8-2024

Socially Valued, Ecologically in Decline: Place Attachment Influences Support for Management Actions in a Quaking Aspen Forest Impacted by Recreation, Soil Contamination, And Ungulates

Georgie Corkery
Utah State University

SOCIALLY VALUED, ECOLOGICALLY IN DECLINE: PLACE ATTACHMENT

INFLUENCES SUPPORT FOR MANAGEMENT ACTIONS IN A

QUAKING ASPEN FOREST IMPACTED BY RECREATION,

SOIL CONTAMINATION, AND UNGULATES

by

Georgie Corkery

A thesis proposal submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Ecology

Approved:

Anna Miller, Ph.D. Major Professor	Jessica Schad, Ph.D. Committee Member
Paul C. Rogers, Ph.D. Committee Member	D. Richard Culter, Ph.D. Vice Provost of Graduate Studies

UTAH STATE UNIVERSITY
Logan, Utah

2024

ABSTRACT

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by

Georgie Corkery, Master of Ecology

Utah State University, 2024

Major Professors: Dr. Anna B. Miller and Dr. Paul C. Rogers
Department: Environment and Society

Quaking aspen (*Populus tremuloides* Michx.) spark strong emotional attachments among many people, yet they are ecologically in decline across North America. Aspen landscapes also serve as popular outdoor recreation destinations. Nuanced and site-specific strategies are required for managing both healthy aspen landscapes and enhancing the outdoor recreation experience. Our study investigated a highly-recreated and ecologically declining aspen forest in Summit County, Utah. There were two distinct phases of data collection. First, we conducted a landscape evaluation using established sampling methods to assess the condition of the aspen. Based on the findings from the landscape evaluation, we identified potential management actions that could improve the condition of the aspen. Subsequently, we implemented a user intercept survey. The survey assessed how aspen is valued by the users who visit our site and prompted users to identify their level of support for the management actions identified above. Results from the ecological evaluation indicate ungulate presence, soil contamination, and recreation are the primary mechanisms negatively impacting the aspen condition across our site. Survey results indicate that place attachment is the primary factor driving support for proposed management actions, though there was broad support for management actions overall. This study can serve as a guide for how managers of high-use aspen landscapes can assess both the ecological and social dimensions of the aspen landscape they manage.

(133 pages)

PUBLIC ABSTRACT

Socially valued, ecologically in decline: Place attachment influences support for management actions in a quaking aspen forest impacted by recreation, soil contamination, and ungulates

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Quaking aspen (Populus tremuloides Michx.) spark strong emotional attachments among many people, yet they are ecologically in decline across North America. Aspen landscapes are also popular outdoor recreation destinations. Site-specific strategies are required for both managing for healthy aspen landscapes and enhancing the outdoor recreation experience. Our study investigated a highly-recreated and ecologically declining aspen forest in Summit County, Utah facing population decline. There were two distinct phases of data collection. First, we evaluated the condition of the aspen and identified potential management actions that could improve the condition of the aspen. Second, we surveyed people who visited the site to recreate. The survey assessed how people value aspen and asked them to rank their level of support or opposition for different aspen management strategies. We found that the presence of ungulate (deer and elk), soil contamination, and recreation worsened the aspen condition. We also found that people were generally supportive of the proposed management actions; specifically, those who had a stronger sense of place attachment were more likely to support management actions. This study can serve as a management guide for aspen landscapes that are recreation destinations.

ACKNOWLEDGMENTS

I would first like to thank Dr. Anna B. Miller and Dr. Paul C. Rogers for helping me become a better researcher, writer, critical thinker, and communicator during my time at Utah State University. I genuinely enjoyed working with you both. I would also like to thank my committee member, Dr. Jessica Ulrich-Schad for her helpful guidance and feedback on this research. Additionally, I would like to extend my gratitude to Dr. Jeanette M. Norton for generously guiding me through the process of testing my soil samples. I am grateful for the support from Snyderville Basin Special Recreation District, the Ecology Center at Utah State University, the Institute of Outdoor Recreation and Tourism at the University of Utah, and the Western Aspen Alliance. Additionally, this research would not have been possible without the help provided to me by the Disability Resource Center, the Quinney College of Natural Resources Code Mentoring Committee, Susan Durham, Piper Christian, and the Utah State University graduate students who helped with data collection, include Leanna DeJong, Evan Holt, Iree Wheeler, Casey Trout, Jake Van Deursen, and Sadie Braddock.

I am grateful for my parents (Wilma and Ripley) and sister (Reanna) for always supporting me and my educational, career, and life goals. This entire process was fueled by the assistance and support from Leanna DeJong, Jes Bruan, Iree Wheeler, Casey Trout, Misha Stemkovski, Jake Richards, and Greg Davis. Thank you to the USU QCNR graduate student community for being so wonderful and encouraging, and thanks to my friends and community in Salt Lake City who have been consistently supportive and inspiring.

Georgie Corkery

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CHAPTER I

A SOCIAL-ECOLOGICAL SYSTEM: QUAKING ASPEN AND RECREATION

Introduction

Quaking aspen (*Populus tremuloides* Michx.) are the most widely distributed tree species in North America (Little & Viereck, 1971; Perala et al., 1990). Aspen have ecological and social dimensions that shape the way we value and manage forested landscapes. Ecologically, aspen serve as a keystone species, providing unique habitat that supports hundreds of dependent species (Chong et al., 2001; Hardenbol et al., 2020; Kuhn et al., 2011; Rogers et al., 2020). Socially, aspen have symbolic, aesthetic, cultural, and instrumental value, including aspen forests serving as recreation destinations (Assal & Keables, 2020; Dahms & Geils, 1997; McCool, 2001; Rogers & Gale, 2017; Williams & Patterson, 1999). Both dimensions are under threat as aspen face uninhibited ungulate browsing (Angelstam et al., 2017; Edenius et al., 2011; Kota & Bartos, 2010; Myking et al., 2011; Usoltsev et al., 2018), fire suppression (Cocke et al., 2005), a changing climate (Martin & Maron, 2012; Rehfeldt et al., 2009), drought (Worrall et al., 2013), and development-related habitat loss (Rehfeldt et al., 2009).

When addressing these threats, land managers must curate unique treatments based on the condition of the specific landscape they oversee (Kitchen et al., 2019). Similarly, managing protected outdoor recreation areas requires an in-depth understanding of user values. User values have guided decision-making related to the social, biophysical, and managerial settings of protected places (McLaughlin & Paradice, 1980), though we are unaware of any study in which user values were incorporated specifically into aspen management. McCool (2001) argued that understanding the social dimensions of aspen is a vital component of any aspen management strategy because treatments that change the landscape also impact the social value and meanings of the landscape. The social-ecological system developed by Miller et al. (2022) helps us understand and frame the interactions between social and ecological dimensions of such a system to then develop methods to address both dimensions in tandem.

Background

Aspen Forest Management

Maintaining healthy and resilient aspen ecosystems is done for multiple purposes, such as wildlife habitat, watershed stability, aesthetics, and recreation (USDA Forest Service, 2018). Having a diverse height structure is a key characteristic of a resilient aspen forest (Crouch et al., 2023; Fahey et al., 2018; Kurzel et al., 2007; Puettmann et al., 2013; Rogers et al., 2014). Common treatment strategies to achieve a diverse height structure in forests experiencing population decline include fencing to deter overbrowsing by ungulates (Bailey et al., 2007; Beschta & Ripple, 2010; Martin & Maron, 2012; Rogers & McAvoy, 2018; Rolf, 2001), controlled burning (Kaye, 2011; Kulakowski et al., 2004; Shepperd et al., 2006), and selective aspen cutting (Covington et al., 1983; Crouch et al., 2023; Higgins et al., 2015; Kitchen et al., 2019; Shepperd et al., 2006; Walters, 1982). It is essential to pair all treatments with vigilant monitoring to ensure desired outcomes (Bork et al., 2013; Rogers & Mittanck, 2014; Seager et al., 2013).

Outdoor Recreation Management

The goal of outdoor recreation management is to balance providing a high-quality outdoor recreation experience with preserving ecological conditions and resources in the spaces where that recreation occurs (Manfredo et al., 1983; Shin, 1997). Recreation managers use a wide variety of user feedback to improve outdoor recreation experiences (Manning, 2022; McLaughlin & Paradice, 1980; Needham & Rollins, 2005). Common tactics mangers use to gather user feedback are to measure users' place attachment (Gundersen et al., 2015; S. R. Martin et al., 2009), motivations (Arnberger et al., 2022; Hall et al., 2010), perceptions of environmental conditions (Flint et al., 2016; Kyle et al., 2004; White et al., 2008), and frequency of visitation (Hammitt et al., 2004, 2009; Hammitt & McDonald, 1983). Specifically, findings from place attachment surveys can enhance the ability of managers to account for deeper meanings associated with the resources they manage and assist in resolving natural resource-based conflicts, particularly where systems may be degraded (Williams & Vaske, 2003). Additionally, studies have measured user support for land management actions in effort to develop socially sustainable management actions that improve recreation experiences (Borrie et al., 2002; Gundersen et al., 2015; S. R. Martin et al., 2009). Strong relationships have been found between willingness to support management and recreation motivations (Gundersen et al., 2015; Hall et al., 2010), perception of environmental conditions (Mallette et al., 2021), and place attachment (Groshong et al., 2020).

Social-ecological Dimension Interactions

Dimensions of social systems, such as recreation, politics, and economics, and elements of ecological systems, such as vegetation, wildlife, and water bodies, influence each other positively, negatively, and neutrally to varying degrees. Miller et al. (2022) developed a framework to contextualize the interactions between those social and ecological dimensions, specifically focusing on recreation-ecosystem interactions. The framework was simplified into a two-dimensional quadrant system to describe the spectrum of interactions within a range of social-ecological systems (Figure 1.1), which could be altered for countless social-ecological systems, including recreation on aspen landscapes. Miller et al. (2022) argues that considering interactions between elements of this framework will advance the field of recreation ecology and effectively address land management problems by considering trades within a recreation ecosystem. ecosystem.

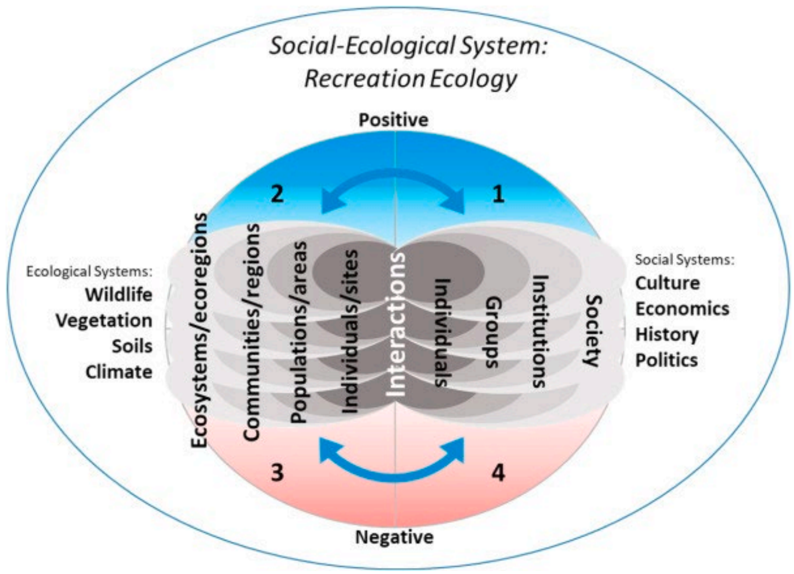

Figure 1.1. Social-ecological systems framework for recreation ecology from Miller et al. (2002). This diagram includes examples of ecological and social systems (non-exhaustive), which occur at a range of nested scales (i.e., individuals/sites, populations/areas, communities/regions, and ecosystems/ecoregions). Interactions between social and ecological systems can range from positive to negative, to a varying degree of intensity. Neutral interactions are also possible. Curved arrows depict feedback between social and ecological systems. Numbers depict four quadrants of possible interactions between these systems.

Research Objectives

At a popular recreation site in Summit County, Utah, land managers observed a decline in the population and condition of a portion of the aspen forest. Forest managers can reference a wealth of literature on treatments to maintain aspen landscapes, though the literature is somewhat weaker on supplying monitoring practices to ensure success (Rogers, 2017). Similarly, recreation managers can use a wide variety of user value assessments to determine strategies to enhance the recreation experience. Both types of management require nuanced approaches to meet the specific needs of the area. In forests that serve as popular recreation destinations, land managers facing a decline in conditions would benefit from a mixed methods approach that incorporates social and ecological data into a single management plan. This approach uses an adaptation of the recreation ecology social-ecological systems framework developed by Miller et al. (2022; Figure 1.2) and has broad implications.

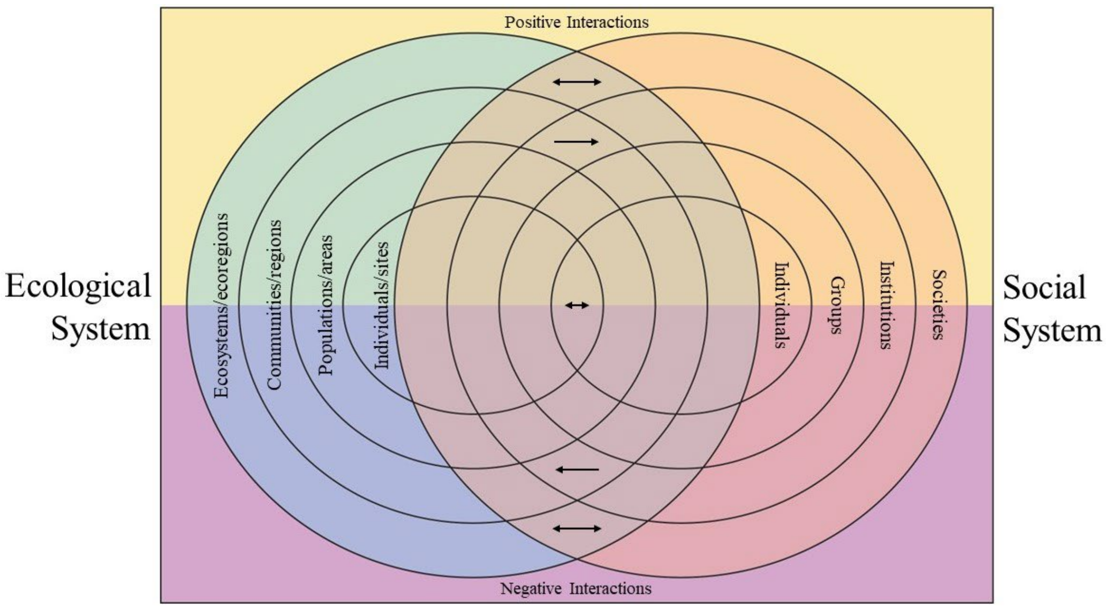

Figure 1.2. Social-ecological systems framework for recreation ecology adapted from Miller et al. (2002). This diagram displays ecological and social systems with nested levels (i.e., individuals/sites, populations/areas, communities/regions, and ecosystems/ecoregions). Interactions between social and ecological systems can range from positive to negative. Neutral interactions are also possible. Arrows depict the direction of the positive or negative impact of the interaction. The location of the arrows indicates which levels the interactions are occurring between and are subject to change depending on the subject of the study.

We set out to understand landscape conditions and user values within a high-use recreation aspen community in northern Utah. Qualitative observations from those working in this area suggested that some of the forest was dying off, but we had little idea as to the extent of the problem or, more pointedly, how recreationists viewed both problems and proposed solutions on this prized landscape. With this in mind, we had two main objectives: 1) determine site-specific land management strategies that improve the aspen condition and 2) assess to what degree users value aspen and support management actions geared toward improving the condition of the aspen forest. With this information, our aim was to provide ecological management strategies to the land managers at our site that reflect the values of the users. More broadly, the ecological and social survey methods from this work can be used by land managers of other forested or, more generally, vegetated areas that also serve as recreation destinations to inspect the social-ecological interactions within their system to assist in management decision making.

Overview of the Thesis

This thesis is formatted as two manuscripts to submit to scientific journals (Chapters II and III). Each manuscript addresses one of the objectives mentioned above. The fourth chapter of this thesis provide a broad discussion of the findings, including research contributions, limitations, and future directions.

The first manuscript assesses the condition of the aspen forest at the site and what variables are most indicative of current forest trends. Specifically, we used conventional aspen landscape survey methods to collect ecological data from 45 plots where aspen was present at the site (Rogers et al., 2010). Soil samples collected from the plots were tested for contaminants in a laboratory. We used exploratory data analysis methods to determine important variables and test differences in condition variations across the site. Based on the findings we determined six management actions that the site land managers could employ as standalone actions or in tandem with each other to improve the condition of the aspen. We intend to publish this manuscript in a forest or land management-centric journal, specifically, the journal *Land* (MDPI).

The second manuscript investigates how users value the aspen forest at the site and their willingness to support the six management actions determined in the first manuscript. We conducted a user intercept survey on people who visit the site to recreate. The purpose of the survey was to quantify the degree to which visitors support or oppose each of the six management actions. The survey also gathered information on recreation use patterns, perceptions of environmental conditions, motivations for using the site, place attachment, and demographic information. Using an ordinal linear regression, we explored what variables contributed to a user's willingness to support management action. We intend to publish this manuscript in an outdoor recreation-centric journal, such as the *Journal of Park and Recreation Administration* (American Academy for Park and Recreation Administration).

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CHAPTER II

QUAKING ASPEN IN A HIGH-USE RECREATION AREA: THE EFFECT OF PEOPLE, UNGULATES, AND SODIUM ON FOREST RECRUITMENT

Abstract

Quaking aspen (*Populus tremuloides* Michx.) landscapes are valued for their biodiversity, water retention, fire mitigation, aesthetics, and recreation opportunities. Across North America, some aspen populations are experiencing population declines as they face uninhibited ungulate browsing, drought, fire suppression, insects, disease, and inappropriate management. Increased human development and recreational use within aspen landscapes can serve as additive stressors, though there is a dearth of literature examining these elements. At a popular recreational area in Summit County, Utah, identifying the cause of apparent decline within a larger aspen community is complicated by development upstream and recreation-related activities. The objectives of this research were to: 1) assess the overall condition of the aspen at the site, 2) understand key variables that influence aspen conditions, and 3) elucidate how aspen fitness varies across the site. We collected data from forty-five plots using established aspen sampling methods, including ungulate presence, tree characteristics, soil chemistry, and environmental descriptors. Using a nonmetric multi-dimensional scaling ordination, multi-response permutation procedures, the Mann-Whiteny test, and the Krustal-Wallace test we found that a combination of higher levels of browsing and elevated soil sodium may be preventing regenerating aspen stems from reaching recruitment size in at least one zone of the study area.

Introduction

Quaking aspen (*Populus tremuloides* Michx.; hereafter aspen) is the most widely distributed tree species in North America (Little & Viereck, 1971; Perala et al., 1990) and an icon of western North American landscapes. Across the globe, aspen populations are in decline due to elevated climate warming, drought, fire suppression, and browsing by ungulates (Angelstam et al., 2017; Edenius et al., 2011; Kota & Bartos, 2010; Myking et al., 2011; Usoltsev et al., 2018; Worrall et al., 2013). In many cases, populations are in mild or rapid decline (Bartos & Campbell, 1998; Di Orio et al., 2005; Strand et al., 2009). Specifically, in western North America, some stands are experiencing population declines (Rogers et al., 2010; Worrall et al., 2008), while others are shifting their range or increasing (Kulakowski et al., 2004; Manier & Laven, 2002). Indeed, both increased and decreased aspen coverage have been documented in the same landscape (Kulakowski et al., 2004; Sankey, 2009). Hence, there is a need for site-specific and appropriate aspen management based on locally data-driven community assessments to address common threats, such as overbrowsing (Rogers & Gale, 2017).

Aspen is of environmental concern because they serve as a keystone species (Hedenås & Ericson, 2000; Oaten & Larsen, 2008; Rogers et al., 2020). Stands of aspen support a high diversity of species and represent an ecologically important habitat type for many plant and animal functional groups (Chong et al., 2001; Hardenbol et al., 2020; Kuhn et al., 2011; Rogers et al., 2020). Aspen is a short-lived, clonal, broadleaf tree species with social value, often serving as a visitor destination (Assal & Keables, 2020; Dahms & Geils, 1997; McCool, 2001; Rogers et al., 2020). Aspen stands are classified as stable or seral (Harniss & Harper, 1982; Rogers et al., 2014). In this study, we are only referring to stable stands, due to the make-up of the aspen community at our study site. Stable aspen stands are characterized by a complex, multi -height and -age stand structure due to continuous gap-phase patterns of mortality and regrowth (Kashian et al., 2007; Kurzel et al., 2007; Mueggler, 1985, 1989). Stable aspen stands with diverse height structures are resilient to interspecific competition and mass insect attacks, stem or root pathogens, or large-scale blowdowns (Crouch et al., 2023; Kurzel et al., 2007; Rogers et al., 2014). Achieving a diverse height structure of stable stand is inhibited by chronic overbrowsing.

