



# Rapid Resource Change and Visitor-Use Management: Social–ecological Connections at the Bonneville Salt Flats

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## Abstract

Parks and protected areas are complex, and managers often need integrated social–ecological science-based information that illuminates the dynamic interactions between the biophysical and social processes. However, modeling and determining social–ecological connections are difficult due to disciplinary paradigms, divergent research questions, and data sets representing different scales. During this investigation, researchers sought to evaluate social–ecological linkages at a large salt pan (Bonneville Salt Flats) in western Utah (US). Specifically, the investigation evaluated how the changing level and location of salt-crust moisture and ponding water influenced visitors' spatial distribution of use and important elements of their experience. The findings indicate that visitors travel more distance, spend more time recreating, and use the Salt Flats in higher densities during dry conditions. However, the results also highlight that importance levels ascribed to specific aspects of the visitor experience remained relatively stable regardless of changes in salt-crust moisture and ponding water. Illuminating such linkages is important because most natural resource issues in society, including resources at the Bonneville Salt Flats, are not solely ecological or social in nature but characterized by deeper enmeshment between the two.

**Keywords** Bonneville Salt Flats · Coupled natural–human systems · GPS visitor tracking · Motivation · Social–ecological systems · Visitor-use management

## Introduction

Parks and protected areas are inherently complex, containing numerous linkages between social actors and ecological processes. Specific linkages between humans and

landscapes are characterized across many scales (i.e., microscopic to global; Werner and McNamara 2007), and simultaneously involve multiple spatial, temporal, social, and biophysical elements (Miller et al. 2017). This plurality of scales is at the heart of contemporary approaches to park and protected area (PPA) management, such as Ecosystem Management (Moreno et al. 2014) and Integrated Coastal Management (Olsen 2003). However, in some contexts, management agencies have yet to fully embrace these reciprocal complexities. To address this issue, Glaser et al. (2008) share one emergent management heuristic, a “social–ecological system” (SES), which describes a “complex, adaptive system consisting of a bio-geophysical unit and its associated social actors and institutions.” As the authors share, “the spatial or functional boundaries of the [SES] delimit a particular ecosystem and its problem context” (p 4).

One element of most PPAs that drive SES dynamics is park visitors (e.g., social actors), who are abundant and increasing. Worldwide, protected areas receive over 800 billion visits per year, and the United Nations World Tourism Organization projects an annual 3.3% increase in

