for visitors. This analysis has also garnered evidence to improve existing campsite monitoring protocols. Management suggestions might include; designating campsites, moving to a reservation system for use, or promoting camping use on more durable surfaces. Furthermore, we believe the ecological conclusions brought forth in this report can be extended to public land campsites, off of a road system, in temperate coastal rainforests. Campsites in British Columbia, Canada and the Pacific Northwest region of the United States would likely prove suitable environments to test the suggested optimized protocol.

Conclusion

While patterns in campsites were hard to discern, looking more broadly at the park region level, beaches in Resurrection (Bulldog) and Aialik Bay (Holgate North and South and Quicksand South) recovered more than beaches in Northwestern Fjord (NW Landing and Sunlight) of KEFJ. Future research would include continued longitudinal monitoring of these campsites. To have data that spans decades and has consistent sampling periods would provide a more robust analysis. An alternative monitoring protocol would call for comprehensive sampling every three to five years focusing on: rapid campsite area measurements, tree damage, vegetation cover onsite and at a control plot, tent rock counts, trail counts, condition class ratings, and ghost tree damage. Research such as this should also expand to other locations. Conducting this study in areas with similar biomes could corroborate and support these results or provide new insight into ecological impacts of backcountry camping.

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CHAPTER 4

CONCLUSIONS AND IMPLICATIONS

My thesis objectives were an effort to improve visitor experience and the natural resource conditions in coastal Alaskan National Parks. My objectives were met by combining social science methodologies, GIS analyses, and multiple statistical applications in Glacier Bay National Park and Preserve (GLBA) and Kenai Fjords National Park (KEFJ). I have analyzed visitor preferred conditions of crowding and coastal campsite conditions using normative theory to establish thresholds, operationalized the extent to which visitors encountered less preferred conditions including the view of cruise ships from their campsites with GIS geoprocessing tools, determined areas of concern based on changing environmental site attributes using random coefficient regression models, and provided a more efficient campsite monitoring protocol utilizing a principal component factor analysis and a paired Student's T-tests. My final chapter summarizes my findings, provides the management implications and research limitations of my work, how I foresee this research progressing, and a synopsis of my graduate degree experience.

Summary of findings

My thesis addressed questions to expand the knowledge of normative theory as it is applied in recreational settings, assist public land managers in attaining high quality visitor experiences, and provide more efficient monitoring methodologies. The following summarizes the findings of each of my research questions:

1. Is GLBA in compliance with the crowding and coastal campsite resource condition thresholds based on visitor preferences?

Social and ecological thresholds were established using normative theory methodologies to define minimum acceptable conditions and the relative level of agreement among respondents. Visitors strongly agreed that group sizes exceeding six individuals were less preferred. Current group sizes in the park suggest that crowding conditions are acceptable to most visitors. With less agreement, visitors established campsites exceeding eight tent rocks were less preferred. Nearly half of the observed campsites had tent rock counts exceeding the preferred condition; however, this may not be as big of an issue for visitors given their weak level of agreement in responses. Managers could address this disturbance to the campsite condition by requesting visitors disperse tent rocks after use in the backcountry orientation.

2. What proportion of campsites in GLBA have a cruise ship within its viewshed?

By conducting a visibility analysis in ArcMap (ESRI 2018. ArcMap: Release 10.6. Redlands, CA: Environmental Systems Research Institute), two-thirds of campsites were identified to have the cruise ship path within their viewsheds. Campsites located within smaller inlets (i.e. John Hopkins Inlet) of the west arm and near highly sought-after locations (i.e. tidewater glaciers and day boat kayaker drop-off/pick-up locations) have a higher relative visibility level of cruise ships with cruise ships appearing larger in these locations as well. Campsites located near Margerie Glacier are exposed to cruise ships for a marginally longer period of time as the cruise ships provide ample viewing opportunities for their passengers in this location. GLBA offers opportunities for visitors who prefer an experience without the sight of cruise ships and less crowding in the east arm of the park.

2.a Is it possible to produce a threshold based on backcountry visitors' preferences for the amount of cruise ships seen?

The mean number of cruise ships seen were plotted for each level of bother and how the encounters effected visitors' wilderness experience and a regression analysis was assessed. While it was not possible to numerically define a threshold for the number of cruise ships seen, we found that an increase in the number of cruise ships seen led to a greater disruption from the visitors' wilderness experience. Again, GLBA does provide opportunities and recommended routes for visitors who do not want to encounter cruise ships during their trip to experience more solitude in the east arm of the park.

3. What is the magnitude of change of the sampled ecological variables over time in camping locations in KEFJ?

Random coefficient regression models were utilized to discern patterns in environmental changes on campsites in the park. The majority of campsites and the sampled variables showed recovery across the five-year study period. Patterns were hard to determine at the campsite and beach level, but when examined at the regional level (by bay), there appeared to be changes in visitor use intensity from Resurrection Bay west to Northwestern Fjord over time. Tree damage, mineral soil exposure, and root exposure were indicator variables sensitive to change while campsite area displayed changes in some locations.

4. How can the monitoring protocol be optimized to reduce indicator redundancy, site observation intervals, and be more efficient in the field?

A principal component analysis and paired Student's T-tests provided evidence to eliminate some redundant indictors and extended the sampling interval to create a comprehensive monitoring protocol. We determined that campsite area did not need to be evaluated at the level of precision of radial transect measurements; consequently, we recommend less cumbersome assessment methods. The final comprehensive monitoring protocol suggests sampling take place every three to five years and include: rapid campsite area measurements, tree damage (noting N/A if there are no trees), percent vegetation cover loss, tent rock counts, trail counts, condition class ratings, ghost tree damage (noting N/A if there are no ghost trees), campsite substrate type, high tide measurements (meters), and noting any campsite abnormalities such as trash or human waste. Successful monitoring protocols are dependent on the logistics and feasibility of sampling including finances, time, and crew availability. Maintaining consistency in sampling intervals and methods is the priority.

Management Implications

Chapters two and three of my thesis illustrate the importance of understanding visitor established thresholds on social, experiential, and natural resource conditions and environmental monitoring in parks and protected areas (PPAs). Our GLBA survey results provided trends in the conditions visitors preferred. Varying types of recreationalists have different motivations and expectations. The best way to accommodate for the greatest variety and amount of visitors is to provide a recreational opportunity spectrum (ROS). In GLBA, this would require keeping the motorized and non-motorized zones.