Overbrowsing by ungulates is a well-documented threat faced by aspen forests in the western United States due to overpopulation, lack of predators, and lack of herd movement (Britton et al., 2016; Rogers et al., 2010; Rogers & Gale, 2017; Zeigenfuss et al., 2008). Overbrowsing prevents aspen regeneration from reaching the next stage class, reducing recruitment to inadequate levels for successful stand replacement (DeByle & Winokur, 1985; Hessl & Graumlich, 2002). Fencing in small areas of aspen is one tactic to reduce browsing (Bailey et al., 2007; Beschta & Ripple, 2009; Fairweather & Tkacz, 1999; Martin & Maron, 2012; Rogers & McAvoy, 2018; Rolf, 2001), but it is not suggested as a long-term solution as fences restrict the movement of other large animals and it is aesthetically unfavorable (Rogers & Šebesta, 2019).

Another potential obstacle for aspen stand replacement is soil contamination. Soil in forested areas may be impacted by mining, tainted ground-water, and other human development, with soil sodium (Na) levels being a main point of concern (Dietrich et al., 2017; Lauer, 2023; Lilles et al., 2010; Tremblay et al., 2019). There is minimal literature on the long-term effects of Na and salinity on aspen growth and stand replacement, though it is known that other woody species are adversely affected by saline soils (Allen et al., 1994; Maas, 1986).

Recreation is another variable when considering stand condition, but the relationship between recreation and aspen population dynamics has yet to be studied. Though studies examining aspen forests have been conducted in areas that are used for recreation, such as in Fish Lake National Forest and the Book Cliffs region in Utah, none directly have considered how recreation impacts the health of the forest or how the health of the forest impacts users (Rogers, 2022; Rogers et al., 2013). Outdoor recreation often has direct and indirect impacts on ecosystem functions, processes, aesthetics, wildlife and, in turn, the ecological integrity of areas as recreational resources (Arnberger & Hinterberger, 2003; Hammitt et al., 2015; Hughes & Macdonald, 2013). The ecological impacts of recreation have the potential to be both beneficial and harmful to the landscape, as in the case of wildlife disturbance (Miller et al., 2022). Similarly, management actions taken to benefit a landscape can affect visitor experiences.

Here, we examined aspen conditions and the factors contributing to their current status. Specifically, we investigated how browsing, overall visual condition, geographic variance, soil chemistry, and key indicators affected long-term aspen health alongside putative human development and wildlife impacts. The objectives of this study were to: 1) assess the current condition of a specific aspen-recreational ecosystem, 2) assess how forest characteristics vary across this system, 3) determine key environmental indicators and their interactions, and 4) propose appropriate site-specific management actions as viable options for managers to sustain aspen forests and recreation opportunities. This study serves as a reference for research and management in aspen communities, as well as other vegetation types, in high-use recreation areas that also may be impacted by adjacent development.

Methods

Study Site

This study took place in two adjacent high-use recreation areas in Summit County, Utah: Right Turn Sage (RTS) and Run-A-Muk (RAM), divided by the Olympic Parkway Road. RTS (453,016.04E 4,507,288.81N) is a trail area designated for hiking, mountain biking, and cross-country skiing with over 16 km of trails, while RAM (453,195.93E 4,507,142.45N) is an off-leash dog area (Figure 2.1). Unlike typical dog parks, RAM offers over five kilometers of well-maintained trail and 17.4 ha of enclosed forested and sagebrush-covered hills. Both areas are managed by the Snyderville Basin Special Recreation District (hereafter Basin Recreation). According to the trail counters (*Eco-Visio*, 2019) maintained by Basin Recreation at each of the three entrances to RTS and RAM, in 2023 there were an average of 584 visitors a day at RAM and 69 at RTS, for a total of 623 daily visitors.

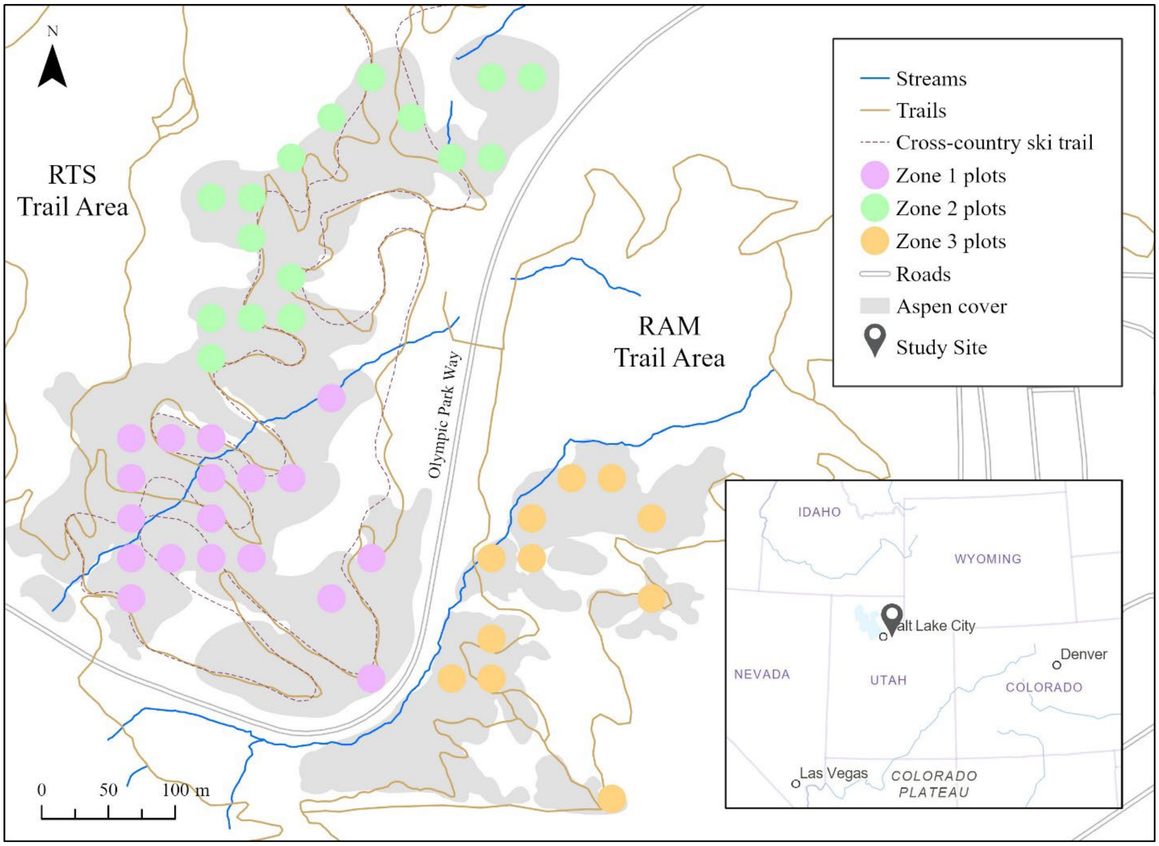

Figure 2.1. Site map of the aspen coverage at Right Turn Sage (RTS) and Run-A-Muk (RAM) trail areas in Summit County, Utah. The map centers on only the aspen cover portion of the RTS/RAM trail areas. Aspen coverage is depicted with gray shading. Streams are shown as by solid blue lines, trails by solid brown lines, cross-country ski trails by dashed brown lines, and roads by solid white line. Survey plots are shown as with circles that are colored by Zone, with Zone 1 plots colored purple, Zone 2 plots colored green, and Zone 3 plots colored orange.

The RTS/RAM trail areas range from 1,963.8 m to 2,109.7 m in elevation, with an average of 2,036.8 m, and slopes ranging from 0.2% to 35.4% trending west/southwest. It covers 1,429.4 ha[1], with an estimated 11.6 ha[1] (~0.8%) of this area dominated by aspen forests. The surrounding, steeper hillsides are dominated by Gambel oak (*Quercus gambelii* Nutt.) and other tall shrubs. The area surrounding the aspen and oak forests consists of shrubs, grasses, and forbs. Other tree species are lightly scattered throughout the forest, including bigtooth maple (*Acer grandidentatum* Nutt.), Rocky Mountain juniper (*Juniperus scopulorum* Sarg.), subalpine fir (*Abies lasiocarpa* Nutt.), and white fir (*Abies concolor* Lindl.). Large herbivores in RTS/RAM include North

American elk (*Cervus elaphus* L.), mule deer (*Odocoileus hemionus* Raf.), and moose (*Alces alces* L.). Though the study area was likely affected by historic livestock grazing, there are no recent uses for domestic animals in this area. From 1991 to 2020, the annual average precipitation for Snyderville, Utah is 44.34 cm mostly in the form of snow (National Centers for Environmental Information, 2024). The average annual temperature was 6.78°C in neighboring Park City, Utah from 2006 to 2020 (National Centers for Environmental Information, 2024).

Utah Olympic Park, built for the 2002 Winter Olympics, is adjacent to the study area boundary and 1.6 km up the road from the RTS/RAM trail area parking lots. In August of 2019, residential housing for Utah Olympic Park was constructed, which altered the perennial and ephemeral path of the streams that flow through RTS/RAM, with the path now descending from a vehicle parking lot. Additional construction for the park is ongoing and may affect run-off content and patterns within the study area.

Field Methods

We collected data at RTS/RAM during July and August of 2022 using established aspen landscape survey methods (Rogers et al., 2010). To locate survey plots, we used ArcPro® (Esri, 2022) to overlay a 30 m grid on the RTS/RAM boundary and randomly sub-selected 45 sample points (plots) that intersect a digital aspen cover layer. The aspen cover layer was created in ArcPro® for this project using satellite imagery from the National Agriculture Imagery Program provided by the Utah Geospatial Resource Center (Utah Geospatial Resource Center, n.d.). At each plot, the environmental variables we recorded are sample area (RTS or RAM), number of vertical stand layers, a visual estimate of stand condition, understory cover, and percent aspen canopy cover.

All measures were assumed to represent conditions within approximately 0.5 ha[1] (radius ~40 m) surrounding the plot location center point . We identified vertical stand layers by looking horizontally through the forest and counting clearly distinguishable aspen layers across the entire site (i.e., short juveniles, tall juveniles, intermediate sub-canopy, and mature canopy stems). The presence of small numbers or patches of regeneration or recruitment did not *a priori* constitute an easily distinguishable "layer." Where layers could not be determined due to continuous vertical stand structure, we recorded four layers - the maximum value.

Stand condition was determined based on a qualitative visual estimation of plot conditions developed as a time-saving method for forest assessment (Rogers & Mittanck, 2014). We used a standardized protocol for visually assessing tree damage, mortality, aspen layers, and overall browse impact to categorize aspen forest conditions as "Poor," "Moderate," or "Good" (Table 2.1). The Moderate category encompasses a much greater range of conditions, whereas Poor and Good groups are defined by proportional extremes.

Table 2.1. Ranking of stand conditions based on visual estimates of overstory, regeneration/recruitment, and browse of aspen regeneration. A stand must meet all the criteria for either "Good" or "Poor" condition, otherwise it is rated as "Moderate." Mortality is defined as standing dead mature trees. Browse includes missing branch tips, buds, and leaves, as well as the presence of multi-stemmed (bushy) aspen regeneration (Rogers & Mittanck, 2014).

Code	Descriptor	Overstory mortality/disease	Vertical stand layers	Visible browse impacts
1	Good	Minimal overstory mortality and stem disease present (<5%)	Several aspen layers (>3)	Browsing impacts on regeneration uncommon (<25%)
2	Moderate	Does not fit 1 or 3	Does not fit 1 or 3	Does not fit 1 or 3
3	Poor	Overstory mortality and/or stem cankers common (>25%)	Layers absent or minimal (≥2)	Browsing impacts clearly evident on regeneration (>50%)

Percent aspen canopy cover was measured along two 24 m transects using a densitometer. The transects ran east to west, were parallel, and 4 m apart. Aspen canopy cover was recorded at 1 m intervals along each transect, only counting live branches above 2 m height and live branches, resulting in fifty canopy cover readings from both transects that were then calculated into an overall stand percentage.

A fecal count of pellet groups was conducted for deer and elk along the same transects in 2 m belts to determine ungulate presence indirectly and approximate the level of aspen browse. No livestock are permitted within the study area, so these fecal types were not tallied. Pellet groups were defined as three or more pellets from the same defecation (Bunnefeld et al., 2006).

Stand structure is generally classified into three height stages: regeneration, recruitment, and mature overstory (Rogers et al., 2010). In this study, an individual aspen "tree" will be referred to as a "stem" - one stem of a single clone that is connected to the larger organism via an underground root network. Aspen stems within a 7 m radius of the center of each plot were tallied and classified as either regeneration (i.e., stems <2 m height), recruitment (i.e., stems ≥ 2 m height and <8 cm diameter breast height [DBH]), or mature (i.e., stems ≥ 2 m height, ≥ 8 cm DBH). Trees other than aspen were recorded noting their species, status (dead or alive), and DBH. Stems were considered separate individual stems if they forked below the soil litter. We categorized regeneration stems into three height classes (<0.5 m, 0.5-1 m, >1- 2 m), and leaders were examined for browsed buds and twigs to determine the percent browsed regeneration. For mature stems, we recorded the status (dead or alive), DBH, and damage. We recorded damage if $>25\%$ of bole circumference, crown, or root area was affected by stem cankers (fungal damage and/or resinosis), stem conks (>1 external conk), open wounds (exposed stem wood without decay from physical damage) root decay (not on the main bole; any visible fungi or exposed rotted roots), leaf damage (not on the main bole; spotted, rolled, eaten, or discoloration on >50% of leaves), or insect damage to bole (pin holes or obvious insect wounds or frass. We divided the number of mature stems with damage by the number of total mature trees to calculate the percent mature stem damage for each plot. All area-based data were summed, by plot, to the ha^{-1} level based on the area of sampling (i.e., either circular plot or rectangular belt transects).

Landscape position variables including elevation, slope, and aspect were derived from a 10 m digital elevation model (DEM) in ArcPro® (Esri, 2022). Aspect was transformed into a moisture index ranging from 0 (southwest aspect) to 1 (northeast aspect) to eliminate inaccuracies from averaging aspect values that straddle 0 degrees (Roberts & Cooper, 1987). We also calculated the distance (m) from the road, hiking/biking trails, cross-country ski trails, and streams for each plot in ArcPro®.

Soil Testing for Na, Ca, Mg, pH, SAR, and EC

A soil sample of ~300 g was collected 1 m north of each plot center from a depth of ~10-15 cm. Soil samples were air-dried, then a saturated paste extract (SPE) was prepared and used to measure the pH and electrical conductivity (EC). The SPE was analyzed by atomic absorption spectroscopy for calcium (Ca) and magnesium (Mg) and by flame emission spectroscopy for sodium (Na) using a 1:10 dilution (Gavlak et al., 2003). The sodium adsorption ratio (SAR) was calculated to assess sodium hazard in soil solution (Horneck et al., 2007). SAR is the proportion of water-soluble Na to Ca plus Mg in the soil and is calculated with the following equation (Davis et al., 2012):

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

The SPEs that yielded high results for Na (>20 mg/kg of soil) were further tested for pH, EC, Na, and 22 additional metals to ensure they were not contaminated during the original testing process (Evers et al., 1997; Horneck et al., 2007). Additionally, the original soil sample from the field were also further tested for pH, EC, Na, and 22 additional metals for SPE's that yielded abnormally high Na levels (>100 mg/kg of soil) to ensure there was no contamination during the preparation of the SPE that would have causes high Na levels (Evers et al., 1997; Horneck et al., 2007).

Data Analysis

We analyzed the data using R version 4.2.2 (R Core Team, 2022) and PC-ORD (McCune & Mefford, 2016). We considered results to be statistically significant at the 95% confidence interval (p <0.05; 69–71). Sampling values for all variables were compiled at the plot level for analysis. We divided plots located in the RTS portion into two elevation-based groups to provide sampling parity, resulting in three (overall) plot zones, as well as acknowledging an apparent natural division in water allocation (Figure 2.1). First, we ran preliminary descriptive statistics on plot-level data to identify outliers, test variance, and explore initial correlations in indicator pairings. We used non-parametric approaches due to the variation of data type and large numbers of zero values (McCune et al., 2002; Zar, 1999). We mapped findings using ArcPro® (Esri, 2022) for visual display and analysis. Analytical efforts for this work were of an exploratory nature (McCune et al., 2002). We sought to determine the most important gradients among a suite of environmental variables (i.e., data reduction) that could serve as key metrics, or "indicators," of study area conditions.

Second, we used non-metric multidimensional scaling (NMDS) to explore correlations within this study's matrix of 45 plots and 26 response variables to highlight key variables (Kruskal, 1964). The wide variation in data types/plot-level variables (e.g., stem counts, percent canopy cover, geometric location, elevation) requires a flexible and defensible analytical approach such as NMDS (Peck, 2010). An initial outlier analysis was performed to check for data anomalies (Peck, 2010). We initiated the ordination with a random start number upon 500 runs of the actual data set using the Sørensen distance measure. The final NMDS solution assessed dimensionality by plotting stress as a function of the number of dimensions or axes. Where two consecutive dimensions were <5 points of stress apart the lower dimension was selected as our optimum solution (McCune et al., 2002).

Third, multi-response permutation procedures (MRPP)—a non-parametric equivalent to MANOVA used for describing within-group agreement of variables in contrast to *a priori* data groups (Mielke et al., 1976)—were used to test group difference for stand condition, sites, and geographic zones. We used R-package *vegan* to run the MRPP (Oksanen, 2009). The Sørensen distance measure was used because it is less susceptible to bias due to outliers and zero values (Peck, 2010). MRPP produces a T-value indicating the degree of difference between treatment group pairs, an A-value which is the chance-corrected within-group agreement (effect size), as well as a p-value establishing a level of test significance (McCune et al., 2002). We tested two group configurations: sampling zones and Na levels categorized into low (<10 mg/soil kg), medium(10-20 mg/soil kg), and high(>20 mg/soil kg) Na content groups as recommended (Jeannette Norton, pers. comm.).

Lastly, we used two non-parametric tests to address indicators individually by significant groups found in MRPP testing: the Wilcoxon-Mann-Whitney U and Kruskal-Wallace tests (Zar, 1999). We used the two-sided Wilcoxon-Mann-Whitney U test to evaluate field variables for differences between plots with adequate recruitment (>1200 stems ha^{-1}), sustainable browse levels ($\leq$20%; Jones et al., 2005), and distance to the road or a stream (<5m and <10 m).

We employed the Kruskal-Wallace test, a non-parametric equivalent to analysis of variance, to test group differences between plots in different zones, with different stand layers, with different Na levels, and with different stand condition rankings. Additionally, the Kruskal-Wallace test served as the main method for evaluating the effectiveness and precision of the visual stand condition ranking (see Table 2.1 for ranking criteria). Stand condition is an amalgamation of recruitment ha^{-1}, dead basal area, browse, percent mature stem damage, and stand layers, so we used the Kruskal-Wallace test if these variables varied significantly between plots ranked as having "Poor," "'Moderate," and "Good" stand conditions (Table 2.1). Confirmation or rejection of qualitative stand ratings, based on actual field measures, is intended to elucidate usefulness of a quick visual rating as a reasonable substitute for more time-intensive field measures.

Results

Descriptive Statistics of Site Conditions

We divided the 45 plots across RTS/RAM into three zones to further understand geographic discrepancies, if any, within the study area: Zone 1, Zone 2, and Zone 3 (Figure 2.1). Table 2.2 displays mean and standard deviations for 29 variables by Zone as well as for the overall study area. Bolded variables have a standard deviation that is greater than the mean in one of the zones or for the overall study area. We found high regeneration and low recruitment, canopy cover, and basal area – indicating an overall site of relatively low productivity and/or increased mortality without replacement. Regeneration, recruitment, and canopy cover have a greater variance than the mean in at least one of the Zones and/or in the overall study area.