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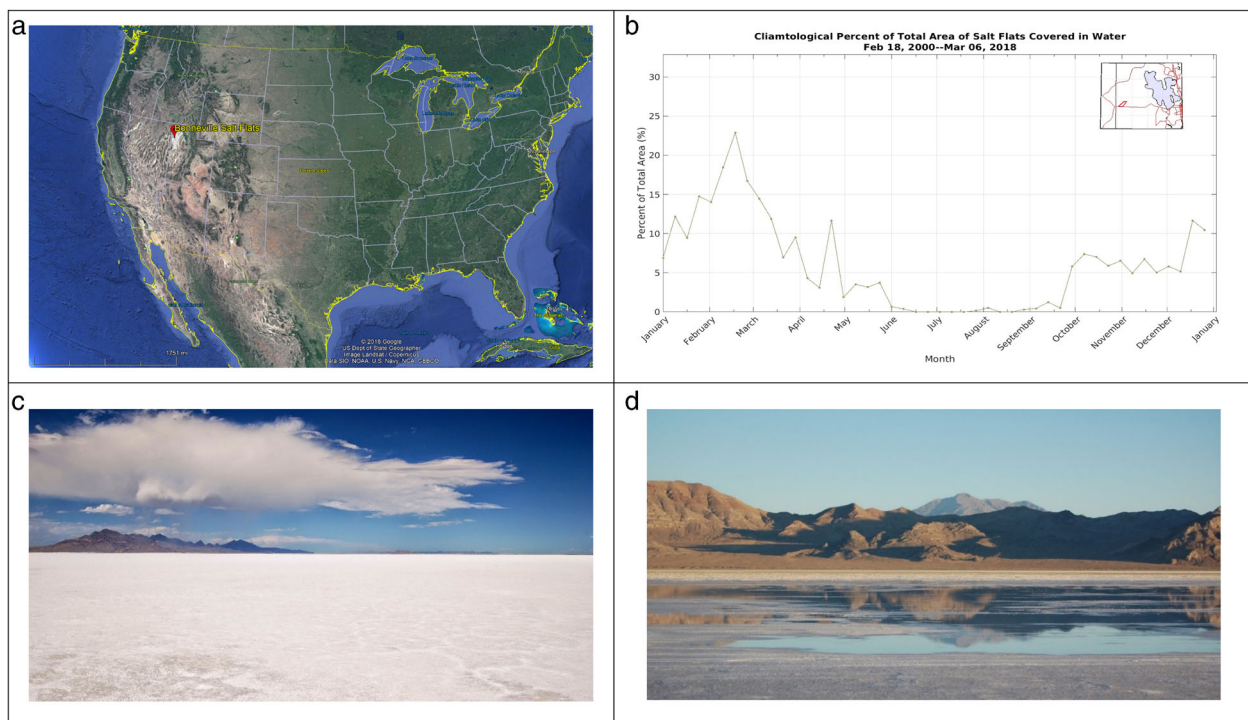
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international tourism-related arrivals between 2010 and 2030 (Fefer et al. 2016). In 2018, in the United States (US), the National Park Service accommodated over 318,000,000 visitors who generated over 1.44 billion recreation hours (National Park Service (NPS) 2019). Similarly, the US Forest Service welcomed over 185,000,000 visitors in 2016 representing all income classes; ~94% of these visitors entered national forests and grasslands for recreation purposes, including hiking, off-highway driving, hunting, camping, and fishing (USFS—United States Forest Service 2016). Both in the US and globally, conceptualizing PPAs as complex SES helps highlight the reciprocal linkages between the behaviors and motivations of these increasing numbers of visitors and the ecosystem elements and processes therein.

Although numerous factors in a SES may affect visitor behaviors and motivations for visitation, the temporal dimension of change—ranging from incremental to more rapid—in PPA resources can be influential. Peterson et al. (2018) discovered five different experiential outcomes associated with long-distance hiking on the Appalachian Trail fluctuated according to incremental variances in trail conditions, such as trail width, presence of mud on the trail, and the trail's uneven surface or roughness. Price et al. (2018) evidenced that campers' selection of campsites in a large riparian area was partially determined by the level of ecological degradation—accrued impacts over time—from recreation use found by visitors at a campsite. Lemelin et al.

(2013) demonstrated that some visitors are motivated to see a specific PPA due to changing resource conditions, particularly PPAs that contain climate-impacted resources thought to soon disappear (e.g., viewing the glaciers at Glacier National Park before they are gone). Thus, it appears that incremental changes in PPA resource conditions often influence visitor behavior (e.g., site selection, travel patterns) and motivations to visit (i.e., resource conditions and experiential outcomes). However, what is less represented in the SES literature is how more-rapid changes in PPA resource conditions, such as changes related weather or seasonal climate that occur within the span of days, weeks, or months, may influence visitors' behavior and perceptions (e.g., air pollution events and recreation behavior; Zajchowski et al. 2019). Understanding how visitors respond to these changes is important, as seasonal variability in resource conditions can lead to discrete periods where recreational impacts are more lasting (i.e., seasonal ponding of water and muddy sections on trails yield greater erosion when impacted than dry trails; Marion 2006).