As the estimated change results described, campsites in KEFJ are improving more than they are degrading. While this is desired, there were some areas of concern that managers should investigate further to determine if the results are concurrent with the existing conditions. Additionally, the proposed protocol should allow for more consistent sampling. The developed protocol should also be test to determine if it does make the field sampling more efficient, effective, and productive. As it is designed it should still provide the park with reliable and sensitive measures of environmental condition. Managers and researchers need to confirm the protocols feasibility to ensure the most consistent sampling in the future.

Given the similar visitor demographics (Harpers Ferry Center Interpretive Planning, 2009), ecological systems, and management strategies the information collected in GLBA can be applied in KEFJ and vice versa. The conclusions from this research can also be extended to public land campsites, off of a road system, in temperate coastal rainforests.

Research Limitations

The results of this study are not broadly generalizable due to the context-specific characteristics of my study sites. They can be applied to provide normative thresholds and present environmental changes on campsites in coastal temperate rainforest locations. The GLBA survey that provided the data to establish norms was conducted over a limited period of time. A survey distributed over several years would provide responses from a broader scope of visitor types. Additionally, the observational data used as the existing conditions for group sizes and tent rocks undispersed on campsites were from two different years. It would have been beneficial in the project to determine if there was a correlation between campsites that support larger group sizes and undispersed tent rocks that are less preferred conditions.

While areas of environmental concern were identified with the available campsite data from KEFJ, additional repeat measures of all of the indicator variables at each sampled campsite would have provided a more robust final analysis. To provide more accurate estimates of change at the individual campsite level, more measures would have been necessary. The investigators tried to limit the amount of human biases by providing simple predetermined categories for a majority of the sampled variables for technicians to select while in the field. This was an effort to make data collection simple and streamlined so data could be collected by several different technicians over time without requiring extensive training. I recognize the potential bias in having different technicians collect the data may elicit some variability in the responses; however, this emphasizes the importance of simplified monitoring protocols that can provide consistency.

Future Research

Investigating spatial and temporal patterns of visitor use is an important principle of recreation ecology. Tracking visitor use by providing participating visitors with GPS units or recreation phone applications, such as Strava when cellphone coverage is available, are emerging practices used to investigate high density use areas (Beeco et al., 2014; Kidd et al., 2018), relationships between use levels and environmental responses (D’Antonio et al., 2013), and visitor behavior in locations with no formal trails or infrastructure (Stamberger et al., 2018). Research is currently underway that explores the spatial and temporal patterns of cruise ships and kayakers in the open-waters of GLBA. Using GPS devices to track backcountry visitor trips, model predictions are being assessed to determine if backcountry visitors actively avoid cruise ships while they are in the open-water. The same GPS tracks are being used to map the ecological similarities of campsites visitors choose to utilize and establish any discernable patterns.

In KEFJ, testing the effectiveness of the new proposed monitoring protocol would be valuable. As it would take a few years to start examining environmental changes, at least nine years to have three samples per campsite, this would be a longitudinal project. Since the study period of the data analyzed in this thesis ended eight years before it was examined, reevaluating the campsites with the original protocol would be of interest in the interim. Understanding how the campsites changed in eight years and determining if the regression models were accurate in predicting areas of concern would only add to the development of an optimized monitoring protocol. Additionally to develop this research further, knowing the amount of visitors that have accessed areas of the park (campsite, beach, or bay) would provide a comprehensive analysis to understand the effect of visitor use levels on the amount environmental change. Identifying how many overnight visitors enter KEFJ and recording some of their trip details; where in the park they camped, how many nights they camp, and how they get to the campsites (sea plane, kayak, motorized boat) would prove helpful for future studies. Having the ability to measure how much ecological change could occur at specific sites would provide managers a guide to how much use a site can handle before irreversible changes happen to the site. Collecting visitor spatial data could be done by providing visitors a GPS unit to track their trip. Park managers could also request that visitors report back their campsite locations upon return from their trip.

Overall Experience Synopsis

Starting my graduate degree I had three goals in mind; 1. Improve my technical and grant writing skills, 2. Learn to use statistical applications and software, and 3. Learn GIS and its associated software applications. I accomplished these goals through my thesis project and the additional project opportunities provided in Dr. Chris Monz' lab. I conducted social and ecological field works in GLBA and Orange County, California as well as joined a project synthesizing data collected from Rocky Mountain National Park. These opportunities made me a better writer and researcher.

While visitor use extent was not a focus of my thesis project, I did have the opportunity to map the effect of a management intervention on visitor use in Rocky Mountain National Park. By analyzing over 300 vehicle GPS tracks, my colleagues and I determined how temporarily diverting visitors away from one of the most popular day use areas, Bear Lake, affected other areas of the park. In this project we determined there was limited substitutability for Bear Lake as diverted visitors ultimately returned to the Bear Lake Corridor at some point during their trip. The direct management solution eased the burden of crowding and overuse in one area but diffused visitor use leading to potential resource and social issues in other areas. Our results and ideas for this project were written for a peer review journal article and are currently in review at the Journal of Parks and Recreation Administration.

I did not have the opportunity to collect data in the field in KEFJ to examine the environmental impacts of campsites, but I did complete field work in Orange County, California parks examining the ecological integrity of formal and social trails. This combined with the field work experience of distributing surveys to visitors in GLBA provided me with both ecological and social science data collect experience. Overall, I am proud of the improvements I have made and challenges I accepted by taking on learning novel social science and ecological approaches, statistical software, and GIS which were all new to me when I started. I am grateful for this experience and excited to see where these new skills take me.

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APPENDIX

Indicator Variable Estimated Annual Change by Campsite and Park Region

Table 3.11a. Indicator variable baseline (intercept) and annual change (slope) estimates by campsite.