Table 2.2. The mean and standard deviation (SD) are displayed for each variable across Zone 1, Zone 2, and Zone 3, as well as for the overall study area. Bolded variables have a standard deviation that is greater than the mean in one of the zones or for the overall study area, and highlighted values are standard deviations that are greater than the mean

	Zone 1		**Zone 2**		**Zone 3**		**Overall Study Area**	
Variables	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Elevation	2,032.80	7.07	2,009.96	11.19	2,013.33	8.38	2019.92	13.88
Slope	7.42	0.75	8.90	2.66	7.36	1.55	7.93	1.93
Aspect	47.85	15.01	47.67	34.98	24.53	10.92	42.09	25.17
Understory cover	2.56	1.58	3.19	2.14	3.45	2.50	3	2.02
% Canopy cover	9.33	10.67	24.88	14.71	25.64	21.52	18.84	16.88
Stand layers	1.94	1.26	2.50	1.03	2.91	0.83	2.38	1.13
Stand condition	2.50	0.62	1.94	0.77	2.27	0.65	2.24	0.71
Regeneration ha^{-1}	4,626.60	4,021.88	3,483.48	2,040.32	5,344.44	5,780.35	4395.63	3976.43
Recruitment ha^{-1}	523.29	772.96	860.72	719.66	974.40	1,477.04	753.54	970.2
Mature ha	256.23	250.57	430.36	279.53	578.73	466.13	396.98	342.12
Recruitment-mature ha^{-1} ratio	3.86	5.11	3.51	4.34	2.38	3.00	3.36	4.33
Live and dead basal area	3.97	3.03	9.44	6.01	9.58	7.20	7.28	5.93
Live basal area	1.30	2.16	6.30	4.96	5.51	4.86	4.11	4.59
Dead basal area	2.67	1.75	3.13	4.59	4.07	4.86	3.18	3.74
Live-total basal area ratio	0.20	0.31	0.74	0.31	0.57	0.38	0.48	0.4
Elk scat ha^{-1}	98.22	224.11	156.00	165.53	37.82	52.47	104	177.38
Deer scat ha^{-1}	271.56	182.38	442.00	518.61	56.73	54.31	279.64	356.72
% browse	0.08	0.09	0.14	0.15	0.05	0.07	0.09	0.12
% damage	0.11	0.22	0.29	0.27	0.29	0.35	0.22	0.28
Soil pH	7.23	0.45	7.38	0.48	7.38	0.54	7.32	0.48
Electrical conductivity dS/m	0.48	0.19	0.44	0.17	0.48	0.21	0.46	0.18
Na (mg)/soil (kg)	17.79	30.96	4.21	1.85	22.33	24.84	14.07	23.87
Mg (mg)/soil (kg)	3.55	2.91	2.35	1.98	9.71	7.81	4.63	5.23
Ca (mg)/soil (kg)	34.78	19.23	36.62	20.00	65.75	37.62	43	27.8
Sodium adsorption ratio	1.07	1.61	0.28	0.06	0.83	0.77	0.73	1.12
Meters to road	110.43	44.79	136.11	58.69	93.08	52.53	115.32	53.55
Meters to summer trials	13.36	11.33	17.12	19.23	21.85	17.94	16.77	16.13
Meters to winter trials	8.46	8.29	16.11	19.59	19.39	17.44	13.85	15.75
Meters to stream	35.01	23.09	75.79	46.62	47.38	49.88	52.53	42.91

Results from the soil testing yielded unusually high results for Na at plot 15, and high results for six additional plots. Figure 2.2 displays Na levels at each plot, with red and black plots having the highest levels of Na and green plots having the lowest.

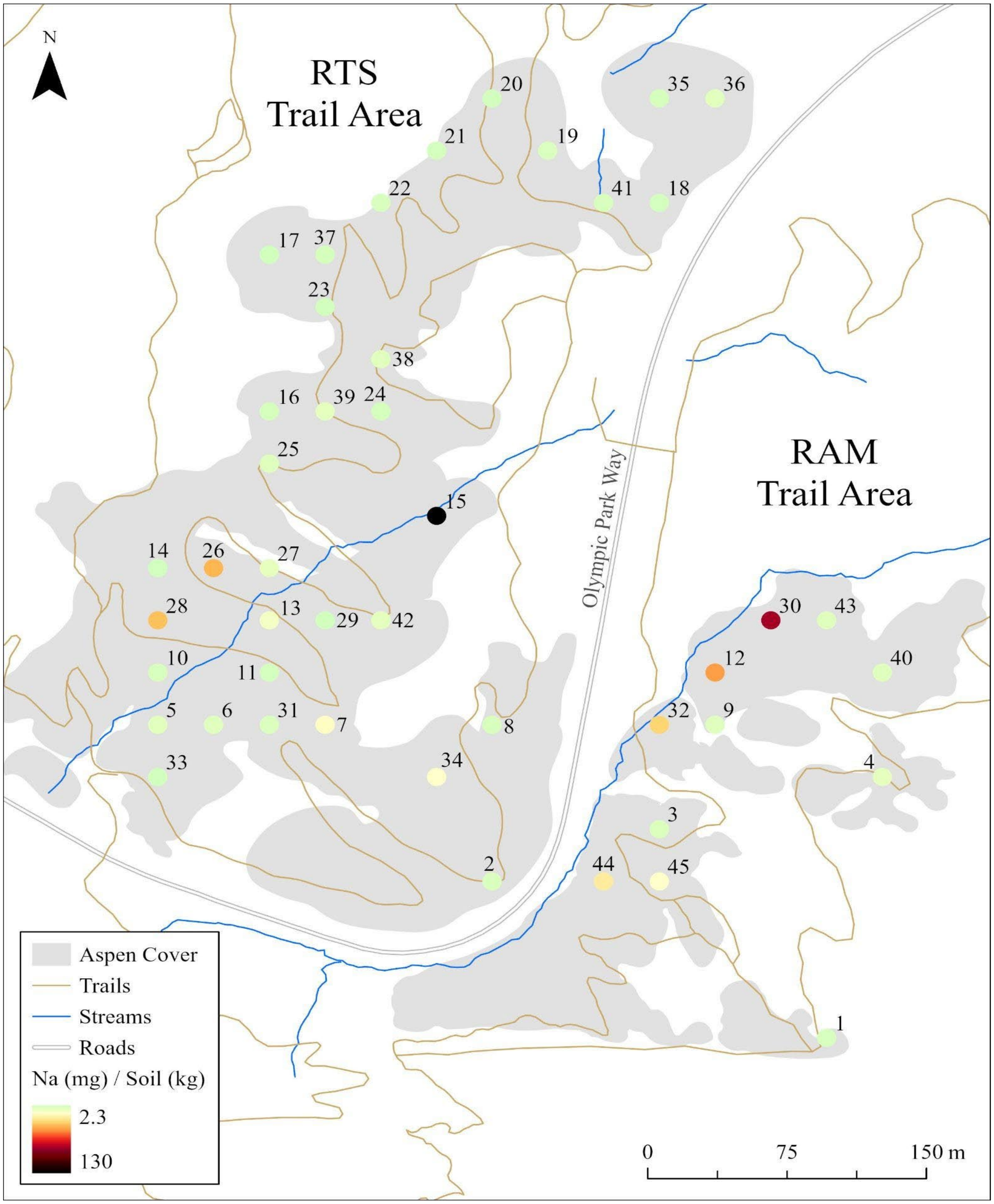

Figure 2.2. Map of soil sodium (Na) levels by plot at the study site. Numbers next to each dot are the plot numbers, The darker the dot is that represents plot location, the higher the Na level.

Ordination Seeking Key Site Indicators

The NMDS ordination produced a three-dimensional solution on a matrix of 45 plots by 26 variables, including zones, for the 2022 dataset with a final stress value of 11.65 with an instability of 0.009. Stability was reached at 39 iterations from a maximum of 400 runs of our "real" dataset. A Monte Carlo test of 400 random data runs versus the real data set verified a significant NMDS outcome ($p = 0.0349$). No plots were eliminated in the outlier analysis, but the variable regeneration was eliminated in the outlier analysis (>2 SD, outlier analysis). Elevation was also removed due to insignificant variation in elevation across the site (Table 2.2). The recruitment-mature ha^{-1} ratio and live-dead basal area ratio variables were also eliminated from the ordination because it contained null values.

The three-axis result described 88.1% of ordination variance (Axis 1: $r^2 = 0.405$; Axis 2: $r^2 = 0.319$; Axis 3: $r^2 = 0.158$, orthogonality Axis 1 and 2 = 96.5%). Although the significance of each axis does not meet our 95% confidence interval standard (Axis 1 = 0.09, Axis 2 = 0.04, Axis 3 = 0.03), we concluded that the significance is adequate, but should factor into our conclusions. Table 2.3 presents all environmental variables with their Pearson's coefficient (*r*) values by axes identified in NMDS. The NMDS is displayed as one joint plot with Axis 1 and Axis 2 where vectors with > +/- 0.5 Pearson's coefficient (*r*) value are displayed as an overlay in Figure 2.3. The length and direction of vectors in Figure 2.3 correspond to variable strength and relationship to the two-dimensional plot-data space. Axis 1 describes a gradient of recruitment abundance negatively correlated to deer scat presence. Axis 2 displays a gradient of canopy cover, mature ha^1, total basal area, and live basal area. On Axis 3, three variables have high Pearson's coefficient (*r*) values, elk scat ha^{-1} ($r = 0.518$), deer scat ha^{-1} ($r = 0.685$), and Na ($r = 0.32$). Several variables do not meet our threshold for Figure 2.3 joint plot display, yet they provide support in their statistical relationships to other variables along dominant ecological gradients. In the joint plots, Zone 1 has less recruitment and poor overstory growth while Zone 2 trends in opposition to Zone 1. Zone 3 has no dominant trend.

Table 2.3. Pearson's coefficients (*r*) between environmental variables and non-metric multidimensional scaling (NMDS) ordination axes. The strongest response variables are in bold font where $r^2 > 0.2$, and the values are shaded gray where $r^2 > 0.2$.

	r		
Variable	**Axis 1**	**Axis 2**	**Axis 3**
Zone	0.143	0.340	-0.377
Slope	0.053	-0.154	0.081
Aspect	-0.154	0.047	-0.086
Understory	0.079	0.207	0.040
Percent canopy cover	0.264	0.658	-0.397
Stand layers	0.338	0.462	-0.237
Stand condition	-0.253	-0.293	-0.028
Recruitment ha^{-1}	0.806	0.466	0.218
Mature ha^{-1}	-0.171	0.755	-0.356
Total basal area	-0.122	0.629	-0.236
Live basal area	0.058	0.587	-0.347
Dead basal area	-0.263	0.276	0.052
Elk scat ha^{-1}	-0.357	0.122	0.518
Deer scat ha^{-1}	-0.449	0.197	0.685
% browse	-0.296	0.210	0.277
% damage	0.234	0.280	0.043
Soil pH	0.060	0.333	0.113
Electrical conductivity (EC)	0.260	-0.259	0.393
Na (mg)/soil (kg)	-0.251	0.207	-0.32
Mg (mg)/soil (kg)	-0.212	0.170	-0.459
Ca (mg)/soil (kg)	-0.152	0.221	-0.411
Sodium adsorption ratio (SAR)	-0.184	0.058	-0.193
Meters from road	0.148	0.406	0.131
Meters from summer trail	-0.220	0.398	0.225
Meters from winter trail	-0.262	-0.038	0.153
Meters from stream	-0.017	-0.038	0.052
Cumulative value	0.405	0.319	0.158

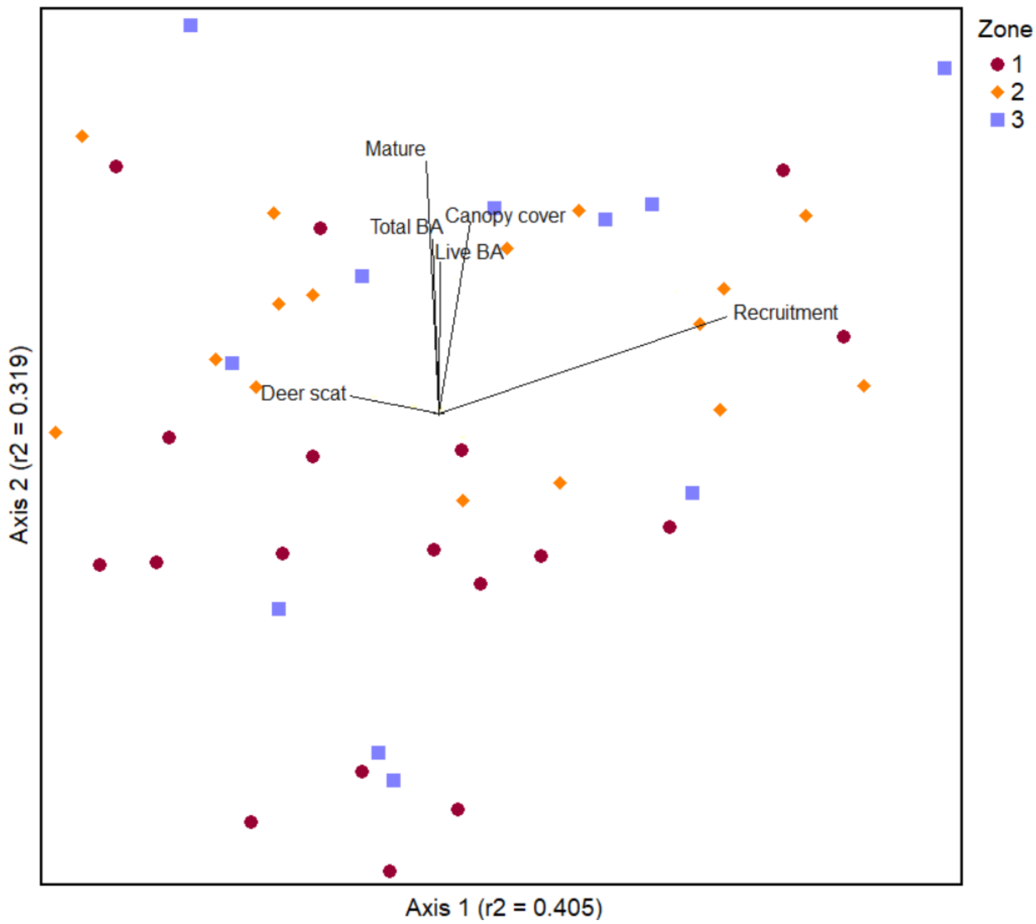

Figure 2.3. Non-metric multidimensional scaling (NMDS) ordination produced a three-dimensional solution on a matrix of 45 plots by 26 variables, displayed as one two-dimensional ordination of Axis 1 and Axis 2. Zone 1 is represented by a dark red circle, Zone 2 by an orange diamond, and Zone 3 by a blue-purple square.

Between-group Difference for Zones and Sodium

We examined several categorical variables for group differences in plots using multi-response permutation procedures (MRPP). The most telling group differences were found by zone and soil Na. When comparing zones, results show that there is greater within group agreement (validation) than between groups for all three pairwise alignments (Table 2.4). Although comparisons are significant (<0.05) for Zone 1 vs 2 (p = 0.025) and Zone 2 vs 3 (p = 0.008), low T-values (-2.49 and -3.4) indicate modest between group differences. Similarly, when comparing plots with low (<10 mg/soil kg), medium (10-20 mg/soil kg), and high (>20 mg/soil kg) Na categories, the MRPP results show that there is stronger within group agreement (validation) than between groups with low and high Na levels (Table 2.4). Comparisons are significant only between low and high Na categories (p = 0.02), but the low T-values (-0.83, -2.7, and -0.45) indicate weak between group differences. In other words, there are significant differences between the three zones and low vs high soil sodium levels, but those differences are not large.

Table 2.4. Multi-Response Permutation Procedures (MRPP) test results for differences in cumulative scores for all variables between geographic groups and soil sodium (Na) categories. Na categories are low (<10 Na mg/soil kg), medium (10-20 Na mg/soil kg), and high (>20 Na mg/soil kg). "T" is the MRPP test statistic which calculates the difference between observed and expected delta. "A" is the chance-corrected within-group agreement.

Zone	**T**	**A**	***p***
Zone 1 vs Zone 2	-2.49	0.03	0.025
Zone 1 vs Zone 3	-1.88	0.03	0.052
Zone 2 vs Zone 3	-3.40	0.04	0.008
Soil Sodium Levels			
Low vs medium	-0.83	0.01	0.18
Low vs high	-2.70	0.04	0.02
Medium vs high	-0.45	0.01	0.26

What indicators cause between-group differences?

Figures 2.4, 2.5, and 2.6 present an array of non-parametric test results—Kruskal-Wallis test for three-way and Mann–Whitney U test for two-way comparisons—to discern the status of recruitment ha^{-1}, percent canopy cover, and stand layers in each Zone (Figures 2.4), ungulate presence through percent browse, elk scat ha^{-1}, and dear scat ha^{-1} in each Zone (Figure 2.5), and Na and SAR levels in relation to distance to stream (Figure 2.6).

Zone 1, the area of initial concern for managers due to apparent mortality, has the lowest mean for canopy cover, stand layers, recruitment, mature, live basal area, and dead basal area (Table 2.2). Zone 2 has the highest mean for elk scat, deer scat, and browse level (Table 2.2). Zone 3 has the lowest mean for elk scat, deer scat, and browse, and the highest mean for canopy cover, stand layers, recruitment, mature, and dead basal area (Table 2.2). Of these, statistically significant zonal differences are only found when comparing stand layers ($X^2 = 7.01$, $p = 0.036$; Figure 2.4[b]), live basal area ($X^2 = 13.732$, $p = 0.001$; Figure 2.4[c]), and deer scat ($X^2 = 11.92$, $p = 0.003$; Figure 2.5[c]). There are trends that are not significant but interesting include the higher elk presence in Zone 2, low recruitment in Zone 1, and low ungulate visitation in Zone 3.

Levels of Na compared to distance from stream was significant in three different comparisons. First, between Na categories and distance from stream ($X^2 = 6.482$, $p = 0.014$), with the Na categories being <10 Na mg/soil kg, 10-12 Na mg/soil kg, and >20 Na mg/soil kg (Figure 2.6[a]). Plots with >20 Na mg/soil kg are within 30 m of a stream, while 75% plots in the other two categories were between 30 m and 80 m from a stream. Second, between distance from stream categories and Na ($X^2 = 8.941$, $p = 0.011$), with the distance categories being <10 m, 10-20 m, and >20 m (Figure 2.6[b]). Plots <10 m from a stream range between 2.38 and 132.65 Na mg/soil kg. Plots 10-20 m from a stream range between 2.31 and 47.9 Na mg/soil kg, with an outlier of 83.79 Na mg/soil kg. Plots >20 m from a stream were under 41.79 Na mg/soil kg but had a mean and median bellow 10. Lastly, between the same distance from stream categories and SAR ($X^2 = 6.626$, $p = 0.036$; Figure 2.6[c]). Similar to plots with high Na, plots with an SAR between 0.20 and 8.15 are <10 m from a stream, while plots 10-20 m from a stream have an SAR of 0.19-2.37, and plots >20 m from a stream have an SAR of 0.17-4.28. In summary, there is a pattern of plots with high SAR and Na near streams. Plots with a high SAR have a high amount of Na compared to Mg and Ca, which could lead to the inability of water to penetrate soil.

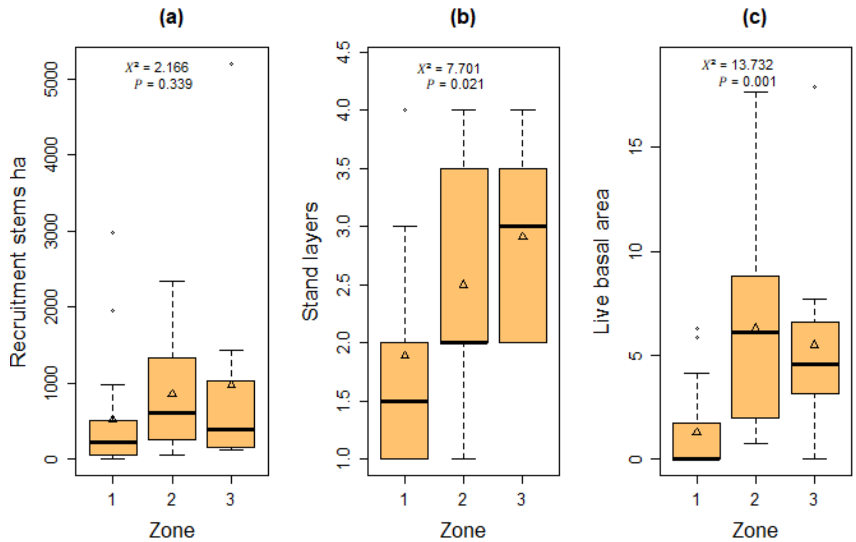

Figure 2.4. Box plots of nonparametric tests describe study site patterns of regeneration, recruitment, and browsing impacts by zones. Analyses graphics are as follows: (a) difference in recruitment ha^{-1} for all study plots; (b) significant difference in stand layers for all study plots; (c) significant difference in live basal area for all study plots. Kruskal-Wallis test results are shown for differences between the three groups including chi-squared (X^2) and significance values (p). The x-axis shows the Zone and the y-axis reports Wilcoxon mean scores. Results are significant when a Monte Carlo-simulated chi-square test using 10,000 runs produced an estimated p-value of <0.05. Output from Kruskal–Wallis test whiskers show minimum and maximum values, open circles are outliers, boxes represent 25%–75% data ranges, horizontal lines within boxes are medians, and open triangle symbols are mean.