To address this deficit, we investigated the confluence of visitors and seasonal changes in resource conditions at an iconic PPA: the Bonneville Salt Flats (Salt Flats). This complex SES is managed by the US Bureau of Land Management (BLM) and stretches from the western edge of Utah's Great Salt Lake to the State's western border with Nevada (Fig. 1). Comprised largely of halite (NaCl), the Salt Flats are a rapidly changing salt-pan, formed through



**Fig. 1** **a** Location of the Bonneville Salt Flats, **b** historic seasonal ponding of the Salt Flats, **c** representative dry, and **d** ponded conditions. Photo credits GoogleMaps (2018), Illminen (2017), Harris (2017), and University of Texas Libraries (2017)

seasonal cycles of flooding, evaporation, and desiccation (FED) into a solid, white crust (Bowen et al. 2017; Lowenstein and Hardie 1985). This crust represents the mineral remnants of a Pleistocene inland sea known as Lake Bonneville, which began drying over 12,000 years ago, leaving behind the salt crust that now spans more than over 77 km<sup>2</sup> (over 7000 ha; Crittenden 1963; Oviatt 2014). Today, the Salt Flats purportedly form one of the seven terrestrial places in the world where the human eye can detect the curvature of the earth (Bureau of Land Management 2018), and are the site of unique social and economic value for a variety of actors, including motorsports enthusiasts, off-highway motorists, international tourists, and mining corporations (Bowen et al. 2017).

Despite the Salt Flats providing an ideal laboratory for investigating SES dynamics, no scholarship has explored the relationship between visitors' off-highway vehicle behavior, important elements of the visitor experience, and the dynamic salt-crust conditions, particularly the seasonally changing levels and location of ponding surface water. In addition, because driving on the salt during ponding water events or times of high moisture content (November to mid-June) may impact salt-crust formation (Bowen 2017; Penrod 2016), knowledge of the seasonal and spatial distribution of off-highway vehicle use is crucial to understand one potential vector for impacts. Furthermore, given the lack of social science research focused on this resource, a baseline understanding of off-highway users' motivations and preferences for visitation conditions during a period when racing is not occurring is crucial to inform management decisions (i.e., direct enforcement of seasonal closures during times of high moisture content).

Therefore, the purpose of this study was to evaluate how the changing level and location of salt-crust moisture (i.e., ponding water) influence visitors' spatial distribution of use and motivations to visit. Underpinned by key SES concepts (Virapongse et al. 2016), we used satellite reflectance data to determine the level and distribution of seasonal, ponding conditions during May (ponding of surface water remaining from meteoric precipitation), June (a moist salt-crust surface), and July (a dry salt-crust surface), while concurrently assessing visitors' onsite travel patterns and motivations to visit, using GPS visitor tracking technology and a quantitative visitor survey. The results begin to illuminate SES relationships between a changing PPA resource, human behavior, and visitor perceptions, while providing information for managers of this unique resource.

## Problem Context

For social actors, the Salt Flats are perhaps best known as the location for the establishment of land speed records set

in the mid-20th century. In the 1960s, motorists, such as Craig Breedlove, Art Alfons, and Gary Gabolich, pursued land speed records in their jet-powered vehicles past 400, 500, and 600 miles per hour on the Salt Flats (Hawley 2010; Noeth 2002). Sponsored and amateur racing continues at the Salt Flats during limited, special-use racing events, however, the majority of visitation occurs through casual off-highway vehicle use (i.e., driving on the Salt Flats in personal automobiles). Casual visitation to the Salt Flats allows for an autonomous travel experience in a dispersed recreation environment not confined by roads, signs, or route markers, where no special equipment or vehicle adjustments are necessary.