Tag Number	Area (m^2)	Condition Class	Vegetation Loss (%)	Tent Rocks	Trails	Ghost Tree Damage	Trash	Human Waste
Abra								
67	17.96	2.00	-226.20	16.00	2.00	1.00	0.00	0.00
	(3.08)+	(0.00)+	(30.70)+	(0.00)+	(0.00)+	(0.00)+	(0.00)+	(0.00)+
68	44.78	3.67	-23.60	16.00	4.00	1.00	0.00	0.00
	(-4.87)+	(-0.33)+	(0.00)+	(0.00)+	(0.00)+	(0.00)+	(0.00)+	(0.00)+
69	NA	1.00	-34.23	16.00	-2.00	1.00	0.00	0.00
		(1.00)+	(9.55)+	(0.00)+	(1.00)+	(0.00)+	(0.00)+	(0.00)+
74	28.72	2.57	-69.11	13.00	1.43	1.00	0.00	0.00
	(-4.15)	(-0.07)	(12.22)	(-2.00)	(0.07)	(0.00)+	(0.00)+	(0.00)+
75	42.61	4.43	4.27	16.00	2.57	1.00	0.00	0.00
	(-1.98)	(-0.43)	(-6.19)	(0.00)+	(-0.07)	(0.00)+	(0.00)+	(0.00)+
90	24.47	2.00	-88.62	24.25	4.50	1.00	0.00	0.00
	(-3.80)+	(0.00)+	(9.76)+	(-2.75)+	(-0.50)+	(0.00)+	(0.00)+	(0.00)+
91	NA	4.50	-15.13	24.25	1.00	1.00	0.00	0.00
		(-0.50)+	(0.00)+	(-2.75)+	(0.00)+	(0.00)+	(0.00)+	(0.00)+
Bear Cove								
18	67.50	4.83	-30.04	6.38	4.50	1.25	1.10	0.00
	(-8.44)+	(-0.50)	(5.16)	(0.37)	(-0.50)**	(0.25)+	(-0.25)+	(0.00)+
38	73.78	4.83	-7.69	14.92	2.58	1.67	1.08	0.00
	(-9.42)+	(-0.50)	(0.00)	(0.25)	(0.25)	(0.00)+	(-0.25)+	(0.00)+
39	48.86	4.83	-3.06	20.33	4.20	1.00	1.75	0.00
	(-3.26)	(-0.50)	(0.26)	(-3.00)	(-0.50)	(0.00)+	(-0.25)+	(0.00)+
40	61.55	3.42	-44.10	7.67	5.17	0.92	1.08	0.00
	(-10.30)+	(-0.25)	(5.16)	(-0.50)	(-0.50)	(0.25)+	(-0.25)+	(0.00)+
41	287.99	3.42	-62.12	-1.00	2.92	1.67	1.08	0.00
	(-46.28)+	(-0.25)	(-0.99)	(3.50)	(0.25)+	(0.00)+	(-0.25)+	(0.00)+
42[1]	137.60	2.50	-94.75	0.00	3.58	1.00	1.08	0.00
	(-28.95)	(-0.50)**	(0.00)	(0.00)+	(-0.75)	(0.00)+	(-0.25)+	(0.00)+
Bulldog								
76	57.00	4.43	-39.58	20.71	3.86	1.00	1.86	0.00
	(-3.10)	(-0.43)	(4.02)	(-1.96)	(-0.36)	(0.00)+	(-0.36)+	(0.00)+
77[1]	40.01	3.14	191.32	27.00	5.00	1.00	0.00	0.00
	(-8.25)	(-0.64)	(-145.16)+	(-5.50)+	(-1.00)**	(0.00)+	(0.00)+	(0.00)+
78	NA	3.00	-20.04	0.00	0.00	1.00	0.00	0.00
		(-1.00)+	(-26.32)+	(0.00)+	(0.00)+	(0.00)+	(0.00)+	(0.00)+
80[1]	120.67	5.57	18.75	13.00	0.29	1.57	1.86	0.00
	(-24.12)+	(-1.07)	(-20.95)*	(-2.00)	(0.21)	(-0.07)+	(-0.36)+	(0.00)+
81	123.10	3.00	-15.32	16.00	-0.29	1.00	1.86	0.00
	(-21.73)	(0.00)	(2.13)	(0.00)+	(0.79)	(0.00)+	(-0.36)+	(0.00)+
Holgate North								
31[1]	28.23	3.92	-52.64	28.09	2.50	1.00	1.08	0.00
	(-5.65)+	(-0.75)	(-6.68)+	(-6.25)	(-0.50)**	(0.00)+	(-0.25)+	(0.00)+
32	14.78	4.58	2.04	15.25	4.58	1.00	1.08	0.00
	(-0.73)+	(-0.75)	(-5.42)	(-2.25)	(-0.75)	(0.00)+	(-0.25)+	(0.00)+