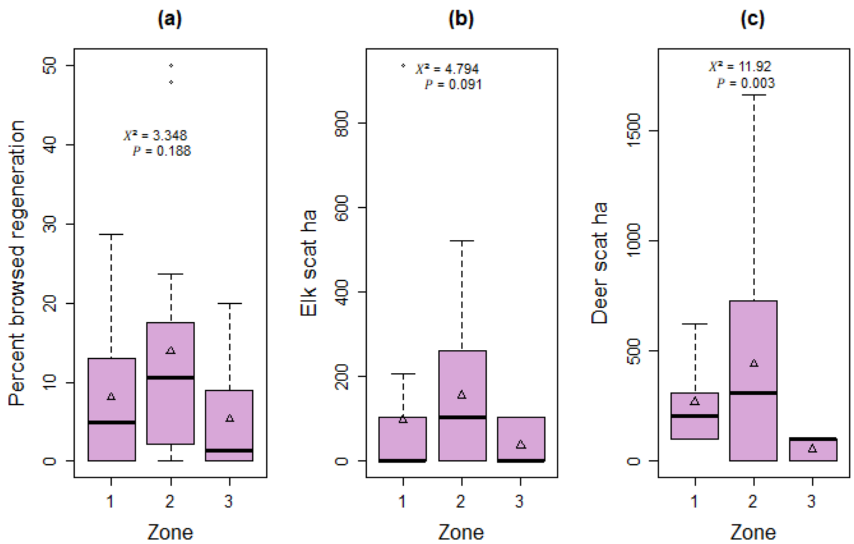

Figure 2.5. Box plots of nonparametric tests describe study site patterns of regeneration, recruitment, and browsing impacts by zones. Analyses graphics are as follows: (a) difference in percent browsed for study plots; (b) difference in elk scat ha^{-1} for all study plots; (c) significant difference in deer scat ha^{-1} for all study plots. Kruskal-Wallis test results are shown for differences between the three groups including chi-squared (X^2) and significance values (*p*). The x-axis shows the Zone and the y-axis reports Wilcoxon mean scores. Results are significant when a Monte Carlo-simulated chi-square test using 10,000 runs produced an estimated p-value of <0.05. Output from Kruskal–Wallis test whiskers show minimum and maximum values, open circles are outliers, boxes represent 25%–75% data ranges, horizontal lines within boxes are medians, and open triangle symbols are mean.

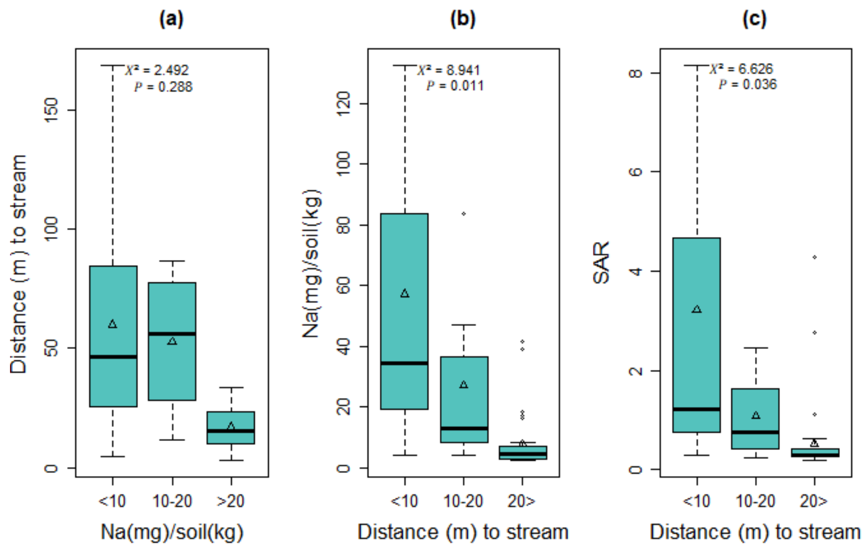

Figure 2.6. Box plots of nonparametric tests describe sodium (Na), sodium adsorption ratio (SAR), and meters from stream. Analyses graphics are as follows: (a) significant difference in meters from streams for study plots with Na levels of <10mg/soil kg, 10-20mg/soil kg, and >20mg/soil kg; (b) significant difference in levels of Na for study plots <10 m, 10-20 m, and >20 m from streams; and (c) significant difference in SAR for study plots <10 m, 10-20 m, and >20 m from streams. Kruskal-Wallis test results are shown for differences between the three groups including chi-squared (X^2) and significance values (p). The x-axis shows the Zone and the y-axis reports Wilcoxon mean scores. Results are significant when a Monte Carlo-simulated chi-square test using 10,000 runs produced an estimated p-value of <0.05. Output from Kruskal–Wallis test whiskers show minimum and maximum values, open circles are outliers, boxes represent 25%–75% data ranges, horizontal lines within boxes are medians, and open triangle symbols are mean.

The Kruskal-Wallace test was used to test the accuracy of stand condition rankings that were visually assessed in the field (Table 2.1). Test results show only one variable is statistically significant when comparing differences in plots with “Poor,” “Moderate,” and “Good” stand condition: recruitment ha^{-1} ($X^2 = 6.3511$, $p = 0.042$). The other variables that contribute to stand condition are not statistically significant: dead basal area ($X^2 = 3.591$, $p = 0.166$), browse ($X^2 = 0.706$, $p = 0.702$), percent mature stem damage ($X^2 = 1.664$, $p = 0.435$), and the number of stand layers ($X^2 = 5.157$, $p = 0.076$).

Discussion

Findings from the analysis indicate that ungulate presence (Figure 3) and soil contamination (Figure1, 6) negatively affect aspen conditions at some localities, though we found that overall the study area is relatively healthy. Browse and Na levels are variables that could explain the disconnect between regeneration stems and recruitment stems—i.e., there is substantial regeneration that is not making it to the next height class. Additionally, maintenance done for recreation could have an impact on the aspen forest. Ungulate presence, Na levels, and recreation use vary by zone and impact aspen in unique ways.

How does aspen condition vary across the study area?

Recruitment stems are a result of the successful growth of regenerating stems into subcanopy trees and is often used to measure structural diversity and "escape" from the reach of browsers (Rogers et al., 2010). Low or absent recruitment strongly suggests a temporal pattern of decline by an inability to replace overstory mortality (DeByle & Winokur, 1985; Kurzel et al., 2007; Rogers et al., 2010; Zeigenfuss et al., 2008). For the entire study site, mean recruitment does not exceed 1,200 stems ha^{-1}—the amount of recruitment ha^{-1} considered the minimum for stand replacement (Table 2.2; Kitchen et al., 2019; Rogers & Mittanck, 2014). However, the mean ratio of recruitment ha^{-1} versus mature ha^{-1} is greater than one for all three zones (Table 2.2), suggesting that there is at least a minimum level of juvenile stems for replacement should the overstory die-off (Rogers & Mittanck, 2014). This cursory assessment, though, is conservative and does not account for rapid mortality or attrition among these saplings prior to their reaching maturity. The amount of regeneration could be a result of gap-phase regeneration occurring because there are canopy openings allowing more sunlight, the mortality of mature aspen stimulating new growth, or the continuous stunting of regeneration stems due to overbrowsing (Calder & St. Clair, 2012; Crouch et al., 2023; Rogers & Mittanck, 2014). The latter could explain why the level of recruitment ha^{-1} is not enough for adequate stand replacement despite the amount of regeneration (Table 2).

Zones across the site were significantly different (Table 2.3). Significant variables contributing to these differences include stand layers (Figure 2.4 [b]), live basal area (Figure 2.4 [c]), and deer scat (Figure 2.5 [c]) being significant indicators, with Zone 1 having the least amount of stand layers and live basal area, and Zone 2 having the least amount of deer scat.

What effect does high-use recreation have on ungulate presence and aspen conditions?

There is a pattern of less ungulate presence where dog walking is high at our site. In Zone 3, the off-leash dog park, the lowest mean elk scat, deer scat, and percent browse (Table 2.5). The smaller degree of ungulate deer scat, elk scat, and browse (Figure 2.5) could be due to higher recreation use and the off-leash dogs or the scents of the dog urine and feces. Free-roaming dogs harass, compete, and prey upon wildlife which alters the activity patterns of wildlife (Arnberger & Hinterberger, 2003; Hughes & Macdonald, 2013). Visscher et al. (2023) found that human impacts on deer use and behavior is greater than that of natural predators (i.e., canids, felids, and ursids), though the same was not true for elk. Other studies found that ungulates, specifically elk, have been documented to avoid areas where humans and dogs are present, though they return during unoccupied hours (Parsons et al., 2016; Thompson & Henderson, 1998), which could be the case at our study site. In the current study, this means that recreators and their dogs could be deterring ungulates from overbrowsing on young aspen, having an indirect positive impact on aspen condition in a portion of this area.

Hunted populations of ungulates have more of a flight response to humans and dogs than unhunted ungulates (Thompson & Henderson, 1998). This is especially true when ungulate and human populations in the area are high, as they are at our site, and habituation in heavy traffic areas may decrease avoidance behavior of ungulates (Stankowich, 2008). Hunting is not permitted at our study site due to safety concerns for visitors of recreation area, so the unhunted ungulates may be more habituated to human and dog presence in the area. In contrast, a recent study by Beirne (2024) shows that large herbivores in high human populated areas became more nocturnal as human activity increases. So it is possible that the high presence of humans and dogs in Zone 3 (Figure 2.5) is deterring deer for long enough to meaningfully reduce browsing. In any case, the relationship of recreationists with abundant off-leash dogs, their impact on ungulate movement and behavior, and in turn the change in the amount of browsing on aspen is a topic worth investigating further.

How is soil contamination impacting aspen communities?

At our study site, indicators of soil contamination occur where aspen recruitment and mature stems are lowest (Figures 2.4 and 2.6). Zone 1 has the highest mean of SAR (1.07) and lowest mean of canopy cover, recruitment ha^{-1}, mature ha^{-1}, and live basal area (Table 2.2). SAR is the concentration of Na in soil measured as a ratio compared to magnesium (Mg) and calcium (Ca) (Barker et al., 2023; Davis et al., 2012). A high ratio of Na compared to Mg and Ca, or a high SAR, is a concern for soil structure because it causes soil particles to disperse instead of clumping or aggregating (Barker et al., 2023; Davis et al., 2012). Aggregated soils have larger pores, allowing water and root systems to move through the soil, whereas dispersion creates small pores that restrict the movement of water and root systems (Barker et al., 2023; Horneck et al., 2007). Dispersion restricts the movement of roots and water (Barker et al., 2023).

This is particularly apparent at plot 15 in Zone 1, a location along a stream with pooled water, creating a marshy area with broadleaf cattails (*Typha latifolia* L.). Plot 15 has the highest SAR (6.31), the highest Na (132.65 mg), and a low electrical conductivity (EC) (0.2 dS/m; Figure 2.2). The combination of an SAR >5 combined with an EC <2 dS/m results in ponding – regularly concentrating water on top of the soil (Barker et al., 2023; Davis et al., 2012). We found a clear pattern of high Na near the streams at our study site. Figure 2.2 shows us that the seven highest Na levels (>20 mg) are near the waterways, indicated by warm colored dots and a black dot for plot 15. Additionally, Figure 2.6 show us that high Na and SAR levels occur most frequently with closer proximity to surface water.

The proximity to streams leads us to speculate about the upstream inputs into the water. The stream that flows through Zone 1 comes directly out of the parking lot for a housing development for the Utah Olympic Park, which was opened in 2019, before which the footprint of that land was undeveloped (see Figure 2.7). Additional Na could be added to the system from the construction of the housing unit, continued construction from the expansion of the Utah Olympic Park, or winter road salting intended to increase traction under icy conditions. Unfortunately, the source of additional Na in the system was beyond the scope of this study, although we are compelled to report that it appears to be negatively affecting aspen forests here. These results suggest further testing of soil contents and investigation into the origins of likely off-sight contamination are recommended.

EC in higher concentrations can reduce plant growth through toxicity effects. High levels of EC induce osmotic stress and limits the ability of roots to intake both water and nutrients, causing plants to wilt even when water is present (Bolu & Polle, 2004; Bradfield & Guttridge, 1984; Davis et al., 2012; Lopez & Satti, 1996). Additionally, high levels of SAR and EC can limit root density, root length, and the ability of roots to intake both water and nutrients (Bolu & Polle, 2004; Bradfield & Guttridge, 1984).

However, Lilles et al. (2012) examined the growth of aspen in naturally saline sites, finding that aspen can grow in soil conditions previously considered unsuitable for forest vegetation (with an EC of 10 dS/m, and SAR of 13) with little evidence of nutritional toxicities or deficiencies. Long term effects of increased salinity included a significant decrease in basal area and overall growth over time. This matches our findings of Zone 1, the area of initial concern, having the lowest mean live basal area and mean dead basal area and the highest mean SAR compared to the other two zones (Table 2.2). Khasa et al. (2002) looked at the effects of salinity on aspen seedlings in short-term greenhouse and field trials, but the results do not translate to aspen landscapes or show long-term effects. Vaario et al. (2011) found that aspen experiencing stress from saline soils had lower leaf count on seedlings. Additionally, leaf necrosis significantly increased with increased salinity. However, this was a short-term study that did not examine long-term effects. Though the relationship specifically between aspen condition, Na, SAR, and EC has not been explored on a long-term basis, impenetrable soil caused by high SAR and low EC is an issue because it restricts the movement of water and roots, which is evident at our study site.

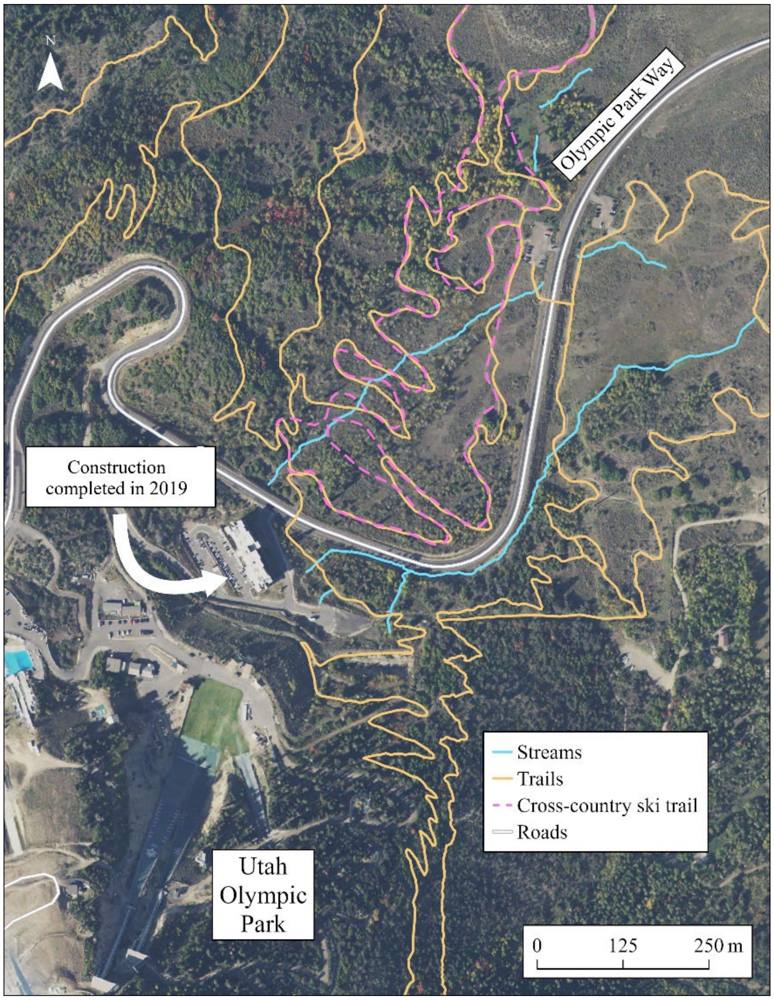

Figure 2.7. Area map of Utah Olympic Park buildings in relation to the streams in the study area. Streams are shown as blue lines, trails are shown as orange lines, cross-country ski trails are shown as dashed orange lines, and roads are sown as white lines.

How might area maintenance impact the aspen landscape?

Recreation is shaping the ecology of our landscape in several ways. Above we posited that the high presence of humans and dogs in Zone 3 could deter ungulate browsing. We also speculated that construction or the application of road salt occurring upstream for recreation at Utah Olympic Park could be the source of sodium at our site. Maintenance done onsite for cross-country skiing is another factor worth considering. Managers mow paths that are ~6 m wide in Zones 1 and 2 roughly twice a year. Aspen regeneration is not exempt from this mowing, which prevents the establishment of any aspen in the designated cross-country ski paths. Repeat mowing may act to deplete carbohydrate reserves in the clonal root network, much like chronic herbivory (Landhäusser & Lieffers, 2002). Such denudation of energy reserves ultimately affects the ability of new suckering to grow and thrive. Twelve out of 34 plots in Zones 1 and 2 combined are within 1 m of or intersect the cross-country ski path (Table 2.1), which means that regeneration stimulated by dying trees within the plots are removed by mowing for at least a third of all plots in Zones 1 and 3. We are unsure of the degree of impact mowing has on the site as a whole as it was not a focus of this study and recommend further investigation.

Conclusion and Management Implications

We examined the condition of a unique, high-use aspen recreational landscape using established aspen landscape survey methods (Rogers et al., 2010). Like many aspen stands in western North America and the Intermountain West region, the aspen forest at our study site is experiencing some declining populations (Rogers et al., 2010; Worrall et al., 2008). Across the study site, there is a lack of the vertical diversity expected of stable aspen stands for sustainable stand maintenance (Kashian et al., 2007; Kurzel et al., 2007; Mueggler, 1985). This appears to be due to a combination of overbrowsing by ungulates and high concentrations of Na in the soil, especially for Zone 1, where there is an area of stagnating water likely resulting from high SAR and low EC of the soil (Baker et al., 2021). The low presence of ungulates in Zone 3 compared to Zones 1 and 2 is likely related to consistent domestic canine presence. However, we are unable to present conclusive evidence to support causality, even in the face of striking geographic disparities in our results.

Contemporary stable aspen management focuses on promoting diversity in vertical structure (Crouch et al., 2023; Fahey et al., 2018; Novák et al., 2022). To promote diversity in height classes, managers emphasize sustainable regeneration and recruitment. If regeneration stems do not attain recruitment status and, sequentially recruitment does not attain overstory status, a height gap forms, and eventually self-replacement ceases (Kitchen et al., 2019; Shepperd et al., 2006).

Findings from this study are somewhat limited due to single point in time measures; however, one-time measures of recruitment can be telling in terms of multi-year trends (Rogers & Mittanck, 2014). We did not expressly examine temporal change at this site because our focus was on the current outlook of the landscape in response to Basin Recreation's request. A companion study is underway to gauge recreational visitor attitudes toward acceptance of a variety of management actions (Chapter III). Therefore, following whatever management actions may be taken, we suggest continued monitoring of the study site to understand system responses alongside ongoing soil testing with varying proximity to the streams. Temporary fencing of small areas is recommended to reduce browsing in Zone 1 and Zone 2 and to further understand the degree to which browsing is contributing to aspen conditions. Similarly, implementing a retention pond to filter out upstream pollutants is recommended to prevent further increases of Na into the system and to examine how soil SAR levels and EC change with the treatment.

Treatments that managers can use to stimulate aspen regeneration include partial cutting, root ripping, and prescribed burns (Rogers et al., 2014; Rogers & Gale, 2017). These disturbances trigger growth hormones and create openings in the overstory to let in sunlight (Beschta & Ripple, 2010; Huffman et al., 1999). Managers should consider these treatments where appropriate. Also to deter overbrowsing, managers could consider permitting or encouraging users with off-leash dogs to visit RTS, where the apparent decline is occurring, for certain periods of time to allow the regeneration in the area to reach the next height class.

This aspen system is unique as it serves as a high-use recreation destination for the local population, specifically for the off-leash dog area, and because of its location directly downstream from continued development. It should be clear from this and other works (Kashian et al., 2007; Rogers, 2022; Zier & Baker, 2006) that aspen forests are often unique and, thus, should not be managed as one type. This systematic survey of a recreation landscape can serve as a reference when examining high-use and near-development aspen communities, as well as forested systems at-large.

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CHAPTER III

RECREATIONISTS' PLACE IDENTITY AND PERCEPTIONS OF A DECLINING QUAKING ASPEN POPULATION: DRIVERS OF SUPPORT FOR MANAGEMENT ACTIONS

Abstract

People are drawn to quaking aspen (*Populus tremuloides* Michx.) landscapes for their unique aesthetics and biodiversity, symbolic meaning, and recreational opportunities. However, the influence of declining aspen populations in some areas of North America on people who frequent aspen landscapes is largely unexplored. To date, there have been no studies examining aspen conditions in tandem with the values of people who recreate in these landscapes. At a popular recreational area in Summit County, Utah, portions of the aspen forest appear to be declining, and there is little understanding of the recreation community's reaction to these declines. This area is intensively used throughout the year for dog walking, hiking, running, mountain biking, cross-country skiing, and experiential learning. For this study, we conducted intercept surveys to understand user values, place attachment, and what variables influence users' willingness to support six potential management actions that would maintain or improve aspen condition. We extended the concept of place identity, a dimension of place attachment, to explore to how people identify with the aspen at the site: we call this construct "aspen identity." Results suggest that users are broadly supportive of the proposed management actions. Strong aspen identity, an accurate perception of the aspen decline, and being motivated to visit the site for the landscape attributes corresponded with an increase in willingness to support management actions to maintain or improve aspen condition at the site. Identifying how

recreationists value aspen as part of the landscape, and aligning management strategies accordingly, can provide valuable insights for forest managers grappling with declining conditions in high-use areas throughout North America.