Paradoxically, the cyclical driver of salt-crust formation and the single physical, limiting factor for off-road vehicular travel is moisture. Winter and spring months bring precipitation that flood the Salt Flats to form an inches-deep, shallow inland sea that dissolves, saturates, then covers the salt crust (Carpenter 2002). During this wet season, rapid fluctuation between flooded and dry conditions can occur over short periods—from as little as few days to several weeks—depending on the frequency and amount of meteoric precipitation (Craft and Horel 2019). Later in the season, summer heat and wind fully abate lingering surface moisture to make vehicular travel possible again. However, common to 21st century salt-pan landscapes, the historic cycles of FED that build and decompose the Salt Flats over the course of each year are not as stable as they once were; precipitation and temperature patterns in recent years are less predictable which has been posited as a result from anthropogenic global climate change (Bowen et al. 2017; Lowenstein and Hardie 1985).

Direct human activity impedes several aspects of the Salt Flat's crust formation. First, the historic construction of roadways (i.e., Interstate 80) across the Salt Flats resulted in the fragmentation of this complex system. Only the northern half of the Salt Flats' historic extent accessible to the public (Bureau of Land Management 2018). Second, compacted roadbeds and subsurface substrate hamper groundwater flows, and therefore brine flows, and winter and spring winds can no longer evenly distribute standing winter brine across the historic extent of the now-fragmented Salt Flats (Baxter 2018; Mason and Kipp 1997). Third, mineral extraction—historically diverted from surface runoff and now also pumped from the shallow brine aquifer during the winter wet season—displaces salts that would later precipitate back into the crust during the dry season from the system (Kipnis and Bowen 2018). The commercial extraction of brine—which is rich in potassium used for manufacturing synthetic fertilizer—is anecdotally blamed for the reduction in the salt crust, particularly along the stretch of the flats that is typically used for land speed racing. Mineral return in the form of the pumping dissolved salts from

mineral extraction operations may aid in replenishing the salt crust (Bowen et al. 2017; Bowen et al. 2018), but requires fresh or undersaturated water, which is a valuable commodity in the Salt Flats' desert environment (Bowen et al. 2017). Finally, visitors to the Salt Flats, many of whom visit to attend automobile race events in summer months, arrive in vehicles and traverse the flats, which may compact the salt crust in specific areas, thus potentially interfering with the Salt Flats' natural FED cycle (Kipnis and Bowen 2018). In fact, even minor changes in the microtopography on the Salt Flats can influence where salt ultimately collects and where it does not (Mason and Kipp 1997); perhaps most surprisingly of all, is the role that salt-loving microbes—some of which thrive on hydrocarbons in fuel and oil left by vehicles—may play in the formation of the salt crust (Bowen et al. 2018). All of these anthropogenic modifications to the Salt Flats have impacted the predictable formation of a thick, stable salt crust that is amenable to vehicular travel. Accordingly, much of the Salt Flats' stability has been compromised primarily due to human impacts on the FED cycle. Yet, despite these changes, the way that visitors respond to the presence or absence of traversable surface conditions at the Salt Flats, has yet to be described, measured, or characterized.

### Motivations for Visiting

To guide our understanding of visitors' motivations for visiting the Bonneville Salt Flats we used expectancy theory, which suggests that human behavior, including PPA visitation, is driven by the desire to attain certain goals, such as experiences (i.e., roadless travel) and their associated benefits (i.e., exhilaration; Manning 2011). Identifying and measuring visitors' motivations and the benefits that result from physical, social, and managerial conditions in PPAs are often conceptualized using a benefits-based management approach (Driver 2008; Thomsen et al. 2018; Winter et al. 2020). Early work by Hass et al. (1980), identified a hierarchical process driving outdoor recreation demand: (1) individuals and groups select specific activities (i.e., roadless travel), (2) they look for specific settings, such as the Salt Flats, that afford specific features associated with those activities (i.e., few vehicles), (3) which are driven by experiential motivations (i.e., experience solitude), (4) which, in turn, yield specific benefits (i.e., sense of freedom). In sum, as Roggenbuck and Driver (2000) argue, it is incumbent upon managers areas to utilize an "outcome-focused management" paradigm to maximize these desired benefits for all visitors (p 47).