Tag Number	Area (m^2)	Condition Class	Vegetation Loss (%)	Tent Rocks	Trails	Ghost Tree Damage	Trash	Human Waste
33	NA	3.92 (-0.75)	-15.24 (-5.67)	28.04 (-3.63)	7.50 (-1.50)	1.00 (0.00)+	1.08 (-0.25)+	0.00 (0.00)+
34[1]	79.52 (-15.90)+	5.00 (-1.00)**	-15.51 (-8.10)+	12.75 (-0.75)+	2.50 (-0.50)**	1.00 (0.00)+	1.08 (-0.25)+	0.00 (0.00)+
35[1]	NA	3.25 (-0.75)	-15.66 (-27.78)+	7.50 (-1.50)+	3.25 (-0.75)	1.00 (0.00)+	1.08 (-0.25)+	0.00 (0.00)+
36	NA	3.50 (-0.50)+	-52.64 (-6.68)+	14.50 (0.50)+	5.50 (-1.50)+	2.50 (-0.50)+	1.50 (-0.50)+	0.00 (0.00)+
Holgate South								
2	87.38 (-16.48)	4.50 (-0.50)+	-59.05 (7.09)+	10.50 (0.00)+	4.50 (-0.50)+	1.00 (0.00)+	0.00 (0.00)+	0.00 (0.00)+
64[1]	32.46 (-6.49)+	5.00 (-1.00)+	NA	5.00 (-1.00)+	0.00 (0.00)+	1.00 (0.00)+	0.00 (0.00)+	0.00 (0.00)+
72[1]	32.97 (-6.34)	5.00 (-1.00)**	35.49 (-26.31)+	3.86 (-0.86)	1.86 (-0.36)	1.00 (0.00)+	0.00 (0.00)+	0.00 (0.00)+
McMullen								
84	35.23 (-4.45)+	2.00 (0.00)+	-71.04 (0.00)	-0.25 (3.75)	-0.50 (0.50)**	1.33 (0.00)+	1.08 (-0.25)+	0.00 (0.00)+
85	-4.34 (2.68)+	-0.50 (0.50)+	-133.95 (20.97)	-16.50 (6.50)+	-0.42 (0.25)	2.42 (-0.25)+	1.08 (-0.25)+	1.08 (-0.25)+
104	47.34 (-6.48)+	2.00 (0.00)+	23.00 (-20.97)	16.00 (0.00)+	2.00 (0.00)+	2.75 (-0.25)+	1.08 (-0.25)+	0.00 (0.00)+
114	NA	NA	-99.00 (0.00)+	NA	1.25 (-0.25)+	1.00 (0.00)+	1.25 (-0.25)+	0.00 (0.00)+
Northeastern								
50	414.34 (-57.82)	2.57 (-0.07)	-89.53 (2.01)	16.00 (0.00)+	0.43 (0.57)	1.00 (0.00)+	0.00 (0.00)+	0.00 (0.00)+
51	35.44 (-5.68)	2.00 (0.00)+	-144.91 (10.20)	0.86 (2.14)	1.57 (-0.07)	1.00 (0.00)+	0.00 (0.00)+	0.00 (0.00)+
52	44.46 (-6.87)*	2.57 (-0.07)	-80.05 (7.98)	7.29 (-0.54)	2.57 (-0.07)	1.00 (0.00)+	0.00 (0.00)+	0.00 (0.00)+
53	54.66 (-10.30)	0.71 (0.29)	-144.91 (10.20)	5.57 (-1.07)	0.14 (0.36)	1.00 (0.00)+	0.00 (0.00)+	0.00 (0.00)+
54	191.49 (-7.87)	3.00 (0.00)	-134.31 (20.25)	16.00 (0.00)+	1.36 (0.36)	1.00 (0.00)+	0.00 (0.00)+	0.00 (0.00)+
55	47.19 (-1.02)+	3.90 (-0.40)	6.39 (-20.07)	10.50 (0.00)+	3.00 (0.00)+	1.00 (0.00)+	0.00 (0.00)+	0.00 (0.00)+
58	70.25 (-8.72)	3.89 (-0.36)	-5.98 (-2.84)	17.57 (-1.57)	-0.14 (0.64)	1.00 (0.00)+	0.00 (0.00)+	0.00 (0.00)+
59	71.83 (-1.37)+	3.67 (-0.33)+	-136.04 (18.52)+	16.00 (0.00)+	4.00 (0.00)+	1.00 (0.00)+	0.00 (0.00)+	0.00 (0.00)+
60	38.76 (4.46)	3.00 (0.00)+	-28.13 (1.67)	17.65 (-1.65)	4.70 (-0.20)	1.00 (0.00)+	0.00 (0.00)+	0.00 (0.00)+

Tag Number	Area (m^2)	Condition Class	Vegetation Loss (%)	Tent Rocks	Trails	Ghost Tree Damage	Trash	Human Waste
88	29.25	4.50	-91.11	26.25	3.00	1.00	0.00	0.00
	(-1.94)+	(-0.50)+	(17.11)+	(-5.25)+	(0.00)+	(0.00)+	(0.00)+	(0.00)+
89	39.17	4.67	-10.46	25.50	-1.33	1.00	0.00	0.00
	(-5.20)+	(-0.50)	(1.83)	(-5.25)	(1.00)	(0.00)+	(0.00)+	(0.00)+
NW Landing								
46	17.47	3.00	-262.74	27.00	3.00	1.00	0.00	0.00
	(-1.04)+	(0.00)+	(81.87)+	(-5.50)+	(0.00)+	(0.00)+	(0.00)+	(0.00)+
47	10.89	0.00	101.68	-12.00	1.00	1.00	0.00	0.00
	(10.25)+	(1.00)+	(-62.64)+	(7.50)+	(1.00)+	(0.00)+	(0.00)+	(0.00)+
48	12.78	-1.00	-20.04	9.00	0.00	1.00	0.00	0.00
	(0.09)+	(1.00)+	(-26.32)+	(-3.00)+	(1.00)+	(0.00)+	(0.00)+	(0.00)+
49	18.45	-1.00	-99.00	3.00	0.00	1.00	0.00	0.00
	(-0.41)+	(1.00)+	(0.00)+	(0.00)+	(1.00)+	(0.00)+	(0.00)+	(0.00)+
Pedersen								
5	303.71	3.00	-27.94	7.29	5.86	1.00	0.00	0.00
	(-61.65)	(0.00)	(1.64)	(-0.54)	(0.14)	(0.00)+	(0.00)+	(0.00)+
6	149.98	2.57	-64.02	3.00	7.43	2.71	0.00	0.00
	(-28.05)	(-0.07)	(-5.65)	(0.00)	(-1.43)	(-0.21)+	(0.00)+	(0.00)+
7	11.71	3.00	-37.78	21.75	4.50	1.00	0.00	0.00
	(2.39)	(0.00)+	(0.00)+	(-3.75)+	(0.50)+	(0.00)+	(0.00)+	(0.00)+
8	15.94	3.00	-34.17	7.50	-0.50	1.00	0.00	0.00
	(-0.32)	(0.00)+	(6.45)+	(-1.50)+	(1.50)+	(0.00)+	(0.00)+	(0.00)+
9	43.24	3.00	-29.29	21.75	2.00	1.00	0.00	0.00
	(-0.06)	(0.00)+	(-2.83)+	(-3.75)+	(1.00)+	(0.00)+	(0.00)+	(0.00)+
11[1]	100.25	0.00	-99.00	-4.50	0.00	-0.50	0.00	0.00
	(-22.28)	(0.00)+	(0.00)+	(1.50)+	(0.00)+	(0.50)+	(0.00)+	(0.00)+
12	20.84	2.86	-86.24	0.00	2.14	2.86	0.00	0.00
	(-1.09)	(-0.36)	(0.00)	(0.00)+	(0.36)	(-0.36)+	(0.00)+	(0.00)+
13	17.10	2.00	-57.03	5.00	-1.00	1.00	0.00	0.00
	(-1.80)+	(0.00)+	(-3.13)+	(-1.00)+	(1.00)+	(0.00)+	(0.00)+	(0.00)+
14	13.61	2.00	-55.24	5.57	0.29	1.00	0.00	0.00
	(-0.78)	(0.00)+	(-3.35)	(-1.07)	(0.71)	(0.00)+	(0.00)+	(0.00)+
16	37.19	4.00	-15.81	0.14	5.86	2.86	0.00	0.00
	(-1.77)	(0.00)+	(-0.16)	(2.61)	(-0.36)	(-0.36)+	(0.00)+	(0.00)+
79	15.61	0.43	-99.00	1.29	0.43	1.00	0.00	0.00
	(-2.32)+	(0.07)	(0.00)	(0.21)	(0.07)	(0.00)+	(0.00)+	(0.00)+
92	NA	3.00	-93.07	3.00	0.00	1.00	0.00	0.00
		(0.00)+	(9.93)+	(0.00)+	(1.00)+	(0.00)+	(0.00)+	(0.00)+
93	9.90	2.00	-116.54	-4.50	3.00	1.00	0.00	0.00
	(0.34)+	(0.00)+	(14.62)+	(1.50)+	(0.00)+	(0.00)+	(0.00)+	(0.00)+
Pocket Cove								
65	52.92	5.29	-18.90	10.50	-1.14	2.86	0.00	0.00
	(-7.03)	(-0.79)	(3.77)	(0.00)	(0.64)	(-0.36)+	(0.00)+	(0.00)+