Introduction

The goal of outdoor recreation management is to balance providing a high-quality outdoor recreation opportunities with preserving ecological conditions and resources (Manfredo et al., 1983; Moore & Driver, 2007; Shin, 1997). Because there is no "one-size-fits-all" protocol for outdoor recreation management, public land managers collect a wide variety of feedback and information from recreationists (hereafter, "users"), such as user experiences and values, to make informed management decisions (Manning, 2022; McLaughlin & Paradice, 1980). Understanding users' preferences, expectations, and evaluations of conditions can result in management decisions that improve outdoor recreation experiences (Needham & Rollins, 2005). Previous studies assessed appropriate management actions and optimized recreation experiences by measuring users' place attachment (Gundersen et al., 2015; Martin et al., 2009), motivations (Arnberger et al., 2022; Hall et al., 2010), perceptions of environmental conditions (Flint et al., 2016; Kyle et al., 2004; White et al., 2008), and frequency of visitation (Hammitt et al., 2004, 2009; Hammitt & McDonald, 1983).

Place attachment specifically is a framework used to measure the value and meaning of place (Gundersen et al., 2015; Martin et al., 2009). Place attachment examines the degree to which people are connected to a place and how those connections influence attitudes, preferences, and experiences more broadly (Kyle et al., 2004; Manning, 2022). Place research in the context of outdoor recreation aims to understand the subjective, emotional, and symbolic meanings associated with natural places and the personal bonds or attachments people form with specific places or landscapes (Beery & Jönsson, 2017; Williams & Stewart, 1998). To gain this understanding, two dimensions of place attachment are often measured: place dependence and place identity. Place identity and place dependence are two dimensions of place attachment (Williams & Vaske, 2003). Place identity refers to the emotional and symbolic aspect of a person's relationship to a place (Jorgensen & Stedman, 2001; Manning, 2022; Williams et al., 1992), including person–place connection between a setting and personal identity or self-identity (Hidalgo & Hernández, 2001; Proshansky, 1978). Place dependence refers to a person's goal and activity needs (Jorgensen & Stedman, 2001; Manning, 2022; Williams et al., 1992), reflecting the importance of a place in providing conditions that support an intended use, such as accessible rock climbing routes or navigable whitewater rapids.

When it comes to management of quaking aspen (*Populus tremuloides* Michx.; hereafter, "aspen") in highly recreated landscapes, social and ecological dimensions should be given equal weight by managers. Aspen is the most widely distributed tree species in North America (Little & Viereck, 1971; Perala et al., 1990). McCool (2001) argues that understanding the human dimensions of aspen is a vital component of managing these systems. We do not have a thorough understanding of what meanings of aspen exist across time or space, nor do we understand how management and restoration might impact those meanings. However, it is clear that aspen provide instrumental, aesthetic, cultural or symbolic, and individual meaning and values (McCool, 2001; Williams & Patterson, 1999). To conduct management without such knowledge risks losing the values associated with those meanings without understanding what is being lost (McCool, 2001).

There are a variety of established protocols and tested common practices that managers can refer to when tailoring a management plan to an aspen forest (Kitchen et al., 2019); however, there are a lack of aspen management practices that incorporate feedback from people who visit aspen landscapes, particularly in reference to potential visual, cultural, or spiritual connections to these landscapes. In addition to understanding current conditions and threats, forest managers addressing aspen population fluctuations need to understand the social value of the landscapes they oversee (McCool, 2001; Mönkkönen et al., 2018). To accomplish this, managers must balance potentially conflicting wants and needs of various stakeholders, especially when aspen forests serve as recreation destinations.

Many studies have investigated public support for land management actions in effort to develop socially sustainable management actions that maintain or improve recreation experiences, including limiting the number of users allowed in an area, implementing timed entry protocols at parks, and requiring hiking or overnight camping permits (Borrie et al., 2002; Gundersen et al., 2015; Martin et al., 2009). The goal of these use restrictions is crowd reduction and reduced ecological impact (Groshong et al., 2020; Manning, 2022). Measuring support for management actions that mitigate impacts on vegetation and wildlife is common practice, such as closing campsites (Price et al., 2018; Rauscher, 1999; Wright, 2000), implementing controlled burns (Toledo et al., 2013), or closing trails when wildlife are present (Elmeligi et al., 2021). Multiple studies have demonstrated a relationship between willingness to support management and recreation motivations (Gundersen et al., 2015; Hall et al., 2010), perceptions of environmental conditions (Mallette et al., 2021), and place attachment (Groshong et al., 2020).

We were interested in understanding user preferences, motivations, and tolerances related to a high-use recreation area centered on an aspen community experiencing varying levels of deterioration. To bridge recreation and aspen management, we administered an intercept survey June-October 2023 in tandem with the ecological survey that we conducted in the summer of 2022 (as detailed in Chapter II). The objectives of this study were to understand: 1) how users at two adjacent recreation areas in Summit County, Utah value the aspen forest present there, 2) how supportive these users are of different management actions for maintaining or improving aspen condition, and 3) what contributes to these users' willingness to support different management actions. We hypothesized that users would be more likely to support management actions if they notice the decreasing aspen population, are frequent visitors to the site, and have a strong sense of aspen identity and place dependence. Ultimately, this study provides insight on factors that contribute to user support for different aspen forest management actions, as well as broader knowledge of user responses to proposed actions in valued landscapes at-large.

Methods

Study Site

This study took place at a high-use recreation area in Summit County, Utah: Right Turn Sage (RTS) and Run-A-Muk (RAM) trail areas. RTS (453,016.04E 4,507,288.81N) is a trail area designated for hiking, mountain biking, and cross-country skiing with over 16 km of trails, while RAM (453,195.93E 4,507,142.45N) is an off-leash dog area. RTS and RAM are divided by the Olympic Parkway Road. Unlike typical dog parks, RAM offers over five km of well-maintained trail and 17.4 ha[1] of enclosed forested and sagebrush-covered hills. According to trail counters at each of the three entrances to RTS/RAM, in 2023 there were an average of 554 visitors per day at RAM, and 69 at RTS, for a total of 623 daily visitors (*Eco-Visio*, 2019). Both areas are managed by the Snyderville Basin Special Recreation District (hereafter, "Basin Recreation"). Basin Recreation is a branch of the Summit County Government; they oversee all recreation facilities, indoor and outdoor, within the county.

RTS and RAM together cover 1,429.4 ha[1], with an estimated 11.6 ha[1] (~0.8%) of this area dominated by quaking aspen. The recreational activities are centered on the aspen habitat, though it only makes up a small portion of the total RTS/RAM area. The RTS trail area is where visible signs of aspen population decline are occurring (see Chapter II). Notably, the area is adjacent to the Utah Olympic Park that was originally built for the 2002 Winter Olympics and continues to train athletes today, and 1.6 km down the road, Olympic Parkway, from the Utah Olympic Park residential housing that was completed in 2019. These sites also overlook the Swaner Preserve & EcoCenter, a nature preserve and educational center that covers 485.6 ha, with RTS/RAM acting as an extension of the preserved open space.

Three elements of RTS/RAM make it a unique recreation area and study site. First, and of most interest to this study, is the aspen which serves as a keystone species supporting diverse plant and wildlife habitat (Chong et al., 2001; Hardenbol et al., 2020;

Kuhn et al., 2011; Rogers et al., 2020). Aspen are the visual focal point of the site. Second, the most popular activity is dog walking due to the large off-leash dog park that is complete with hiking trails, elevation gain, opportunities for wildlife viewing, streams that provide water for dogs on hot summer days, and shaded areas of aspen and Gamble oak (*Quervus gambelii* Nutt.). Lastly, RTS/RAM is a particularly appropriate site for this study because it is a relatively small area near the visiting population, has frequent repeat visitors who are local to the area (unlike a National Park or other tourist destination), and is managed by Basin Recreation which is able and willing to implement management actions that users deem favorable.

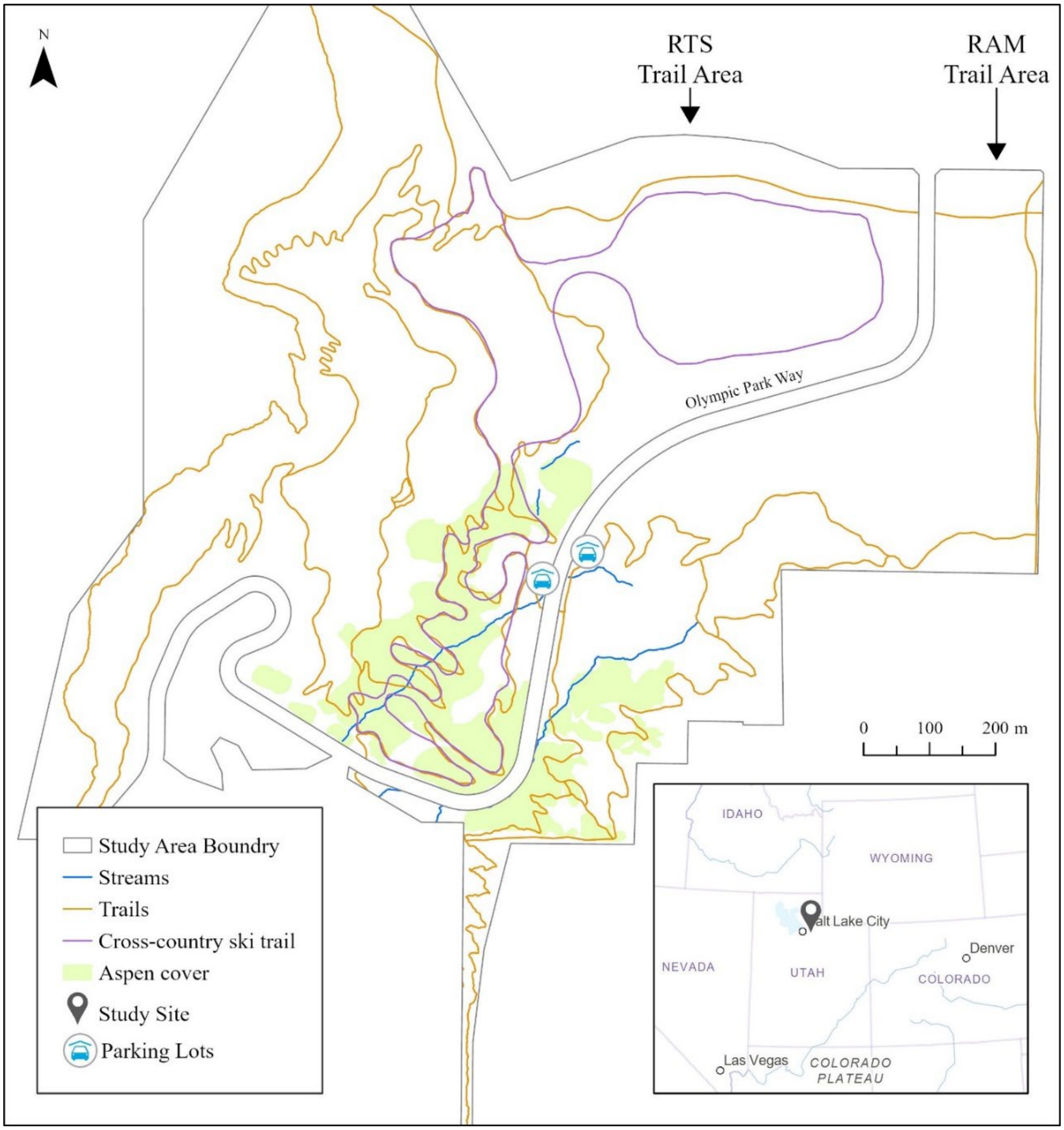

Figure 3.1. Map of the study site, the Right Turn Sage (RTS) and Run-A-Muk (RAM) trail areas in Summit County, Utah that are separated by Olympic Park Way, a road that leads to the Utah Olympic Park. Displayed are trails, the cross-country ski trails, and the aspen cover.

Data Collection

We administered visitor intercept surveys June-October 2023, four days per month, alternating between sites, and stratified across days of the week and time of day to ensure an accurate representation of total day-use visitation. The surveys were self-administered questionnaires on a tablet using the Qualtrics survey application (Qualtrics, Provo, Utah). We asked one person per visitor group who was 18 years or older to participate in the survey. To minimize selection bias, we requested that the individual within the group who had the closest upcoming birthday participate in the survey.

Using the CheckMarket sample size calculator (Medallai, 2021), we calculated 384 to be the minimum sample size required for accurate estimates. This calculation required the population size, estimated response rate, standard error, and confidence rate specific to the sample population. We used a standard 5% margin of error, a 95% confidence level, and an estimated response rate of 70% (Dillman et al., 2014; Needham et al., 2008), though intercept surveys of this nature usually have a response rate slightly higher than 70% (Davis et al., 2012; Melstrom, 2015; Vaske, 2008).

To calculate the population size, we used trail counter data provided by Basin Recreation of 204,564.25 individual annual visits. This count includes individuals who repeatedly visited RTS/RAM and who were recorded multiple times by the trail counters, but it is impossible to know how many of the visits were repeat visits. Though the metric is flawed, it is the best population size gauge for visitors of the area.

Only users who had finished recreating were asked to participate in the 5-minute survey. If they declined to participate, they were verbally asked if they came here regularly, if they are a permanent or seasonal resident, and what their zip code is to later calculate nonresponse bias. In all cases, the research technician noted perceived gender, recreation activity, time of day, location (RTS or RAM), group size if applicable, and if they declined or participated in the survey. A verbal recruitment script detailing how research technicians should approach potential participants can be found in Appendix B. To reduce bias and other sources of research error, standardized training specific to the survey was provided for the research technicians, including human subject research certifications, and survey distribution practice prior to implementation with users.

Survey Questions

The purpose of this survey was to understand the degree to which users demonstrate attachment to the site or the aspen at the site, if they perceive declining aspen, and what management actions they would support to maintain or improve the condition of the aspen (see survey questions in Table 3.3; full survey, Appendix A).

Before participants answered survey questions, they were presented with an informed consent document required by the Utah State University Institutional Review Board. Once informed consent was obtained, the first set of questions aimed to understand user patterns, including site, activity, years visiting, and frequency of visiting. Next was a question asking participants if they perceive a change in the amount of aspen in the area, and if so, how that affects them.

Five-point Likert scales (from 1 = Disagree to 5 = Agree) were used to address motivations to visit the site and the two dimensions of place attachment; place identity and place dependence. Place identity and dependence are measured using two similar scales—one by Warzecha and Lime (2001) and the other by Williams and Vaske (2003; Table 3.1). We used four place dependence and four place identity scale items from William and Vaske (2003) to measure place attachment, but adapted place identity scale items to measure how users identify with the aspen on the landscape. We referred to this concept as aspen identity.

Table 3.1. Two scales that are commonly used to measure place identity and dependence in a recreation context (Warzecha & Lime, 2001; Williams & Vaske, 2003).

	Warzecha and Lime (2001)	Williams and Vaske (2003)
Place Identity	I am very attached to this place.	I am very attached to "X".
	I identify strongly with this place.	I identify strongly with "X".
	I feel this place is a part of me.	I feel "X" is a part of me.
	This place means a lot to me.	"X" means a lot to me.
	This place is very special to me.	"X" is very special to me.
	I would prefer to spend more time here if I could.	Visiting "X" says a lot about who I am.
Place Dependence	No other place can compare to this area.	No other place can compare to "X".
	I get more satisfaction out of visiting this place than any other.	I get more satisfaction out of visiting "X" than any other.
	This area is the best place for what I like to do.	"X" is the best place for what I like to do.
	The time I spent here could have just as easily be spent somewhere else.	The things I do at "X" I would enjoy doing just as much at a similar site.
	This place makes me feel like no other place can.	Doing what I do at "X" is more important to me than doing it in any other place.
	I can't imagine a better place for what I like to do.	

A 7-point Likert scale (from 1 = Strongly Oppose to 7 = Strongly Support) was used to address users' willingness to support management actions that could preserve or improve aspen condition at RTS/RAM that were determined by the findings of Chapter II. Brief context was provided for each proposed management action. A 7-point scale was used here instead of a 5-point scale because more detail on the degree of user support will be used in deciding which management actions to implement. Lastly, we utilized a set of demographic questions from the 2019 National Park Service Pool of Known Questions to ensure results are comparable to other recreation studies and because the questions have been previously tested (National Park Service U.S. Department of the Interior, 2019).

Data Analysis

First, an Exploratory Factor Analysis (EFA) was conducted on two categories of independent variables (motivations, and place attachment; see Table 3.3 for variable meaning) to reduce the redundancy of scale items and simplify the interpretation of the logistic regression. Scale item reliability was assessed with Cronbach's Alpha, which returned coefficients greater than 0.7 for all scales (Bland & Altman, 1997; DeVellis & Thorpe, 2021; Kline, 2023). Variables that reduced the Cronbach's alpha coefficients were selectively removed.

Once the latent variables were established, we used an ordinal linear regression (OLR) as the primary statistical method to analyze the data in R version 4.2.2 (R Core Team, 2022) using the R-package *MASS* (Ripley et al., 2024) and R-package *lmtest*. Results were considered statistically significant at the 95% confidence level ($p < 0.05$; McCune et al., 2002; Vaske, 2019; Zar, 1999). OLRs are specifically designed for response variables that have more than two ordered categories, such as Likert data. Six models were created, one for each of the six management actions for which survey participants ranked their willingness to support on a Likert scale of one (strongly oppose) to seven (strongly support). An OLR was run for each pairing of explanatory and response variables.

Lastly, we visualized the relationship between independent variables from our hypothesis and the level of support for the proposed restorative management actions for a more nuanced understanding in R version 4.2.2 (R Core Team, 2022) using the R-package *MASS* (Ripley et al., 2024), R-package *lmtest* (Hathorn et al., 2022), and R-package *ggplot2* (Wickham & Chang, 2014). We did this using two different methods depending on the independent variable: 1) using results from the ORL model, where the predicted probabilities are visualized in a line plot, illustrating how the likelihood of different educational levels varies with changes in place identity; 2) using stacked proportional bar charts to show the distribution of support among participants.

Results

Descriptive

Research technicians approached 495 users, 454 of whom elected to participate in the study, yielding a response rate of 87%. Most users reported being permanent residents (74%) or seasonal residents (8%) of Summit County or a neighboring county. The sample was nearly evenly distributed between men (45%) and women (55%), most of whom reported to be white (92%). The median age of users was 52 with 98% reporting that they had attended at least some college or more (41% of the sample had a graduate degree) and roughly half of these users (48%) reported making more than $100,000 in household income in 2022 (77% reported making more than $75,000 and 8% making less than $50,000). A majority of users (87%) were returning visitors and roughly half of the users reported that they have been visiting the site for five years or more (53%). Table 3.2 displays more demographic information for returning, first-time, and all users. We separated returning and first-time users to highlight that a majority of survey participants (87%) were returning users and because first-time users were not given all of the survey questions. A summary of all survey responses can be seen in Table 3.3, which includes the survey questions from which the variables are derived, how they are measured or coded, and the sample size, mean, and standard deviation for each variable. Survey questions not given to the first-time users are marked.

Table 3.2. Demographic information of the survey participants. Survey participants are divided into returning users and first-time users.