Recent collaboration across the US federal agencies has adopted portions of this hierarchical outcome-focused management approach within the Interagency Visitor-Use Management Framework (2016). In doing so, agencies can

use motivations to help identify indicators, which are measurable, manageable variables that help define the quality of a visitor experience and thresholds, the minimum acceptable condition of an indicator. Conceptually, many motivations can represent an indicator that is not yet operationalized (Manning 2011). An example of the motivation-indicator connection might be represented by the motivation to "avoid crowds," operationalized as the indicator "number vehicles in view at one time" at the Salt Flats with an associated threshold, such as "3." Often researchers identify motivations, indicators, and thresholds using a multiphase approach, where specific motivations and indicators are identified by either managers or visitors, and thresholds are then established in subsequent phases of research. Researchers have identified hundreds of motivations and indicators in many contexts with numerous populations (Manning 2011). For example, research scholarship evaluated the level and type of ecological degradation at campsites (Price et al. 2018), wildlife-visitor proximity (Miller and Freimund 2018), and ambient air quality conditions (Zajchowski et al. 2019).

Although a wide variety of studies use motivations as a base to understand indicators for desired experiences and benefits across diverse PPAs, no research has yet identified motivations for visiting large salt pans with rapidly changing conditions. In cases of where motivations and indicators are unknown, Manning (2011) shares that researchers use a variety of quantitative and qualitative methods to identify indicators, often derived from visitors' motivations. Semi-structured interviews with visitors (Hallo and Manning 2009), visitor rankings of potential motivations and indicators (Manning et al. 2002), importance–performance estimates (Pilcher et al. 2009), threat matrices (Manning and Moncreif 1979), and consultation with park staff and content analyses (Manning et al. 2005) are all approached used to elicit motivations and indicators and determine their relative importance. In this study, visitors provided rankings of motivations previously identified in consultation with both managers and stakeholders of the Bonneville Salt Flats.

### Construct Stability

One component of motivations, indicators, and thresholds scholarship is "stability," or how visitors' rankings and ratings of motivations, indicators, or thresholds vary over time (Manning 2011). The literature surrounding stability provides a conceptual basis for investigating the temporal stability of motivations and related indicators in a specific PPA. Generally, stability investigations involve comparing results of two or more cross-sectional studies that duplicated methods in different years at the same PPA. Usually, the stability of the threshold (i.e., three vehicles) for an indicator (i.e., the number of vehicles in view at the Salt Flats)

is the dependent variable of interest, and the independent variable—“time”—is thought to be the unit of influence (i.e., the number of vehicles changed across time). Although there are several examples of thresholds changing across time in broader society, previous PPA research has demonstrated relatively stable perceptions in numerous visitor studies across diverse settings with different populations. For example, studies in the US have found no statistically significant differences in rafters’ evaluations during a 10-year period on the Rogue River in Oregon (Shelby et al. 1988), over a 41-year range with wilderness users in the Bridger Wilderness in Wyoming (Hall and Davidson 2013), across 22 years with day users in Denali National Park in Alaska (Bacon et al. 2001) and spanning 12 years with paddlers at the Apostle Islands National Lakeshore in Wisconsin (Kuentzel and Heberlein 2003).

Represented to a much lesser extent in the literature are studies that evidence changes in motivations (or non-operationalized indicators) over a substantially shorter period, such as a few months as opposed to several years. Also, limited investigations have focused on motivation or indicator stability, as most concentrate on evaluating stability in the threshold. Furthermore, no previous studies have evaluated motivation or indicator stability concurrently with changing resource conditions. In this study, we focused on motivation (or non-operationalized indicator) stability during a period of rapid resource change across 3 months at the Bonneville Salt Flats. The implications stemming from this investigation have capacity to impact management decisions. For example, if the motivations for visiting change significantly as resource alteration occurs, then planning, management, and monitoring visitor experiences in a PPA would have to incorporate these changes. In other words, if motivations and resource conditions significantly covary, then managers may need temporal or resource-dependent indicators, complicating the management and monitoring of visitor experiences. However, if motivations remain relatively stable, regardless of resource or seasonal change, then managers may more confidently rely on data derived from a scientific investigation to inform management decisions.