Tag Number	Area (m²)	Condition Class	Vegetation Loss (%)	Tent Rocks	Trails	Ghost Tree Damage	Trash	Human Waste
73	73.81 (-11.95)+	2.67 (-0.33)+	-64.34 (12.27)+	19.67 (-1.83)+	0.00 (0.00)+	1.00 (0.00)+	0.00 (0.00)+	0.00 (0.00)+
Quicksand North								
27	34.98 (3.77)+	3.00 (0.00)+	-38.37 (7.08)+	3.00 (0.00)+	3.00 (0.00)+	1.00 (0.00)+	0.00 (0.00)+	0.00 (0.00)+
28	54.92 (-9.24)+	4.50 (-0.50)+	-20.13 (1.00)+	-8.25 (3.75)+	3.50 (-0.50)+	3.50 (-0.50)+	0.00 (0.00)+	0.00 (0.00)+
30	7.96 (-0.06)+	2.00 (0.00)+	-96.60 (18.94)+	0.00 (0.00)+	1.50 (0.50)+	1.00 (0.00)+	0.00 (0.00)+	0.00 (0.00)+
83	25.41 (-2.49)+	3.00 (0.00)+	-5.58 (0.00)+	7.50 (-1.50)+	6.00 (-1.00)+	1.00 (0.00)+	0.00 (0.00)+	0.00 (0.00)+
Quicksand South								
19[1]	107.77 (-21.55)+	5.00 (-1.00)+	NA	NA	3.50 (-0.50)+	3.50 (-0.50)+	0.00 (0.00)+	0.00 (0.00)+
21[1]	36.34 (-7.27)+	2.50 (-0.50)+	NA	7.50 (-1.50)+	1.00 (0.00)+	-0.50 (0.50)+	0.00 (0.00)+	0.00 (0.00)+
22	NA	7.50 (-1.50)+	NA	7.50 (-1.50)+	4.50 (-0.50)	3.50 (-0.50)+	0.00 (0.00)+	0.00 (0.00)+
23[1]	25.13 (-5.03)+	5.00 (-1.00)+	NA	26.25 (-5.25)+	5.00 (-1.00)+	3.50 (-0.50)+	0.00 (0.00)+	0.00 (0.00)+
24	24.46 (-3.04)+	3.50 (-0.50)+	-72.68 (0.00)+	21.75 (-3.75)+	3.50 (-0.50)+	1.00 (0.00)+	0.00 (0.00)+	0.00 (0.00)+
25	68.70 (-11.17)+	4.50 (-0.50)+	-95.02 (18.41)+	3.00 (0.00)+	4.50 (-0.50)+	1.00 (0.00)+	0.00 (0.00)+	0.00 (0.00)+
26	27.50 (-0.74)+	4.50 (-0.50)+	-33.31 (3.24)+	24.25 (-2.75)+	0.50 (0.50)+	1.00 (0.00)+	0.00 (0.00)+	0.00 (0.00)+
Southwestern								
56	9.32 (1.45)	1.36 (0.36)	-22.95 (4.34)	16.00 (0.00)+	-1.29 (0.71)	1.00 (0.00)+	0.00 (0.00)+	0.00 (0.00)+
57	10.85 (0.46)	2.00 (0.00)+	-15.13 (0.00)+	16.00 (0.00)+	-0.67 (0.33)+	1.00 (0.00)+	0.00 (0.00)+	0.00 (0.00)+
61	8.28 (0.71)	3.67 (-0.33)+	-23.24 (4.05)+	19.67 (-1.83)+	1.00 (0.00)+	1.00 (0.00)+	0.00 (0.00)+	0.00 (0.00)+
94	18.50 (-1.93)+	0.50 (0.50)+	-29.46 (4.78)+	2.25 (2.75)+	0.50 (0.50)+	1.00 (0.00)+	0.00 (0.00)+	0.00 (0.00)+
95	19.32 (-2.38)+	2.00 (0.00)+	-187.82 (29.61)+	2.25 (2.75)+	2.00 (0.00)+	1.00 (0.00)+	0.00 (0.00)+	0.00 (0.00)+
107[1]	39.51 (-7.90)+	NA	NA	NA	NA	NA	NA	NA
Sunlight								
66	355.90 (-115.76)+	1.00 (0.00)+	20.04 (-39.68)+	10.50 (0.00)+	0.00 (0.00)+	1.00 (0.00)+	0.00 (0.00)+	0.00 (0.00)+

Tag Number	Area (m^2)	Condition Class	Vegetation Loss (%)	Tent Rocks	Trails	Ghost Tree Damage	Trash	Human Waste
Verdant								
63	95.52	2.14	-9.67	20.71	-1.71	2.86	0.00	0.00
	(-13.58)	(-0.14)	(-0.68)	(-1.96)	(0.71)	(-0.36)+	(0.00)+	(0.00)+
70	54.92	4.71	-59.30	10.50	3.86	1.29	0.00	0.00
	(-10.08)*	(-0.71)	(11.91)	(0.00)	(-0.36)	(0.21)+	(0.00)+	(0.00)+
71	72.43	4.71	-10.96	16.93	1.57	1.00	0.00	0.00
	(-10.35)	(-0.71)	(1.35)	(-2.68)	(-0.07)	(0.00)+	(0.00)+	(0.00)+
86	38.41	1.57	-15.13	13.64	-1.71	1.43	0.00	0.00
	(-4.54)+	(-0.07)	(0.00)	(-0.39)	(0.71)	(0.07)+	(0.00)+	(0.00)+
87[1]	31.52	5.00	NA	26.25	5.00	1.00	0.00	0.00
	(-6.30)+	(-1.00)+		(-5.25)+	(-1.00)+	(0.00)+	(0.00)+	(0.00)+
105[1]	64.59	7.50	NA	40.00	3.50	1.00	0.00	1.50
	(-12.92)+	(-1.50)+		(-8.00)+	(-0.50)+	(0.00)+	(0.00)+	(-0.25)+
106	-13.84	3.50	27.98	-8.25	2.50	1.00	0.00	0.00
	(9.20)+	(-0.50)+	(-10.32)+	(3.75)+	(-0.50)+	(0.00)+	(0.00)+	(0.00)+