	Returning users	First-time users	All users
Total survey participants	394	60	454
Permanent resident of Summit County or neighboring county	80.05%	35.19%	74.42%
Seasonal resident of Summit County or neighboring county	6.65%	7.41%	6.74%
Not a resident of Summit County or neighboring county	13.30%	57.41%	18.84%
Population			
Women	55.21%	49.15%	45.15%
Men	44.27%	50.85%	54.40%
Self-identified gender	0.52%	0.00%	0.45%
Age			
Median age (years)	53	46	52
18-24	0.69%	8.16%	1.77%
25-44	30.69%	36.73%	31.56%
45-54	22.41%	24.49%	22.71%
55-64	26.21%	16.33%	24.78%
65 and over	20.00%	14.29%	19.17%
Race and ethnicity			
American Indian or Alaska Native	1.50%	3.28%	1.76%
Asian	2.49%	1.64%	2.42%
Black	0.50%	0.00%	0.44%
Hispanic or Latino	3.99%	1.64%	3.74%
Middle Eastern	0.25%	0.00%	0.22%
Native Hawaiian or other Pacific Islander	0.50%	0.00%	0.44%
White	89.03%	90.16%	90.75%
Not listed	1.75%	3.28%	1.98%
Education attainment			
Less than high school	0.00%	1.69%	0.22%
High school graduate/GED	2.33%	1.69%	2.24%
Vocational/trade school certificate	8.53%	16.95%	9.64%
Some college	6.72%	6.78%	6.73%
Bachelor's degree	41.86%	30.51%	40.36%
Master's degree	26.10%	28.81%	26.46%
Doctoral degree	4.91%	5.08%	4.93%
Professional degree	9.56%	8.47%	9.42%
2022 household income (before taxes)			
Less than $25,000	1.63%	6.90%	2.35%
$25,000 to $34,999	1.90%	1.72%	1.64%
$35,000 to $49,999	3.80%	6.90%	4.23%
$50,000 to $74,999	10.33%	8.62%	10.09%
$75,000 to $99,999	9.78%	18.97%	11.03%
$100,000 to $149,999	20.38%	22.41%	20.66%
$150,000 to $199,999	15.49%	10.34%	14.79%
$200,000 or more	36.68%	24.14%	34.98%

Table 3.3. Summary statistics of the study variables. The category of each variable, the variable name used in the analysis, the question wording associated with the variable name, variable measurement/coding, number of respondents (*n*) who answered the question (*n*), mean score of the responses, and standard deviation (SD) of the responses is provided. Categories of variables that were reduced using an Exploratory Factor Analysis are designated with *. Categories of variables and variables that were not given to first-time users are designated with **†**.

Variables	Question wording	Variable coding	n	Mean	SD
User patterns					
Returning	Have you visited this recreation area before?	0 = no; 1 = yes	no = 60; yes = 394	0.87	0.34
Site	Which part(s) of the Run-A-Muk and RTS trail areas do you access when you visit? / Which part(s) of the RAM and RTS trail areas will you access today?	1 = RTS; 2 = RAM; 3 = both	RTS = 64; RAM = 234; both = 147	NA	NA
Activity	What activities do you participate in in this recreation area? / What activities will you participate in today in this recreation area?	0 = no dog (hiking, running, wildlife watching, educational programs, biking, other); 1 = dog walking/dog park use	no dog = 77; dog = 377	0.83	0.38
Years†	Approximately how many years have you recreated in the Run-A-Muk and RTS trail areas?	Continuous	390	6.00	5.94
Frequency†	About how often do you typically visit this recreation area?	1 = never; 2 = less than once a month; 3 = once a month; 4 = several times a month; 5 = several times a week	summer = 391; fall = 364; winter = 353; spring = 353	summer = 4.31; fall = 4.23; winter = 3.81; spring = 4.13	summer = 0.93; fall = 0.99; winter = 1.33; spring = 1.06
Perceived decrease†	Have you noticed a change in the amount of aspen in the Run-A-Muk and RTS trail areas since you started recreating here?	0 = did not perceive decrease (significant increase, slight increase, no change, don't know); 1 = did perceive decrease (slight decreases, significant decrease)	395	0.15	0.35
Motivations*†					
Trails	I come here because I like the quality of the trails.	1 = disagree; 2 = somewhat disagree; 3 = neutral; 4 = somewhat agree; 5 = agree	390	4.80	0.51
Dog	I come here for the off-leash dog area.		384	4.64	1.02
Proximity	I come here because it is close to where I live.		387	4.25	1.19
Color	I come here for the color of the fall leaves.		387	4.01	1.10
Shade	I come here because I like the shade provided by the trees.		386	3.83	1.13
Streams	I come here because I like the streams.		382	3.71	1.16
Social	I come here because I like meeting/interacting with other people.		385	3.60	1.19
Solitude	I come here for solitude.		386	3.42	1.28
Aspen	I come here for the aspen.		385	3.37	1.16
Spiritual site	I have a spiritual connection to this area.		383	3.21	1.36
Spiritual aspen	I have a spiritual connection to the aspen in this area.		382	3.05	1.33
Wildlife	I come here to see wildlife.		384	2.94	1.28
Place attachment*†					
Place dep 1	This is the best place for the type of recreation I like to do.	1 = disagree; 2 = somewhat disagree; 3 = neutral; 4 = somewhat agree; 5 = agree	386	4.03	0.98
Place dep 2	Doing what I do here is more important to me than doing it in any other place.		386	3.82	1.01
Place dep 3	I get more satisfaction out of recreating here than in any other place.		386	3.71	1.05

Place dep 4	The things I do here I would enjoy doing just as much at a similar site.		387	3.56	1.16
Aspen ID 1	I would prefer to spend more time in aspen if I could.		378	4.11	0.87
Aspen ID 2	Landscapes with aspen provide an experience like no other landscape in this area can.		377	4.05	0.91
Aspen ID 3	I get more satisfaction out of spending time in aspen landscapes than other landscapes.		376	3.88	0.91
Aspen ID 4	I am very attached to aspen.		377	3.77	1.02
Management Actions					
Signage	Put up educational signs about aspen ecology and management practices.		439	5.72	1.20
Pond	Add water retention ponds to filter pollution out of the water before it enters the area.	1 = strongly oppose; 2 = oppose; 3 = somewhat oppose; 4 = neutral; 5 = somewhat support; 6 = support; 7 = strongly support	438	5.71	1.26
Education	Have educational events to explain aspen ecology and management practices.		441	5.40	1.23
Cutting	Selectively cut mature aspen to stimulate new aspen growth.		440	5.18	1.34
Fence	Surround some areas with an 8 ft fence to prevent elk, deer, and moose from eating young aspen.		438	4.55	1.71
Trail	Reduce cross-country ski trail mileage to allow for aspen regrowth.		440	4.45	1.62

The six management actions proposed in the survey, in order from most to least supported, are adding educational signage, installing a retention pond, educational events, selective cutting, fencing, and reducing cross-country ski trails. For all six management actions, less than 25% of survey participants opposed the management action. For all management actions except reducing cross-country ski trails, at least ~50% of participants were in support. The number of responses for each management action was between 438 and 441. Figure 3.2 displays the proportion of overall willingness to support each management action.

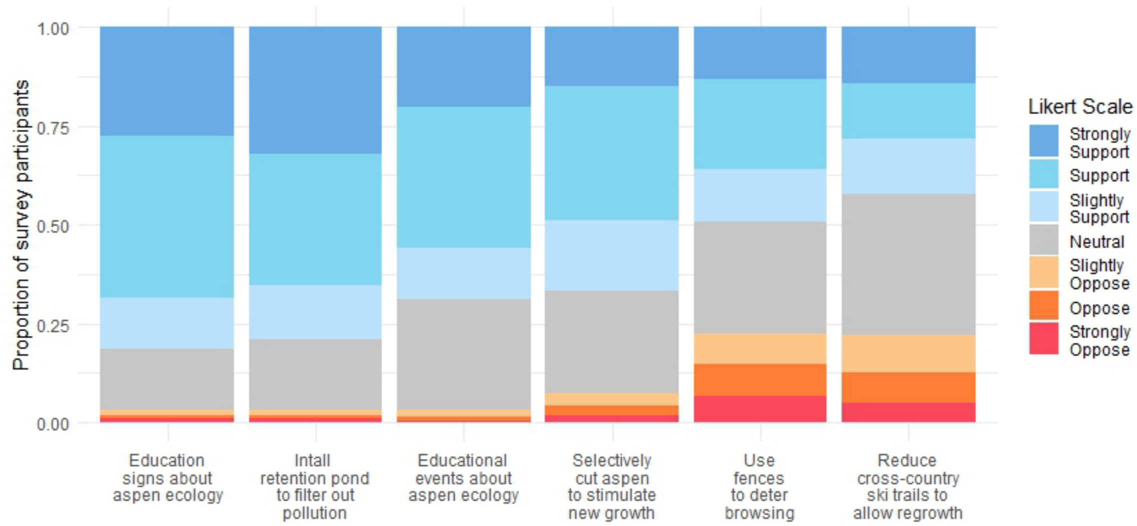

Figure 3.2. Stacked bar chart showing the percentage of respondents who opposed or supported the six management actions proposed that could maintain or improve the condition of the aspen at the study site. Management actions are ordered by most to least support. Note that the wording for each management action in this chart is paraphrased from the original wording in the survey. Find the original wording in Table 3.3. The number of responses for each management action ranges between 438 and 441.

Independent Variable Dimension Reduction

The frequency variable, measuring how often users visit the site, was reduced from four 1-5 scales (one for each season; fall, winter, spring, summer) to a single 1-5 scale by taking the mode from the four scales for each survey participant. Scale values are explained in Table 3.3.

The Exploratory Factor Analysis (EFA) on the motivation variables produced four latent variables that represent factors that motivated users to visit the site: landscape, social, solitude, and spiritual factors. Each factor has a unique scale range produced by the EFA. The landscape factor ranges from -2.4 to 2, the social factor ranges from -3.6 to 1.5, the solitude factor ranges from -1.9 to 1.6, and the spiritual factor ranges from -2.3 to 2.1. The landscape, solitude, and spiritual factors have scales that center around zero, and therefore have approximately an equal number of survey participants who were and were not motivated by that variable. The social latent variable has a scale that is centered at

2.1, meaning more participants were not motivated by social factors than participants that were motivated by social factors (Table 3.4).

Table 3.4. Exploratory Factor Analysis results for the motivation variables. Only scores >0.3 displayed. Factors are interpreted as 1 = landscape, 2 = spiritual, 3 = social, and 4 = solitude based on groupings.

	Factor Loading Scores			
Statement	**Landscape**	**Spiritual**	**Social**	**Solitude**
I come here for the aspen	0.829			
I come here for the color of the fall leaves	0.709			
I come here because I like the streams	0.619			
I come here to see wildlife	0.606			
I come here because I like the shade provided by the trees	0.575			
I have a spiritual connection to the aspen in this area		0.899		
I have a spiritual connection to this area		0.770		
I come here because I like meeting / interacting with other people			0.586	
I come here for the off-leash dog area			0.547	
I come here because I like the quality of the trails				
I come here for solitude				0.625

As expected from the place attachment work done by William and Vaske (2003), the EFA reduced the place attachment variables into two latent variables: aspen identity and place dependence. Aspen identity ranged from -3.7 to 1.6 and place dependence ranged from -3.0 to 1.4, meaning more survey participants did not have a sense of aspen identity or place dependence on the site (Table 3.5).

Table 3.5. Exploratory Factor Analysis results for place attachment variables; place dependence (place dep) and aspen identity (aspen ID). Only scores >0.3 displayed. Factors are interpreted as 1 = Place dependence and 2 = Aspen identity. There is no Place dep 4 because the prompt was phrased in the negative, in opposition to the other phrases.

		Factor Loading Scores	
Variable	**Statement**	**Place dependence**	**Aspen identity**
Place dep 1	This is the best place for the type of recreation I like to do.		0.844
Place dep 2	Doing what I do here is more important to me than doing it any other place.		0.795
Place dep 3	I get more satisfaction out of recreation here than in any other place.		0.877
Aspen ID 1	I would prefer to spend more time in areas with aspen if I could.	0.847	
Aspen ID 2	Landscapes with aspen provide an experience like no other landscape in this area can.	0.808	
Aspen ID 3	I get more satisfaction out of spending time in aspen landscapes than other landscapes.	0.865	
Aspen ID 4	I am very attached to aspen.	0.811	

In total, the EFAs resulted in six latent explanatory variables: aspen identity, place dependence, and four motivation variables (landscape, social, spiritual, and solitude). We used the latent variables along with the variables of site, frequency, activity, gender, age, income, and perceived decrease of aspen (hereafter, “perceived decrease”), as the explanatory variables in the OLR. The full models contained all 13 explanatory variables (Table 3.6). We ran reduced models with explanatory variables that were significant when paired with the corresponding response variable (management action), but there was limited change in the findings and worse model fits, so we excluded them from the results table. Aspen identity was the only variable that showed consistent significance, being significant for all models except for the full fence model. Site was significant for the reduced ski trails model and perceived decrease was significant for the full ski trails models. No other variable was significant in any other model.

Table 3.6. Table of the coefficient (Coef.) and significance (Sig.) of the explanatory variables in the ordinal logistic (OLR) model, which are the six proposed management actions that would maintain or improve the condition of aspen at the site. Significance is denoted with . = $p < 0.1$, * = $p < 0.05$, ** = $p < 0.01$, and *** = $p < 0.001$. Model statistics include the log likelihood, the likelihood ratio chi-square statistic (LR X^2), the McFadden's Pseudo r^2, Akaike information criteria (AIC), Bayesian information criteria (BIC), and sample number (*n*).

		Signage			**Pond**			**Education**			**Cutting**			**Fence**			**Ski Trails**		
Category	**Variable**	**Coef.**	**Sig.**		**Coef.**	**Sig.**		**Coef.**	**Sig.**		**Coef.**	**Sig.**		**Coef.**	**Sig.**		**Coef.**	**Sig.**	
Use patterns	Site	-0.63	1.95		0.16	0.66		0.07	0.84		-0.29	1.63		-0.07	1.17		0.54	0.09	.
	Activity	0.44	0.15		0.05	0.87		-0.20	1.47		0.26	0.37		0.55	0.06	.	0.23	0.43	
	Frequency	0.07	0.50		0.00	0.99		0.18	0.11		0.10	0.27		0.12	0.17		0.13	0.15	
Perceptions	Perceived decrease	0.08	0.80		0.33	0.32		-0.17	1.40		0.47	0.14		0.15	0.63		0.60	0.06	.
Demographic	Age	-0.01	1.73		-0.01	1.94		0.00	1.40		-0.01	1.73		-0.01	1.83		-0.01	1.90	
	Gender	0.01	0.98		0.05	0.80		-0.17	1.58		-0.17	1.59		0.12	0.56		-0.18	1.63	
	Income	0.00	1.69		0.00	0.16		0.00	1.94		0.00	0.10		0.00	0.70		0.00	0.79	
	Years	0.00	0.89		0.00	1.05		0.01	0.86		-0.05	1.91		-0.05	1.94		0.01	0.80	
Motivations	Landscape	0.11	0.33		0.03	0.76		-0.05	1.36		0.01	0.96		0.15	0.18		0.00	1.00	
	Social	-0.01	1.04	*	0.21	0.17		-0.05	1.27		0.03	0.85		-0.01	1.05		-0.10	1.52	
	Solitude	-0.03	1.15		-0.27	1.93		0.12	0.40		0.29	0.04	*	0.16	0.23		0.11	0.43	
	Spiritual	-0.21	1.95		0.04	0.72		-0.09	1.60		-0.23	1.98		0.04	0.68		-0.16	1.88	
Place attachment	Aspen identity	0.38	0.00	***	0.37	0.00	***	0.57	0.00	***	0.41	0.00	***	0.09	0.42		0.51	0.00	***
	Place dependence	0.21	0.13		0.13	0.35		0.18	0.20		0.00	1.02		0.14	0.29		0.02	0.88	
Model statistics	Log likelihood	-193			-192			-195			-216			-250			-227		
	LR *X2*	361			359			364			407			475			429		
	Pseudo r2	0.71			0.72			0.72			0.71			0.70			0.72		
	AIC	401			399			404			447			515			469		
	BIC	472			470			475			518			585			540		
	n	136			136			137			137			224			136		

Visualizing Support for Management by Variables

To further test our hypothesis and obtain a more nuanced understanding of what variables contributes to a user's willingness to support management actions, we examined how four explanatory variables (perceived decrease, frequency, motivation landscape, and aspen identity – the variables from our hypothesis) were associated with survey participants' willingness to support management actions (Figures 3.3, 3.4, 3.5, and 3.6). Only four of the six management actions were tested (fencing, cutting, installation of a retention pond, and reducing cross-country ski trails). The two excluded management actions, hosting education events on aspen and adding signage about aspen, were not included in this examination because, although they have the potential to increase awareness and appreciation, they are not ecological restoration actions. For all four explanatory variables, the trend found in Figure 3.2 continued, with support being strongest for installing a retention pond and weakest for reducing cross-country ski trails.

Survey participants with stronger aspen identity were more supportive of all four ecological restoration management actions, especially the installation of a retention pond (Figure 3.3). The same was true for survey participants with a stronger motivation to visit the site for landscape attributes, though the relationship between support and aspen identity was greater and more significant than the relationship between support and stronger motivation to visit the site for landscape attributes (Table 3.6, Figure 3.3, Figure 3.4). Additionally, aspen identity was highly statistically significant for all management actions except fencing, and motivation to visit the site for landscape attributes was not statistically significant for any management action (Table 3.6).

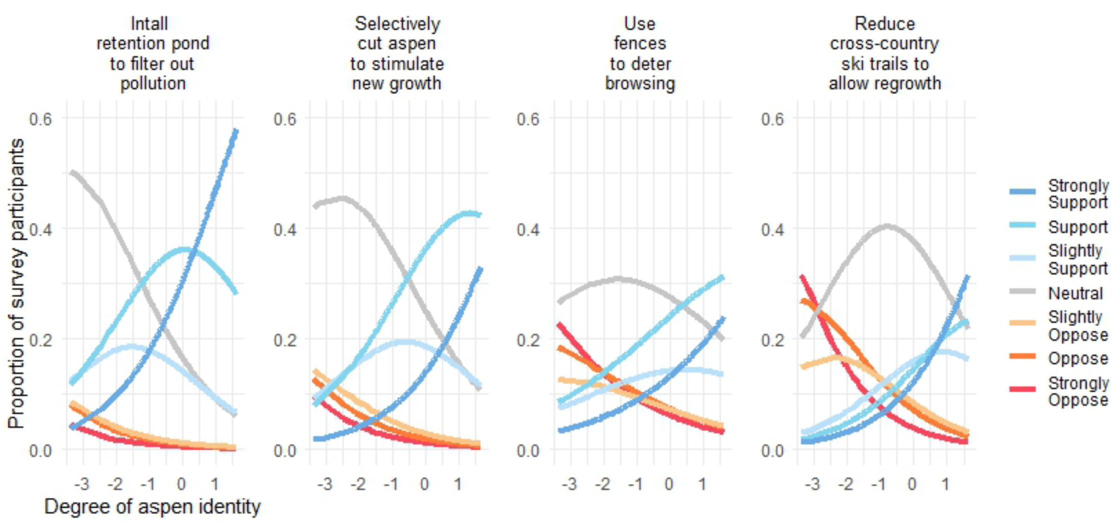

Figure 3.3. Proportion of survey participants who were in support of and opposition to four management actions (along the x-axis), and the difference of those proportions between survey participants with different levels of aspen identity. Table 3.4 describes the factor loadings for aspen identity. The x-axis scale was determined by the Exploratory Factor Analysis.

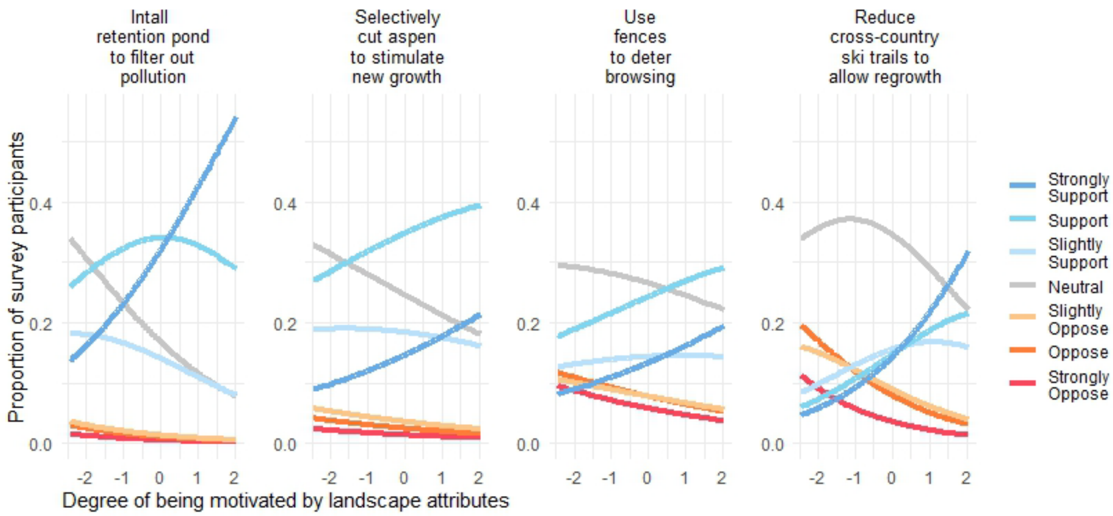

Figure 3.4. Proportion of survey participants who were in support of and opposition to four management actions (along the x-axis), and the difference of those proportions between survey participants with different levels of motivated to visit the site for landscape attributes including the aspen, the color of the leaves in the fall, the shade provided by the trees, wildlife, and the streams (Table 3.4). The x-axis scale was determined by the Exploratory Factor Analysis.

A majority of survey participants did not perceive the decrease in the aspen population (n = 337) and 15% did perceive the decrease (n = 58). Survey participants who did perceive the decrease in the aspen population were less likely to have a neutral opinion and were both more in support and more in opposition to all four ecological restoration management actions than survey participants who did not (Figure 3.5). However, the differences between support and oppose were only statistically significant for reducing cross-country ski trails to allow regrowth (Table 3.6).