### Spatiotemporal Visitation Patterns

Beyond investigating the covariance of motivations and changing resource conditions, we are also interested in the relationship between visitors’ spatiotemporal distribution of use and ponding surface water as another SES linkage. In PPA scholarship, previous work has documented visitor travel patterns as indicative of a spatially conditioned process, which highlights the reciprocal, SES linkages between space, time, visitors, and resources (Beeco and Brown 2013; Beeco et al. 2013). Specifically, Beeco and Brown (2013) argue that the physical terrain structure, along with

anthropogenic infrastructure, may affect the spatial trajectory of visitors, leading to the concentration in specific areas or dispersion to less crowded areas. Researchers have also explored the temporal dimensions of travel patterns through spatiotemporal analysis (Birenboim et al. 2013). Spatiotemporal data helps identify how much time visitors spend in specific locations, the distribution of visitors, the identification, evaluation, and evolution of possible resource impacts, and where and when mitigation of problems may be prevented (D’Antonio et al. 2010). This information can help PPA officials effectively manage complex SES by designing management responses (i.e., area closures) that respond to spatiotemporal trends.

Recent advancements in GPS technology have made it possible to collect spatiotemporal data with affordable devices that feature high-resolution and accurate time–space data (e.g., Birenboim et al. 2013; Riungu et al. 2018). The utilization of GPS data loggers allows for a direct measure of spatial and temporal patterns, including use density and distribution (Riungu et al. 2018). However, until this study, researchers had not evaluated the covariance between visitor travel patterns and ponding water at a large salt pan.

### Research Questions

In summary, although the literature indicates that incremental change in PPA resource conditions may affect visitor behavior and perceptions, the influence of short-term, more-rapid changes in PPA resource conditions has been less investigated. To evaluate how the changing degree and location of salt-crust moisture and ponding water influence visitors’ spatiotemporal distribution of use and motivations to visit, we addressed the following research questions and tested the associated hypotheses:

**RQ1:** How does the presence and distribution of surface water impact the spatiotemporal distribution of visitor use at the Bonneville Salt Flats?

Hypothesis 1: When more surface water is present, visitors will travel less overall distance during a visit.

Hypothesis 2: When more surface water is present, visitors will exhibit less total visitation time and less travel time on the Salt Flats.

Hypothesis 3: When more surface water is present, there will be lower densities of overall visitor use (using point data) on the Salt Flats.

**RQ2:** How stable are visitors’ motivations as changes occur in the level and distribution of ponding water at the Bonneville Salt Flats?

Hypothesis 4: When more surface water is present, visitors will express stronger motivations for stationary-oriented experiences (e.g., taking pictures, enjoying views) compared with movement-oriented

experiences (e.g., roadless travel, enjoying open space without obstruction).

RQ3: How can modeling and displaying relationships between rapidly changing resource conditions, visitor behavior, and visitors' motivations inform management and understandings of complex SESs?

## Methods

To address these research questions, we leveraged multiple data sets and approaches, including (1) reflectance land surface modeling techniques, (2) GPS visitor tracking and spatiotemporal analysis, and (3) quantitative visitor surveys, while subsequently testing for differences in response tendencies. We describe each of these approaches below, including onsite sampling techniques at the Salt Flats.