Variable baseline of predicted 2008 value (Yearly Change). For all variables, a negative yearly change indicates improvement, 0 is no change, positive yearly change indicates degradation.

[1]Recovered campsite

+ Sample size of 2. P-value is not attainable.

*P-value < 0.05

**P-value <0.001

Table 3.11b. Indicator variable baseline (intercept) and annual change (slope) estimates by campsite.

Tag Number	Mineral Soil (%)	Fire Rings	Tree Stumps	Tree Damage	Root Exposure	Latitude (ºN) Longitude (ºW)
Abra						
67	38.00	0.00	0.00	2.67	2.67	59.8945
	(0.00)+	(0.00)+	(0.00)+	(-0.33)+	(-0.33)+	149.6438
68	85.00	0.00	0.00	2.67	1.00	59.8944
	(0.00)+	(0.00)+	(0.00)+	(-0.33)+	(0.00)+	149.6440
69	98.00	0.00	0.00	1.00	1.00	59.8942
	(0.00)+	(0.00)+	(0.00)+	(0.00)+	(0.00)+	149.6447
74	29.43	0.00	0.00	1.00	1.57	59.8943
	(9.82)	(0.00)+	(0.00)+	(0.00)+	(-0.07)+	149.6423
75	120.86	0.00	0.00	1.43	0.71	59.8944
	(-11.61)*	(0.00)+	(0.00)+	(0.07)+	(0.29)+	149.6443
90	71.75	0.00	0.00	1.00	3.50	59.8944
	(-11.25)+	(0.00)+	(0.00)+	(0.00)+	(-0.50)+	149.6425
91	-52.00	0.00	0.00	1.00	1.00	59.8943
	(30.00)+	(0.00)+	(0.00)+	(0.00)+	(0.00)+	149.6419
Bear Cove						
18	120.08	0.00	5.42	1.00	1.00	59.7907
	(-20.75)	(0.00)+	(-1.25)	(0.00)+	(0.00)+	149.6167
38	85.50	0.33	-0.42	1.00	1.00	59.7896
	(0.00)	(0.00)	(0.25)	(0.00)+	(0.00)+	149.6167
39	84.46	0.00	-0.42	1.00	1.00	59.7897
	(3.12)	(0.00)+	(0.25)	(0.00)+	(0.00)+	149.6167
40	48.42	0.00	-0.42	1.00	1.67	59.7898
	(8.75)	(0.00)+	(0.25)	(0.00)+	(0.00)+	149.6167
41	52.79	0.33	0.00	1.00	1.00	59.7903
	(-8.88)	(0.00)	(0.00)+	(0.00)+	(0.00)+	149.6166
42[1]	2.5	0.00	0.00	1.00	1.00	59.7905
	(0.00)	(0.00)+	(0.00)+	(0.00)+	(0.00)+	149.6161
Bulldog						
76	92.64	0.00	0.00	2.86	1.00	59.8913
	(-0.89)	(0.00)+	(0.00)+	(-0.36)+	(0.00)+	149.5580
77[1]	63.00	-0.86	0.00	2.86	2.86	59.8914
	(0.00)+	(0.36)	(0.00)+	(-0.36)+	(-0.36)+	149.5577
78	2.50	1.00	0.00	1.00	1.00	59.8921
	(0.00)+	(0.00)+	(0.00)+	(0.00)+	(0.00)+	149.5632
80[1]	145.50	1.29	0.00	2.86	2.29	59.8912
	(-25.00)	(-0.29)	(0.00)+	(-0.36)+	(-0.29)+	149.5572
81	85.50	1.29	0.00	2.71	2.86	59.8913
	(0.00)	(-0.29)	(0.00)+	(-0.21)+	(-0.36)+	149.5572
Holgate North						
31[1]	38.00	0.00	0.00	1.33	1.33	59.8456
	(0.00)+	(0.00)+	(0.00)+	(0.00)+	(0.00)+	149.7887
32	94.88	0.00	0.00	1.33	1.33	59.8456
	(-5.63)	(0.00)+	(0.00)+	(0.00)+	(0.00)+	149.7889