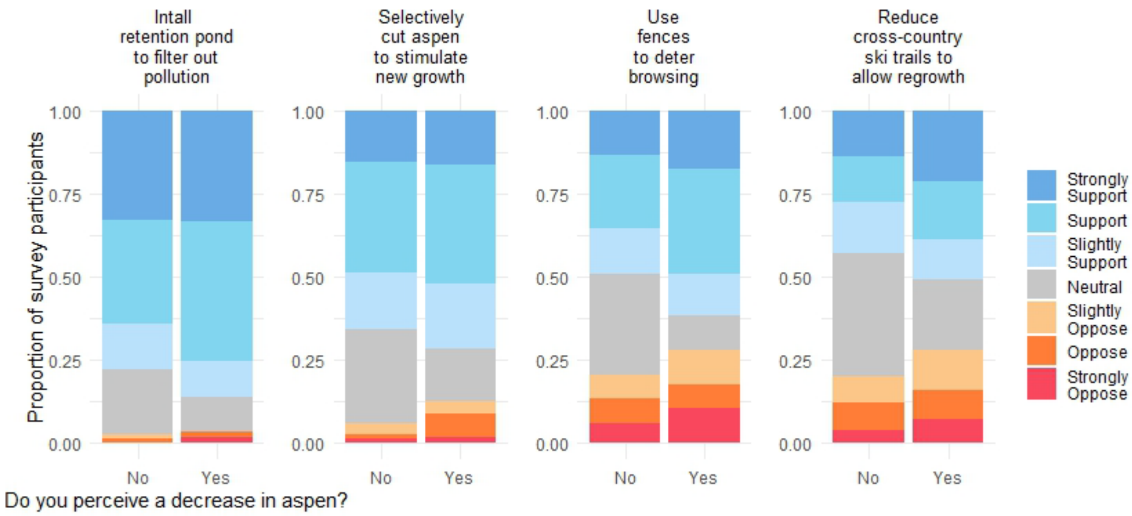

Figure 3.5. Stacked bar graph showing the proportion of survey participants who were in support of and opposition to four management actions (along the x-axis), and the difference of those proportions between survey participants who did and did not perceive the decrease in the amount of aspen at the site.

The average frequency of visits for a returning survey participant was several times a month throughout the year (Table 3.3). Results for the relationship between frequency of visits and support for management actions were mixed (Figure 3.6) and not statistically significant (Table 3.6). Survey participants who visited the site with greater frequency were more in support of installing a retention pond and reducing ski trails, and less supportive of selectively cutting mature aspen. Frequency of visits does not have an apparent effect on support for fencing.

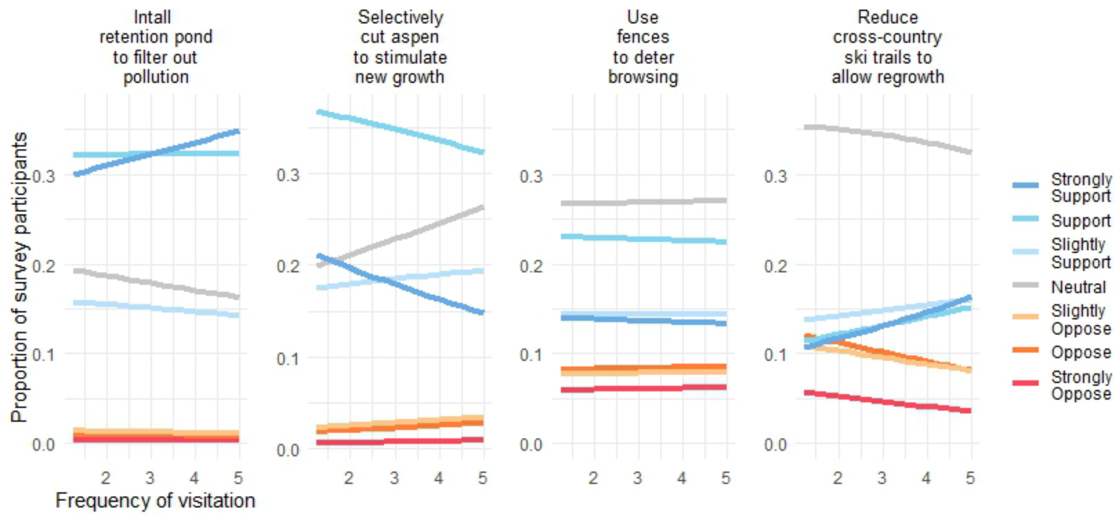

Figure 3.6. Proportion of survey participants who were in support of and opposition to four management actions (along the x-axis), and the difference of those proportions between survey participants who visited the site more or less frequently. Along the x-axis, 1 = never; 2 = less than once a month; 3 = once a month; 4 = several times a month; 5 = several times a week (Table 3.3). Excluded from this figure are data points for survey participants who were first-time visitors to the site.

Discussion

Survey participants were generally in favor of the proposed management actions. At least 75% of participants were supportive of or neutral to all six proposed management actions that would maintain or improve the aspen condition at the site. However, the degree of support varied between potential management actions.

Our results strongly support the hypothesis that survey participants were more supportive of management actions to maintain or improve the forest condition of the site if they had a strong sense of aspen identity (Table 3.6, Figure 3.3). Additionally, our results support the hypotheses that participants who noticed the aspen population decline, visited the site more frequently, and were motivated to visit the site for the landscape attributes were more supportive of the proposed management actions (Figures 3.4, 3.5, 3.6). It should be noted that participants who noticed the aspen population decline were also more in opposition to the proposed management actions (Figure 3.5). Though only aspen identity was statistically significant (Table 3.6), significance is not the only meaningful metric. The correlations visualized in Figures 3.4, 3.5, and 3.6 between support and landscape attribute motivations, frequency, and perception of change indicate strong patterns.

Varying Support for Different Management Actions

Proposed management actions that reduce access or have the potential to hinder the aesthetics of the site received the least support. Reducing cross-country ski trails was the least supported management action and is the only management action that would impact users' ability to recreate. The concept of users resisting the reduction in the freedom of choice is supported by Moore & Driver (2007). Because of this, we would expect the number of users opposed to the reduction of cross-country ski trails to increase if the survey had been administered during the cross-country skiing season. In contrast, both adding signage about and hosting education events on aspen ecology and management of the site in no way reduces recreation options for users. This might explain why less than 5% of users opposed those management actions. Moreover, increased ecological knowledge gained from such actions may positively influence future users' acceptance of even the most impactful management actions.

Responses may, to some extent, have depended on perceptions of the aesthetic impacts of the different management actions (Hammitt et al., 1994; Polat & Akay, 2015). This correlates with our findings that landscape attributes are an important motivation for visitation to the site, two of which are the aspen generally and fall leaf coloration of aspen (Table 3.3). For example, although putting up fencing would not restrict users' ability to recreate, fences would be a visual impairment, impairing the natural setting

(Hull et al., 2000). This might explain why fencing was the second least supported management action. Relatedly, perceived negative aesthetic effects of selective cutting of aspen to stimulate regrowth could explain why this practice was the third least supported.

The three most supported management actions (adding signage, installing a retention pond, and hosting educational events) would not aesthetically impair the site, though it could be argued that similar to selective cutting, users would not know what the aesthetic impact of installing a retention pond would be. However, the survey prompt about retention ponds included language about pollution (Table 3.3). Thus, survey participants may have been more supportive of installing retention ponds because their negative associations with pollution outweighed any negative associations they may have had with the aesthetic impact of installing such facilities (Barnett et al., 2018).

Aspen Identity

Unlike many studies done at National Parks, National Monuments, and State Parks, where visitors are often first-time visitors and thus have less of a personal connection to the area (Benson et al., 2013; Ghazvini et al., 2020), 81% of the survey participants in this study were locals who regularly visit the study site. This may have contributed to participants' propensity to support the proposed management actions and high aspen identity (Groshong et al., 2020; Kyle et al., 2004). Although proximity and familiarity with a place are not necessary to form an attachment to place, they can contribute to place attachment (Bricker & Kerste, 2000; Korpela, 1989). Thus, the high frequency of visitation to the study site from locals might explain why 69% of survey participants agreed or somewhat agreed to the four aspen identity statements on the survey (Table 3.3). Unsurprisingly, aspen identity was significant ($p = 0.001$) in the full

OLR models for all six proposed management actions except for fencing. Similarly, in a study conducted by Kyle et al. (2004), place identity was strongly associated with support for managerial efforts associated with environmental preservation.

Motivated by Landscape Attributes

Survey participants who indicated that they visited the site for the aspen, the color of fall leaves, wildlife viewing, proximity to streams, and availability of shade provided by the trees also were highly motivated to visit the site for its landscape attributes (Table 3.4). Crouch et al. (2023) found that the ability to provide wildlife habitat and recreation opportunities is an instrumental value of aspen. Additionally, aspen hold aesthetic values that center around the tree's appearance (McCool, 2001). The white bark and spectacular fall coloration set aspen apart from other tree species in this region, providing important aesthetic and cultural values (Assal & Keables, 2020; Dahms & Geils, 1997; McCool, 2001). This might explain why those strongly motivated to visit the site for the landscape attributes were more supportive of management actions that would maintain or improve those attributes (Figure 3.4).

Perceived Decrease in Aspen

Our finding that the survey participants who did notice the decline were more supportive of the proposed management actions is consistent with a similar study done by D'Antonio et al., (2012). Furthermore, our study found that only a minority of survey participants noticed the decline in the aspen population (Table 3.3), which is consistent with similar outdoor recreation studies that found that find that most users do not identify worsening or poor environmental conditions in recreation areas beyond trash and human waste (Johnson & Kamp, 1996; Lynn & Brown, 2003; Martin et al., 1989). For this study, the lack of perceived aspen decline could in part be explained by the fact that half of the survey participants only visited the RAM trail area, when the population of aspens in decline that prompted this study is in the RTS trail area (Chapter II). However, the area of aspen decline is visible from both sites. Additionally, most of the survey participants visited the site with their dogs, so although 33% of survey participants visited both sides of the site, they are likely visiting the RAM trail area more often for the off-leash dog area. A confounding factor is that the RAM trail area is accessible from two different parking lots: one in the RTS trail area (via a pedestrian tunnel under Olympic Parkway) and the other in the RAM trail area. This may have resulted in survey participants indicating that they visited both RTS and RAM because they parked in the RTS trail area despite not using the trails in the RTS trail area. Either way, declining environmental conditions have been found to negatively affect the quality of visitor experiences (Johnson & Kamp, 1996; Lynn & Brown, 2003; Martin et al., 1989), which could be occurring at our site.

Frequency of Visitation

Of the survey participants who were returning users, half indicated visiting the site several times a week, and 40% indicated visiting monthly. This frequent level of visitation might be because many users are dog owners who visit the site to exercise and socialize their dogs. Our hypothesis that increased frequency of visitation would be associated with increased support for aspen management is partially confirmed. However, high frequency of visitation was associated with less support for selective cutting and an almost neutral opinion regarding fencing (Figure 3.6).

Other studies that have investigated a high frequency of use and a user's bond or attachment to that place found that repeated previous experience correspond with an emotional bond with places (Hammitt et al., 2004; Hummon, 1992; Lewis, 1979; Low & Altman, 1992; White et al., 2008; Williams et al., 1992). More recent studies further support a positive relationship between frequency of visitation and place attachment (Plunkett et al., 2019; Romolini et al., 2019; Sharp et al., 2015). Place identity specifically has been found to have a positive relationship with frequency (Hammitt et al., 2004; Williams & Vaske, 2003), and both frequency and place identity have been found to have a positive relationship with support for management. Several studies that compared visitation frequency to activity specialization levels found that high frequency was associated with high specialization levels, and high specialization levels were associated with strong support for use limits intended to mitigate environmental impacts (Hall et al., 2010; Hammitt & McDonald, 1983; Sorice et al., 2009).

Limitations

There are several limitations to this survey method. First, because recreators visiting the area are assumed to not all come from the same geographic area, there is no specific population to use as a reference to weight or assess the representativeness of the survey data. Second, though research technicians conducted surveys evenly over different times of day and days of the week, only recreators coming June through October had the opportunity to participate, omitting users who only visited RTS/RAM to cross country ski in the winter. Therefore, this approach does not capture a fully representative sample of year-round recreation at the site.

Management Recommendations and Future Research

Results of this study indicate that there is strong support for installing a retention pond to filter out pollution from upstream sources before it enters the study area. The retention pond could be installed out of sight from users where the stream enters the RTS trail area. Additional soil testing, before and continuously after the installation, is recommended to monitor changes in soil contaminants. We recommend this course of action in response to apparent upslope sources of sodium to near-stream aspen communities (Chapter II), as well as strong user support for both installation of a retention pond.

Another management tactic that Basin Recreation could implement is a trial of fencing to deter overbrowsing by ungulates in areas of deteriorating forest health (Chapter II) with the potential to compare how the condition of aspen changes over time in areas with fencing versus without fencing. Managers could then use surveys to determine how the fencing impacts user experience, as well as their perceptions of forest recovery. The same could be done with selectively cutting mature aspen to stimulate regrowth, though selectively cutting is not a treatment we currently recommend without further monitoring, alongside measures to mitigate browsing. We highly recommend a continued overall monitoring program to measure if any implemented management actions improve the condition of the aspen or if adjustments need to be made to the management actions (Rogers 2017).

We do not recommend reducing cross-country ski trails without further understanding of how this could impact users during the cross-country skiing season (i.e., before conducting a survey in the winter months similar to the one administered for this study). However, the novelty of potential physical impacts on aspen clones of repeat cutting of juvenile stems during off-season maintenance of cross-country ski trails deserves further investigation.

Lastly, land managers should consider installing educational signage and hosting educational events that discuss aspen ecology and management at the site. Protected areas are the most common place in which adults encounter nature and are exposed to new ideas about the environment (Johns & Pontes, 2019), so providing educational opportunities about aspen at the site is an opportunity to expose a new audience to aspen ecology. Increased environmental education is highly associated with higher participation in environmentally friendly behaviors and environmental stewardship (Merenlender et al., 2016; Stern et al., 2008).

Methods from this study, including the measurement of place attachment, can be incorporated in future similar land management studies in highly recreated areas that examine user values and support for different management actions. Place attachment emphasizes that in addition to being geographic locations, places are fluid, changeable, dynamic settings of social interaction and memory (Stokowski, 2002; Williams & Vaske, 2003). Such places can change as the environmental and social conditions change. Managers who measure user place attachment are better equipped to manage highly recreated forested landscapes because they understand the social values tied to the area. Using a version of place identity that is retrofitted to assess a landscape attribute, in our case aspen, can help land managers prioritize restoration and preservation efforts.

Future research here and at similar recreation settings should further investigate users that are least supportive of management actions and how managers could best communicate aspen ecology and management goals with users. Existing research can provide guidance on how managers can best communicate with recreators to increase pro-environmental behaviors (Johns & Pontes, 2019; Stern et al., 2008) and fill in research gaps regarding how to cultivate an attachment to and a sense of stewardship for aspen among visitors. Land managers seeking to understand social-ecological systems to enhance decision making can use this study as a template for a wide variety of recreation areas.

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CHAPTER IV

USING THE SOCIAL-ECOLOGICAL SYSTEMS FRAMEWORK TO MANAGE ASPEN LANDSCAPES

Summary of Findings

The two studies presented in this thesis provide a better understanding of how to determine site-specific land management strategies to improve quaking aspen (*Populus tremuloides* Michx.; hereafter aspen) forest conditions and reflect user values when grappling with variably declining aspen recreational ecosystems. This thesis adapted the social-ecological systems developed by Miller et al. (2022) to understand and frame the relationship and interactions between the social and ecological dimensions of our study. The framework focuses on recreation ecology and highlights interactions between ecological systems and social systems, specifically wildlife and recreation, and how those interactions exist on a positive to negative spectrum (Miller et al., 2022). The original model (Figure 4.1) has different levels or scales within each system, and where the systems overlap is where the interactions occur. We adapted the model (Figure 4.2) to highlight how interactions can occur between different levels from each system, e.g., a society can impact an individual in the ecological system, or an ecosystem can impact a group in the social system. Similar to Miller et al. (2022), interactions exist on a continuum from positive or negative, and can be uni- or bi-directional.

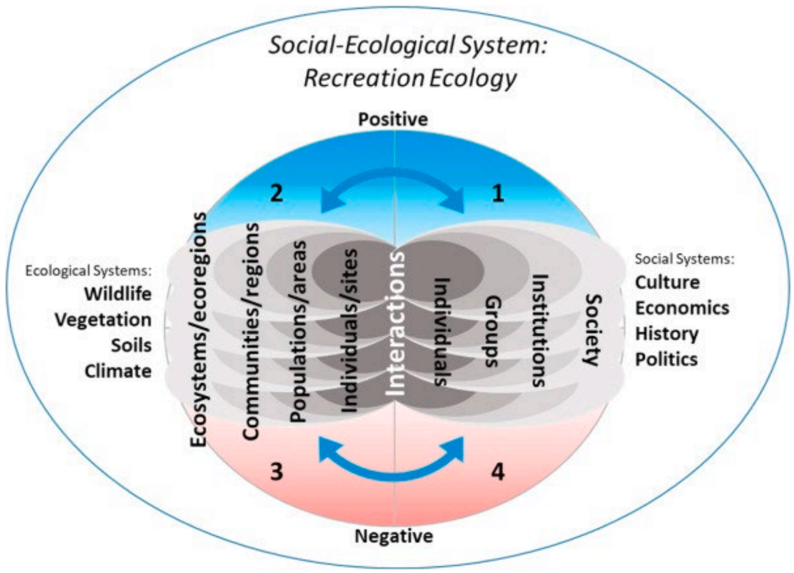

Figure 4.1. Social-ecological systems framework for recreation ecology from Miller et al. (2002). This diagram includes examples of ecological and social systems (non-exhaustive), which occur at a range of nested scales (i.e., individuals/sites, populations/areas, communities/regions, and ecosystems/ecoregions). Interactions between social and ecological systems can range from positive to negative, to a varying degree of intensity. Neutral interactions are also possible. Curved arrows depict feedback between social and ecological systems. Numbers depict four quadrants of possible interactions between these systems.

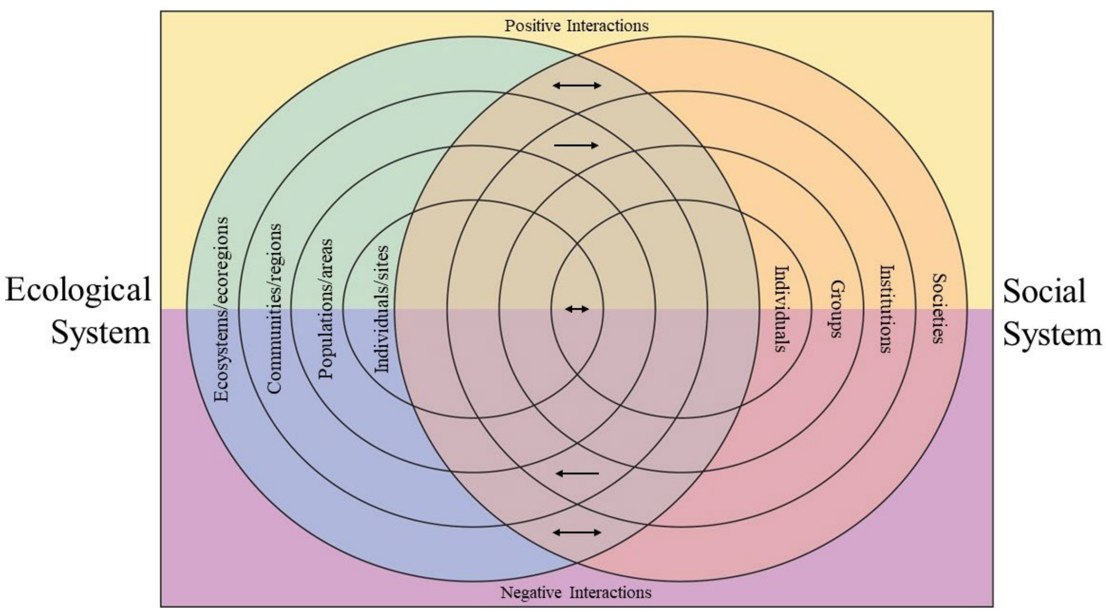

Figure 4.2. Social-ecological systems framework for recreation ecology adapted from Miller et al. (2002). This diagram displays ecological and social systems with nested levels (i.e., individuals/sites, populations/areas, communities/regions, and ecosystems/ecoregions). Interactions between social and ecological systems can range from positive to negative. Neutral interactions are also possible. Arrows depict the direction of the positive or negative impact of the interaction. The location of the arrows indicates which levels the interactions are occurring between and are subject to change depending on the scope of the study.