### Modeling Resource Conditions

To investigate periods of ponding surface water on the Salt Flats, we used MODIS MOD09A1 land surface product (NASA LP DAAC 2015) to retrieve reflectance data for each MODIS band. The MOD09A1 is a seven band, atmospherically corrected product that estimates the spectral reflectance for each band as if researchers had measured at the ground using 500 m resolution (Vermote et al. 2015). MOD09A1 uses an eight-day composite window to select the best value for each pixel after considering cloud, solar zenith angle, and atmospheric effects. This reduces the temporal frequency of the product to eight days but substantially reduces measurement variability. Quality data for this product is contained within the same data file and only tile h09v04 was used for this dataset as the entire spatial domain fell within the boundaries. The entire temporal range of data for the MODIS instrument was used to understand the changes in water coverage that spans 18 years beginning in February 2000 to July 2018.

To estimate the likelihood that standing water covered a MODIS pixel, we used the normalized difference water index (NDWI; McFeeters 1996). The NDWI is a ratio of a combination of the near infrared (NIR = MODIS band 2 =  $\rho_{\text{NIR}} = 841\text{--}876$  nm) and green bands (GREEN = MODIS band 4 =  $\rho_{\text{GREEN}} = 545\text{--}565$  nm) ranging from  $-1$  to  $+1$  with large positive values highlighting surface water throughout much of the pixel. Researchers have applied this method to a variety of remote sensing instruments including MODIS with reasonable accuracy (e.g., Doña et al. 2016). Recently, Bowen et al. (2017) used the NDWI with Landsat satellite data to identify and remove pixels covered in water when creating area estimates of the salt crust on the Salt Flats as pixels covered in water complicate the calculation of salt-crust area. Using this reflectance approach, we

created data displays for specific levels of ponding water in May (ponding surface water), June (moist surface), and July (dry surface) of 2017, which coincided with the visitor sampling period.

### Sampling Visitors

To ensure a representative sample, we selected visitors recreating at the Salt Flats using a stratified random probability sampling approach in which one person at least 18 years of age from each travel party (i.e., personal vehicle) was asked to carry a GPS data logger and complete a questionnaire. Sampling occurred in 2017 during peak visitation season when permitted racing events were not occurring (May through July) and we stratified sampling by day of the week, week of the season, and time of the day. We selected this stratification to capture typical use during non-racing peak season and to increase the representativeness of the sample by ensuring that all visitors had equal probability of inclusion in the study during sampling periods (Vaske 2008). We conducted entrance intercepts on the Bonneville Speedway Access Road, a paved access road leading to the Salt Flats. We intentionally positioned our intercept location  $\sim 3$  miles distant from where visitors can drive onto the Salt Flats at the end of the access road in an attempt to decrease or alleviate the potential of visitors altering their behavior due direct visual observation by the research team. During the entrance intercept, a trained research assistant informed visitors about the study, and distributed a questionnaire and GPS logger device. Visitors returned GPS devices to the research team at the original intercept location when leaving the Salt Flats and completed the quantitative questionnaire focused on motivations for visiting.

Before our sampling period, the BLM posted a small sign ( $9 \times 11$  in) at the side of the access road encouraging visitors not to drive on the Salt Flats when the salt surface was wet. However, this sign was vandalized and subsequently shredded by wind prior to sampling, resulting in an unreadable message. Neither the BLM nor the research team repaired or replaced the sign during the sampling period.

### Spatiotemporal Distributions of Use

Researchers chose to use the Canmore GT-740FL Sport for GPS visitor tracking. White et al. (2015) indicated that the Canmore model achieved the highest accuracy, durability, and ease of use compared with three other receivers (Garmin Oregon 600, GlobalSat DG-100, and GlobalSat DG-200). The Canmore GT-740FL has extended battery capabilities, is  $\sim 2.5 \times 1.3$  cm, and is equipped with a power button but no LCD interface. We configured the units to record a waypoint (decimal degrees) and time stamp at 15-s intervals. The units allow for retroactive analysis—the research team could not

evaluate visitor travel patterns in real time, which was communicated to visitors at the intercept location.