Tag Number	Mineral Soil (%)	Fire Rings	Tree Stumps	Tree Damage	Root Exposure	Latitude (°N) Longitude (°W)
33	87.38	0.00	0.00	1.33	1.33	59.8455
	(-5.63)	(0.00)+	(0.00)+	(0.00)+	(0.00)+	149.7890
34[1]	51.75	0.00	0.00	1.00	0.50	59.8453
	(11.25)+	(0.00)+	(0.00)+	(0.00)+	(0.50)+	149.7888
35[1]	75.50	0.00	0.00	1.33	1.33	59.8454
	(-12.50)+	(0.00)+	(0.00)+	(0.00)+	(0.00)+	149.7888
36	75.50	0.00	0.00	0.50	1.00	59.8457
	(-12.50)+	(0.00)+	(0.00)+	(0.50)+	(0.00)+	149.7890
Holgate South						
2	63.00	0.00	0.00	1.00	1.00	59.8318
	(0.00)+	(0.00)+	(0.00)+	(0.00)+	(0.00)+	149.7688
64[1]	NA	0.00	0.00	2.67	2.67	59.8365
		(0.00)+	(0.00)+	(-0.33)+	(-0.33)+	149.7717
72[1]	156.64	0.00	0.00	1.00	1.00	59.8380
	(-29.64)	(0.00)+	(0.00)+	(0.00)+	(0.00)+	149.7740
McMullen						
84	98.00	0.00	0.00	1.33	1.00	59.7634
	(0.00)+	(0.00)+	(0.00)+	(0.00)+	(0.00)+	149.7685
85	98.00	-0.42	0.00	1.00	1.00	59.7635
	(0.00)+	(0.25)	(0.00)+	(0.00)+	(0.00)+	149.7684
104	98.00	0.00	0.00	1.00	1.00	59.7633
	(0.00)+	(0.00)+	(0.00)+	(0.00)+	(0.00)+	149.7686
114	NA	0.75	0.00	1.00	1.00	59.7627
		(0.25)+	(0.00)+	(0.00)+	(0.00)+	149.7684
Northeastern						
50	57.29	-0.86	-0.86	2.71	2.86	59.8016
	(-8.04)+	(0.36)	(0.36)	(-0.21)+	(-0.36)+	150.0138
51	2.50	-0.86	0.00	2.71	2.86	59.8018
	(0.00)	(0.36)	(0.00)+	(-0.21)+	(-0.36)+	150.0138
52	15.50	0.00	0.00	2.86	2.86	59.8015
	(0.00)	(0.00)+	(0.00)+	(-0.36)+	(-0.36)+	150.0137
53	2.50	0.00	0.00	2.86	2.86	59.8015
	(0.00)	(0.00)+	(0.00)+	(-0.36)+	(-0.36)+	150.0135
54	63.00	0.00	0.00	0.36	1.00	59.8007
	(0.00)	(0.00)+	(0.00)+	(0.36)+	(0.00)+	150.0126
55	79.00	0.00	0.00	1.00	1.00	59.8009
	(-4.75)	(0.00)+	(0.00)+	(0.00)+	(0.00)+	150.0126
58	101.57	2.57	0.00	1.00	1.00	59.8004
	(-3.57)	(-0.57)	(0.00)+	(0.00)+	(0.00)+	150.0123
59	117.17	0.00	0.00	1.00	1.00	59.8006
	(-15.83)+	(0.00)+	(0.00)+	(0.00)+	(0.00)+	150.0125
60	103.50	0.00	0.00	2.20	2.80	59.8005
	(-6.75)	(0.00)+	(0.00)+	(-0.20)+	(-0.30)+	150.0128
88	66.75	0.00	0.00	3.50	3.50	59.8004
	(6.25)+	(0.00)+	(0.00)+	(-0.50)+	(-0.50)+	150.0125

Tag Number	Mineral Soil (%)	Fire Rings	Tree Stumps	Tree Damage	Root Exposure	Latitude (ºN) Longitude (ºW)
89	98.00	0.00	0.00	1.00	1.00	59.8004
	(0.00)	(0.00)+	(0.00)+	(0.00)+	(0.00)+	150.0124
NW Landing						
46	18.00	3.00	12.00	1.00	1.00	59.7563
	(22.50)+	(-1.00)+	(-4.00)+	(0.00)+	(0.00)+	149.8944
47	-23.50	0.00	3.00	4.00	4.00	59.7564
	(13.00)+	(0.00)+	(-1.00)+	(-1.00)+	(-1.00)+	149.8945
48	2.50	0.00	0.00	1.00	1.00	59.7565
	(0.00)+	(0.00)+	(0.00)+	(0.00)+	(0.00)+	149.8945
49	2.50	0.00	0.00	1.00	1.00	59.7566
	(0.00)+	(0.00)+	(0.00)+	(0.00)+	(0.00)+	149.8945
Pedersen						
5	-41.93	1.00	1.57	2.29	1.00	59.8796
	(20.68)	(0.00)+	(-0.07)	(-0.29)+	(0.00)+	149.7369
6	2.50	1.29	0.00	1.00	1.57	59.8797
	(0.00)	(-0.29)	(0.00)+	(0.00)+	(-0.07)+	149.7370
7	-88.25	-1.50	-1.50	3.50	1.00	59.8798
	(30.25)+	(0.50)+	(0.50)+	(-0.50)+	(0.00)+	149.7367
8	2.50	1.00	0.00	1.00	-0.50	59.8797
	(0.00)+	(0.00)+	(0.00)+	(0.00)+	(0.50)+	149.7366
9	-50.75	-1.50	0.00	3.50	1.00	59.8797
	(17.75)+	(0.50)+	(0.00)+	(-0.50)+	(0.00)+	149.7366
11[1]	2.50	0.00	0.00	1.00	-0.50	59.8796
	(0.00)+	(0.00)+	(0.00)+	(0.00)+	(0.50)+	149.7373
12	2.50	1.29	-0.86	1.00	2.29	59.8798
	(0.00)	(-0.29)	(0.36)	(0.00)+	(-0.29)+	149.7370
13	-6.17	0.00	-1.33	1.00	1.00	59.8797
	(4.33)+	(0.00)+	(0.67)+	(0.00)+	(0.00)+	149.7369
14	-27.93	0.00	-0.86	1.00	2.29	59.8799
	(12.68)	(0.00)+	(0.36)	(0.00)+	(-0.29)+	149.7367
16	43.71	-0.29	0.00	1.00	1.00	59.8795
	(8.04)	(0.29)	(0.00)+	(0.00)+	(0.00)+	149.7371
79	2.50	0.00	0.43	2.67	1.43	59.8799
	(0.00)	(0.00)+	(0.71)	(-0.33)+	(0.07)+	149.7364
92	-50.75	0.00	3.50	1.00	-0.50	59.8795
	(17.75)+	(0.00)+	(-0.50)+	(0.00)+	(0.50)+	149.7368
93	2.50	0.00	3.00	1.00	1.00	59.8795
	(0.00)+	(0.00)+	(0.00)+	(0.00)+	(0.00)+	149.7367
			Pocket Cove			
65	108.71	0.00	0.00	1.00	2.29	59.8533
	(-4.46)	(0.00)+	(0.00)+	(0.00)+	(-0.29)+	149.6577
73	77.17	1.00	-0.67	0.33	0.33	59.8535
	(4.17)+	(0.00)+	(0.33)+	(0.33)+	(0.33)+	149.6577
			Quicksand North			
27	66.75	0.00	0.00	1.00	1.00	59.7886
	(6.25)+	(0.00)+	(0.00)+	(0.00)+	(0.00)+	149.7885