In the first study (Chapter II), we assessed variability of conditions of across the landscape, i.e., the ecological system, as well as what indicators are most accurately describing those conditions. For the second study (Chapter III), we surveyed users to measure how they valued the aspen forest at the site and their willingness to support the management actions that could maintain or improve the forest fitness, i.e., the social system. We conducted both studies at a high-use, semi-forested recreation area in Summit County, Utah.

Study 1 (Chapter II)

By using established aspen landscape survey methods and testing soil samples, we found that forest conditions vary between the three zones at our site. Substantial portions of the forested component of this landscape were in satisfactory condition, though our systematic survey was able to detect those that were not. We determined that ungulate (mule deer and elk) presence and soil contamination were key indicators of poor aspen conditions. Ungulates were least present where recreation use was highest and dogs are allowed to be off-leash. Indicators of soil contamination co-occurred with areas where there was the lowest recruitment and live mature aspen stems. Soils seem to have higher sodium levels with greater proximity to streams. This is of particular interest because, up stream, road salt is applied to the highway and parking lots during winter months and there is ongoing construction, both of which are likely contributors of off-site contamination. Across all three zones we found that a substantial amount of regeneration is not making it to the next height class; a key indicator of overall aspen community resilience (Rogers et al. 2010). Overbrowsing by ungulates and high sodium levels are likely contributing to this failure of succession as older stems begin to die-off.

Additionally, though we did not investigate this as part of our survey, we suspect that vegetative mowing that is done to maintain the cross-country ski trails could be stressing the aspen and contributing to population decline.

Study 2 (Chapter III)

By conducting a user intercept survey, we found that people who visit the recreation area are generally in favor of the management options that we proposed. For all six management actions, less than a quarter of survey participants were in opposition. Excluding the proposal to reduce cross-country ski trails, at least half of the participants were in support of each management action tested. Using an ordinal linear regression, we determined that survey participants who had a stronger aspen identity were motivated to visit the site for landscape attributes (i.e., not just human/dog exercise), and those who noticed a decline in the aspen population were more supportive of ecological restoration management actions. Results for the relationship between frequency of visits and support for management actions were mixed. The relationship was strongest between support for management actions and aspen identity, and, for all but one management action, the correlation between strong aspen identity and willingness to support was highly statistically significant.

The Social-ecological System

We found several notable interactions in the social and ecological dimensions at our study site, including positive, negative, and neutral interactions. The main positive interaction we found is that aspen is one of the main motivators for users to visit the study site and positively impacts the recreation experience (Chapter III). This may contribute to the high sense of users' place attachment to the site, specifically their aspen identity, which was positively correlated with support for management actions that would maintain or improve the condition of the aspen in our study. More broadly, attachment to place has been found to be positively correlated with both support for management and having a stronger sense of land stewardship (García-Martín et al., 2018; Groshong et al., 2020; Kyle et al., 2004; Lokocz et al., 2011; Thomas et al., 2024). In summary, aspen and the users had a positive, bi-directional interaction (Figure 4.2). An interaction between the aspen and the users that was not present was that a majority of users did not perceive the declining condition of the aspen – i.e., the apparent decline of the aspen population and health did not impact users' recreation experiences (negatively or positively). This finding is consistent with similar outdoor recreation studies that found that find that most users do not identify worsening or poor environmental conditions in recreation areas, with exception of trash and human waste (Johnson & Kamp, 1996; Lynn & Brown, 2003; Martin et al., 1989)

The two negative interactions are speculative. First, in Chapter II we reasoned that the positive correlation between high sodium absorption ratios with proximity to stream could be due to upstream construction or the salting of roads in the winter. The high sodium absorption ratios are negatively correlated with aspen health and abundance. In this scenario, construction and road maintenance is negatively interacting with the aspen. Second, though we did not examine the relationship between mowing that is done to maintain the cross-country ski trails and forest conditions, we ventured that mowing is a source of stress on the aspen as it depletes carbohydrate resources allocated for regeneration, similar to how intensive browsing negatively impacts aspen conditions (Britton et al., 2016; Rogers et al., 2010; Rogers & Gale, 2017; Zeigenfuss et al., 2008).

Lastly, in Chapter II we found that ungulate presence and browsing occurred less at the study site where more users were present and where off-leash dogs were permitted, which indicates that ungulates may be deterred by both increased human use and free ranging dogs. This is a chain of interactions in which users and dogs negatively impacted the presence of elk and deer, which limited the amount of browsing of aspen, therefore positively impacting the health of the forest.

Research Contributions

These two studies aim to provide a template for land managers who want to integrate social and ecological dimensions into their decision-making process, specifically using our adapted social-ecological systems framework first developed by Miller et al. (2002) to detail interactions between the various levels or scales in social and ecological aspects of their systems (Figure 4.2). Additionally, both studies expanded on existing methods. Chapter II incorporated soil testing into established aspen landscape survey methods (Rogers et al., 2010), contributing new knowledge on aspen sodium tolerance. Though there are studies that examine aspen sodium tolerance, most of them are done in controlled settings and none of them test for long term effects (Khasa et al., 2002; Lilles et al., 2010, 2012; Vaario et al., 2011).

Chapter III expanded on the framework of place attachment to account for an attribute of a place, specifically aspen environments. We used measurements for place identity, a dimension of place attachment that refers to the emotional and symbolic aspect of a person's relationship to a place (Jorgensen & Stedman, 2001; Manning, 2022;

Williams et al., 1992), to measure how users were attached to the aspen on the landscape. To our knowledge, this is the only study that attempts to understand how aspen forest conditions impacts the recreation experience and the value of aspen to a recreation setting.

Research Limitations

The findings from Chapter II are limited because ecological data was measured only once and not over an extended period. This restricts us from fully understanding ecosystem trends. However, one-time measures of recruitment can be telling in terms of multi-year developments (Rogers & Mittanck, 2014), so we were able to provide baseline data for future reference, some of which are at least indicative of recent patterns. Our initial soil testing here should be considered a coarse-scale approach; with detection of elevated sodium levels expanded/detailed sampling should be strongly considered. Additionally, we only tested soil samples from the site for electric conductivity, pH, sodium absorption ratio, sodium, magnesium, and calcium. If the source of high sodium is the upstream construction and road salt applications, it is likely that additional pollutants effecting reproduction, growth, and mortality of vegetation at this site.

Survey methods used in Chapter III also have limitations. Primarily, only users present June through October had the opportunity to participate, omitting users who only visited the site to cross-country ski in the winter. Therefore, this approach does not capture a fully representative sample of year-round visitors. Additionally, because we assume users visiting the area do not all come from the same geographic area, there is no specific population to use as a reference to weigh or assess the representativeness of the survey data.

Future Research Directions

Future research could aim to better understand several of the relationships we observed in both studies. In the first study (Chapter II) we found a correlation between higher presence of users and off-leash dogs and lower rates of browsing. Though the relationship between humans and dogs have been examined before (Arnberger & Hinterberger, 2003; Hughes & Macdonald, 2013; Parsons et al., 2016; Thompson & Henderson, 1998; Visscher et al., 2023), exploring recreation and dogs as a novel ungulate browse deterrent method on aspen landscapes would be useful for other high-use forests. Also, in Chapter II, we found high sodium levels in areas of low aspen recruitment. Conducting studies addressing long term aspen sodium tolerance could inform management on other aspen landscapes that are adjacent to, downwind from, or downstream from significant system disruptions. At our study site, soil testing could be conducted more thoroughly with increased soil sample plots taken before and after the installation of a retention pond to filter upstream pollutants. Such investigations will be required to pinpoint and mitigate what appear to be ongoing system contaminations.

In the second study (Chapter III), we began to explore the relationship between aspen presence in the landscape and the recreation experience by measuring motivations and place attachment. Further exploration of this topic would be useful for understanding how different aspen restoration treatments impact recreation experiences by conducting surveys before and after treatment applications. Additionally, conducting interviews with open ended questions to ask users how they value aspen could provide baseline insights on social values and meanings associated with aspen that are currently poorly understood (McCool, 2001). Lastly, survey results from Chapter III could be further analyzed to identify spatial patterns. We collected data on users' favorite and least favorite locations at the site, but we did not use the data because we narrowed our focus to examine users' willingness to support management actions.

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APPENDIX A

SURVEY INSTRUMENT

User Experience Survey in Run-A-Muk and Right Turn Sage Trail Areas

Consent Waiver

You are invited to participate in a research study by Dr. Anna Miller, an Assistant Professor in the Department of Environment and Society at Utah State University.

The purpose of this research is to inform future management practices that benefit both the recreators of the Run-A-Muk and RTS trail areas and the aspen forest in the area.. Specifically, we are interested in learning about how recreators here value the aspen forest. You are being asked to participate in this research because you recreate here.

Your participation in this study is voluntary and you may withdraw your participation at any time and for any reason. If you take part in this study, you will be asked to participate in a survey that will take 5 minutes.

A possible risk of participating in this study is loss of confidentiality. We cannot guarantee that you will directly benefit from this study, but it has been designed to learn more about how recreators value this area and want to see it managed. If you would like to request safety measures from the research team regarding COVID-19 or other transmissible diseases, please indicate those requests to the surveyor. Utah State University cannot guarantee masking or vaccines, but the researchers may be willing to accommodate any safety requests you have.

We will make every effort to ensure that the information you provide remains confidential. We will not reveal your identity in any publications, presentations, or reports resulting from this research study. However, it may be possible for someone to recognize the specifics you share with us.

We will collect your survey responses using Qualtrics. Online activities always carry a risk of a data breach, but we will use systems and processes that minimize breach opportunities. This survey data will be securely stored in a restricted-access folder on Box.com, an encrypted, cloud-based storage system, and only shared with the research team.

You can decline to participate in any part of this study for any reason and can end your participation at any time. If you have any questions about this study, you can contact Georgie Corkery at georgie.corkery@usu.edu. If you have any concerns about this study and would like to speak from someone not part of the research team, please contact Utah State University's Human Research Protection Office at (435) 797-0567 or irb@usu.edu.

By continuing to the survey you consent to participating in this survey and acknowledge that you are 18 years of age or older. You agree that you understand the risks and benefits of participation, and that you know what you are being asked to do. You also indicate that you can ask the research team any questions about your participation and are clear on how to stop your participation in this study if you choose to do so. You may request a copy of this form for your records.

User Experience Survey in Run-A-Muk and Right Turn Sage Trail Areas

1. Have you visited this recreation area before?
    - o Yes → Proceed to question 2
    - o No → Proceed to question 2a

2. What activities do you participate in in this recreation area? *Select all that apply.* → Proceed to question 3
    - ☐ Mountain biking
    - ☐ Cross country skiing
    - ☐ Dog walking/dog park use
    - ☐ Hiking (without a dog)
    - ☐ Wildlife watching
    - ☐ Educational programs
    - ☐ Other → Fill in the blank ______________

2a. What activities will you participate in today in this recreation area? *Select all that apply.* → Proceed to question 3a
  - ☐ Mountain biking
  - ☐ Cross country skiing
  - ☐ Dog walking/dog park use
  - ☐ Hiking (without a dog)
  - ☐ Wildlife watching
  - ☐ Educational programs
  - ☐ Other → Fill in the blank ______________

3. Which part(s) of the Run-A-Muk and RTS trail areas do you access when you visit? *Select all that apply.* → Proceed to question 4
    - ☐ RTS trail side (mountain bike / cross country ski area) west of Olympic Park Way
    - ☐ Run-a-Muk trail area (dog park area / cross country ski area) east of Olympic Park Way

3a. Which part(s) of the Run-A-Muk and RTS trail areas will you access today? *Select all that apply.* → Proceed to question 10
  - ☐ RTS trail side (mountain bike / cross country ski area) west of Olympic Park Way
  - ☐ Run-a-Muk trail area (dog park area / cross country ski area) east of Olympic Park Way

4. Please indicate where on the map is your favorite place to go.
   Why is it your favorite? _________

5. Please indicate where on the map is your **least** favorite place to go.
   Why is it your **least** favorite? _________

6. Approximately how many years have you recreated in the Run-A-Muk and RTS trail areas?
    - o *[Drop down menu (with <1, 2, 3, … 50)]*

7. About how often do you typically visit this recreation area? *Select one for each season (row).*

	Several times a week	Several times a month	Once a month	Less than once a month	Never
Summer	☐	☐	☐	☐	☐
Fall	☐	☐	☐	☐	☐
Winter	☐	☐	☐	☐	☐
Spring	☐	☐	☐	☐	☐

8. Have you noticed a change in the amount of aspen in the Run-A-Muk and RTS trail areas since you started recreating here?
   - o Significant increase
   - o Slight increase
   - o No change → skip to question 10
   - o Slight decrease
   - o Significant decrease
   - o Don't know → skip to question 10

9. What effect has the change in the amount of aspen had on your enjoyment in the Run-A-Muk and RTS trail areas?
   - o Negative effect
   - o Slight negative effect
   - o No effect
   - o Slight positive effect
   - o Positive effect

Would you like to elaborate? *[Optional]*

10. Indicate your level of agreement with the following statements about recreating in the Run-A-Muk and RTS trail areas:

	Disagree	Somewhat disagree	Neutral	Somewhat agree	Agree
I come here because it is close to where I live.	☐	☐	☐	☐	☐
I come here because I like the quality of the trails.	☐	☐	☐	☐	☐
I come here for the off-leash dog area.	☐	☐	☐	☐	☐
I come here because I like meeting/interacting with other people.	☐	☐	☐	☐	☐
I come here for solitude.	☐	☐	☐	☐	☐
I come here because I like the shade provided by the trees.	☐	☐	☐	☐	☐
I come here to see wildlife.	☐	☐	☐	☐	☐
I come here for the aspen.	☐	☐	☐	☐	☐
I come here because I like the streams.	☐	☐	☐	☐	☐
I come here for the color of the fall leaves.	☐	☐	☐	☐	☐
I have a spiritual connection to this area.	☐	☐	☐	☐	☐
I have a spiritual connection to the aspen in this area.	☐	☐	☐	☐	☐

11. Indicate your level of agreement with the following statements about **Run-A-Muk and RTS trail areas:**

	Disagree	Somewhat disagree	Neutral	Somewhat agree	Agree
Doing what I do here is more important to me than doing it in any other place.	☐	☐	☐	☐	☐
I get more satisfaction out of recreating here than in any other place.	☐	☐	☐	☐	☐
This is the best place for the type of recreation I like to do.	☐	☐	☐	☐	☐
The things I do here I would enjoy doing just as much at a similar site.	☐	☐	☐	☐	☐

12. Indicate your level of agreement with the following statements about **aspen:**

	Disagree	Somewhat disagree	Neutral	Somewhat agree	Agree
Aspen provides an experience like no other landscape in this area can.	☐	☐	☐	☐	☐
I get more satisfaction out of spending time in aspen landscapes than other landscapes.	☐	☐	☐	☐	☐
I would prefer to spend more time in aspen if I could.	☐	☐	☐	☐	☐
I am very attached to aspen.	☐	☐	☐	☐	☐

13. Indicate your level of support for the following management practices **to maintain a healthy aspen forest:**

	Strongly oppose	Oppose	Somewhat oppose	Neutral	Somewhat support	Support	Strongly support
Surround some areas with an 8 ft fence to prevent elk, deer, and moose from eating young aspen.	☐	☐	☐	☐	☐	☐	☐
Conduct controlled burns (small scale "spot" burns) to promote new aspen growth.	☐	☐	☐	☐	☐	☐	☐
Selectively cut mature aspen to stimulate new aspen growth.	☐	☐	☐	☐	☐	☐	☐
Have educational events to explain aspen ecology and management practices.	☐	☐	☐	☐	☐	☐	☐
Put up educational signs about aspen ecology and management practices.	☐	☐	☐	☐	☐	☐	☐
Add water retention ponds to filter pollution out of the water before it enters the area.	☐	☐	☐	☐	☐	☐	☐
Reduce cross-country ski trail milage to allow for aspen regrowth.	☐	☐	☐	☐	☐	☐	☐

14. What year were you born? *[Optional]*
    - *[Drop down menu (1900-2023)]*

15. Are you a permanent resident of the US? *[Optional]*
    - Yes → What is your Zip code __ __ __ __ __
    - No → What is your country of residence? ___________________

16. Are you a permanent or seasonal resident of Summit County or a neighboring county?
    - Permanent resident → How many years have you been a permanent resident of Summit County or a neighboring county? *[Drop Down]*
    - Seasonal resident → How many years have you been a seasonal resident of Summit County or a neighboring county? *[Drop Down]*

- Neither

17. What is the highest level of formal education you have completed? *[Optional]*
    - Less than high school
    - High school graduate/GED
    - Vocational/trade school certificate
    - Some college
    - Associate's degree (AA, AS, etc.)
    - Bachelor's degree (BA, AB, BS, etc.)
    - Master's degree (MA, MS, MEd, MSW, MBA etc.)
    - Doctorate degree (PhD, EdD, etc.)
    - Professional degree (MD, DDS, DVM, LLB, JD, etc.)

18. What ethnicity do you identify with? *[Optional]*
    - Not Hispanic or Latino
    - Hispanic or Latino
    - Not listed → Fill in the blank ______________

19. What race do you identify with? *Select all that apply.* *[Optional]*
    - American Indian or Alaska Native
    - Asian
    - Black
    - Native Hawaiian or other Pacific Islander
    - White
    - Not listed → Fill in the blank _________

20. What gender do you identify with? *[Optional]*
    - Female
    - Male
    - Prefer to self identify → Fill in the blank ______________

21. Which category best represents your household income before taxes in 2022? *[Optional]*
    - Less than $25,000
    - $25,000 to $34,999
    - $35,000 to $49,999
    - $50,000 to $74,999
    - $75,000 to $99,999
    - $100,000 to $149,999
    - $150,000 to $199,999
    - $200,000 or more

22. Do you have any other comments you would like to share at this time? *Optional*

APPENDIX B

VERBAL RECRUITMENT SCRIPT

Verbal Recruitment Script

When approaching a single individual: "Hello, my name is [*first and last name*] and I am a research technician with Utah State University and Snyderville Basin Special Recreation District. We are conducting a social survey on the user experience at the Run-A-Muk and RTS trail areas. *If you have not already done so*, would you be willing to participate in a 5-minute survey?

- **NO → "**Would you be willing to answer three short questions verbally?"
    - **For every declining participant:** Note the decline, perceived gender, recreation activity, time of day, location (site one or site two), group size, if applicable, and if they are entering the site or leaving (about to start their activity or just finished)
    - **YES** → "Thank you. We greatly appreciate it. 1) Do you come here regularly? 2) What is your zip code? 3) Are you a permanent or seasonal resident to the area?"
        - **After participants answer the questions → "**Thank you so much for your time. Have a great day!"
    - **NO** → "No worries. Have a great day!"
- **YES** → "Thank you. We greatly appreciate it. The survey is on this iPad. Please read the informed consent form at the beginning and know that you can withdraw your participation at any time."
    - **After participants complete or finish the survey → "**Thank you so much for your time. Have a great day!"

When approaching a group: "Hello, my name is [*first and last name*] and I am a research technician with Utah State University and Snyderville Basin Special Recreation District. We are conducting a social survey on the user experience at the Run-A-Muk and RTS trail areas. *If you have not already done so*, would someone from your group be willing to participate in a 5-minute survey?

- **NO → "**Would you be willing to answer three short questions verbally?"
    - **NO** → "Would you be willing to answer three short questions verbally instead?"
        - **For every declining participant:** Note the decline, perceived gender, recreation activity, time of day, location (site one or site two), group size, if applicable, and if they are entering the site or leaving (about to start their activity or just finished)
        - **NO** → "No worries. Have a great day!"
        - **YES** → "Thank you. We greatly appreciate it. 1) Do you come here regularly? 2) What is your zip code? 3) Are you a permanent or seasonal resident to the area?"
            - **After participants answer the questions → "**Thank you so much for your time. Have a great day!"
    - **YES** → "Thank you. We greatly appreciate it. 1) Do you come here regularly? 2) What is your zip code? 3) Are you a permanent or seasonal resident to the area?"
        - **After participants answer the questions → "**Thank you so much for your time. Have a great day!"
- **YES** → "Can we have the person with the nearest upcoming birthday take the survey? We are trying to randomize who participates in the survey."
    - **NO** → "Would you be willing to answer three short questions verbally instead?"

        - **For every declining participant:** Note the decline, perceived gender, recreation activity, time of day, location (site one or site two), group size, if applicable, and if they are entering the site or leaving (about to start their activity or just finished)
        - **YES** → "Thank you. We greatly appreciate it. 1) Do you come here regularly? 2) What is your zip code? 3) Are you a permanent or seasonal resident to the area?"
            - **After participants answer the questions** → **"**Thank you so much for your time. Have a great day!"
        - **NO** → "No worries. Have a great day!"
    - **YES** → **"**Thank you. We greatly appreciate it. The survey is on this iPad. Please read the informed consent form at the beginning and know that you can withdraw your participation at any time."
        - **After participants complete or finish the survey** → **"**Thank you so much for your time. Have a great day!"