Tag Number	Mineral Soil (%)	Fire Rings	Tree Stumps	Tree Damage	Root Exposure	Latitude (ºN) Longitude (ºW)
28	66.75	0.00	0.00	1.00	1.00	59.7888
	(6.25)+	(0.00)+	(0.00)+	(0.00)+	(0.00)+	149.7884
30	35.00	0.00	0.00	1.00	1.00	59.7880
	(-6.50)+	(0.00)+	(0.00)+	(0.00)+	(0.00)+	149.7894
83	98.00	0.00	0.00	1.00	1.00	59.7884
	(0.00)+	(0.00)+	(0.00)+	(0.00)+	(0.00)+	149.7889
Quicksand South						
19[1]	NA	0.00	0.00	1.00	1.00	59.7841
		(0.00)+	(0.00)+	(0.00)+	(0.00)+	149.7897
21[1]	NA	0.00	0.00	-0.50	1.00	59.7840
		(0.00)+	(0.00)+	(0.50)+	(0.00)+	149.7896
22	NA	0.00	0.00	1.00	1.00	59.7835
		(0.00)+	(0.00)+	(0.00)+	(0.00)+	149.7895
23[1]	NA	0.00	0.00	1.00	1.00	59.7831
		(0.00)+	(0.00)+	(0.00)+	(0.00)+	149.7891
24	71.75	0.00	0.00	1.00	-0.50	59.7827
	(-11.25)+	(0.00)+	(0.00)+	(0.00)+	(0.50)+	149.7889
25	66.75	0.00	0.00	1.00	1.00	59.7826
	(6.25)+	(0.00)+	(0.00)+	(0.00)+	(0.00)+	149.7889
26	63.00	0.00	0.00	1.00	1.00	59.7828
	(0.00)+	(0.00)+	(0.00)+	(0.00)+	(0.00)+	149.7891
Southwestern						
56	98.00	0.00	0.00	2.71	2.71	59.7641
	(0.00)	(0.00)+	(0.00)+	(-0.29)+	(-0.29)+	150.0605
57	98.00	0.00	0.00	1.00	1.00	59.7643
	(0.00)+	(0.00)+	(0.00)+	(0.00)+	(0.00)+	150.0605
61	98.00	0.00	0.00	1.00	1.00	59.7640
	(0.00)+	(0.00)+	(0.00)+	(0.00)+	(0.00)+	150.0608
94	98.00	0.00	0.00	3.50	3.50	59.7644
	(0.00)+	(0.00)+	(0.00)+	(-0.50)+	(-0.50)+	150.0602
95	85.50	0.00	0.00	3.50	3.50	59.7644
	(0.00)+	(0.00)+	(0.00)+	(-0.50)+	(-0.50)+	150.0604
107[1]	NA	NA	NA	NA	NA	59.7643
						150.0606
Sunlight						
66	83.00	0.00	0.00	1.00	1.00	59.7493
	(-22.50)+	(0.00)+	(0.00)+	(1.00)+	(1.00)+	149.9845
Verdant						
63	98.00	1.29	0.00	1.00	1.00	59.6986
	(0.00)	(-0.29)	(0.00)+	(0.00)+	(0.00)+	149.7329
70	74.79	0.29	3.86	0.14	1.00	59.6968
	(4.46)	(0.21)	(-0.86)	(0.36)+	(0.00)+	149.7387
71	74.79	1.29	-2.57	1.00	2.86	59.6967
	(4.46)	(-0.29)	(1.07)	(0.00)+	(-0.36)+	149.7388
86	98.00	-0.86	0.00	1.00	1.00	59.6986
	(0.00)	(0.36)	(0.00)+	(0.00)+	(0.00)+	149.7331

Tag Number	Mineral Soil (%)	Fire Rings	Tree Stumps	Tree Damage	Root Exposure	Latitude (°N) Longitude (°W)
87[1]	NA	0.00 (0.00)+	0.00 (0.00)+	1.00 (0.00)+	1.00 (0.00)+	59.6982 149.7340
105[1]	NA	0.00 (0.00)+	0.00 (0.00)+	1.00 (0.00)+	1.00 (0.00)+	59.6984 149.7334
106	150.50 (-17.50)+	0.00 (0.00)+	0.00 (0.00)+	1.00 (0.00)+	1.00 (0.00)+	59.6981 149.7343

Variable baseline of predicted 2008 value (Yearly Change). For all variables, a negative yearly change indicates improvement, 0 is no change, positive yearly change indicates degradation.

[1]Recovered campsite

+ Sample size of 2. P-value is not attainable.

*P-value < 0.05

**P-value <0.001

Table 3.12a. Indicator variable baseline (intercept) and annual change (slope) estimates by park region.

Region	Area (m^2)	Condition Class	Vegetation Loss (%)	Tent Rocks	Trails	Ghost Tree Damage	Trash	Human Waste
Aialik Bay	66.79 (-11.05)**	3.64 (-0.44)**	-42.31 (1.42)	10.55 (-0.85)*	2.64 (-0.14)*	0.72 (-0.09)*	0.44 (0.13)**	0.02 (0.00)
Northwestern Fjord	66.99 (-7.61)*	2.43 (-0.06)	-74.96 (6.70)	11.47 (-0.37)	1.40 (0.23)*	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Resurrection Bay	78.36 (-12.78)*	3.41 (-0.48)*	-56.19 (-4.30)	16.80 (-2.04)	2.00 (-0.07)	0.18 (-0.03)	0.34 (0.27)*	0.00 (0.00)

Variable baseline of predicted 2008 value (Yearly Change). For all variables, a negative yearly change indicates improvement, 0 is no change, positive yearly change indicates degradation.

*P-value < 0.05

**P-value <0.001

Table 3.12b. Indicator variable baseline (intercept) and annual change (slope) estimates by park region.

Region	Mineral Soil (%)	Fire Rings	Tree Stumps	Tree Damage	Root Exposure
Aialik Bay	62.35	0.14	0.13	0.81	0.82
	(-0.28)	(0.01)	(0.03)	(0.00)	(0.03)
Northwestern Fjord	63.90	0.13	0.34	1.66	1.54
	(-2.17)	(-0.01)	(-0.07)	(-0.23)**	(-0.20)**
Resurrection Bay	74.59	0.46	0.00	1.57	1.44
	(-5.05)	(-0.04)	(0.00)	(-0.20)	(-0.23)*

Variable baseline of predicted 2008 value (Yearly Change). For all variables, a negative yearly change indicates improvement, 0 is no change, positive yearly change indicates degradation.

*P-value < 0.05

**P-value <0.001