Once units were returned, the researchers first imported GPS tracking data into MS Excel where an initial cleaning of the data occurred following the procedures described by Beeco et al. (2014). We used four primary cleaning considerations before deleting a data point deemed potentially influenced by technological error: (1) raw GPS data were inspected for 15-s intervals for all consecutive waypoints to validate that waypoints were consistently recorded, (2) mapped GPS data were visually inspected if consecutive waypoints were congruous with a 15-s interval, (3) physical feasibility was assessed (e.g., Could humans actually be in that location?), and (4) an analysis of patterns of GPS point trails was conducted (e.g., Are the points consistent with human behavior?).

Next, to address Hypotheses 1 and 2, we conducted a comparison of mean travel time and distance across May (ponding water on surface), June (moist surface), and July (dry surface), using a one-way ANOVA with a Bonferroni post hoc test using SPSS 24.0. We used the imperial system (miles and minutes) for visitor data (distance and time) because these are the units often most easily interpreted and understood by the US land managers without requiring conversion. For all ANOVAs in this study, standard calculations for leverage, kurtosis, and skewness were used to verify univariate normality of the data (Tabachnick and Fidell 2007). Partial eta squared ( $\eta^2$ ) was used as one interpretation of effect size for significant differences between months. Cohen (1988) and Miles and Shevlin (2001) suggest that a  $\eta^2$  value of  $\sim 0.01$  indicates a small effect size, while 0.06 is medium, and 0.14 is large. However, even small effect sizes can have substantial implications for practice and theory (Fidler and Cumming 2012). For all ANOVAs used in this study, necessary assumptions were met, including assurance of no statistical outliers as detected by box plots, independence of observations, normally distributed residuals (Shapiro–Wilk’s test), and homogeneity of variances (Leven’s test) (Tabachnick and Fidell 2007). Results of a pre-study power analysis indicated that at least 33 visitors per month ( $n = 32.69$ ) were needed to achieve a 0.80 power level to detect a moderate effect ( $\eta^2 = 0.06$ ) using a standard significance level ( $p < 0.05$ ) (Kraemer and Blasey 2015). Finally, to address Hypothesis 3, the researchers used point and line density functions in ArcMap ArcGIS software (10.3) to determine density. Density refers to the number of waypoints within a given area and serves as a proxy for the concentration of visitors during a specified time.

## Motivation Stability

To identify important motivations, we selected a two-step mixed methods instrument development variation approach (Creswell and Plano Clark 2011) because (1) not all

quantitative measures or instruments for the phenomenon under investigation were available, (2) some variables were unknown, and (3) due to the novelty of the investigation, numerous frameworks or theories were applicable (Morgan 1998; Morse 1991). First, we conducted semi-structured interviews ( $M = 45$  min;  $n = 16$ ) using a modified Seidman method (Seidman 2013) with equivalent groups of Salt Flat managers, visitors, and stakeholders. The purpose of these interviews was to understand visitors’ motivations and desired experiences related to visitation. We audio-recorded each interview to identify response patterns for motivations to visit; participants answered open-ended questions (i.e., What experiences at the Salt Flats are important for visitors?) and responses were coded by two authors to identify motivations or the non-operationalized indicators. Using a similar process to Rose et al. (2016), following individual coding, both authors established agreement through iterative conversations. Subsequently, we constructed a quantitative questionnaire with eighteen motivations items (see Table 1) and used a modified ranking described by Manning et al. (2002) that employed one Likert-scale question about preference (1 = not important at all; 5 = extremely important) and two rank order questions. The questionnaire also included three measures for past-visitation history and demographic categories aligned with the US Census Bureau.

**Table 1** Motivations for visiting the Bonneville Salt Flats (non-operationalized indicators)

“The opportunity to...”

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View stars without seeing human lights  
 Enjoy natural views without human structures within sight  
 View wildlife  
 Be away from crowds of people  
 Experience natural sounds without human-produced noise  
 Enjoy long open spaces without obstructions or structures  
 Understand the geologic history of the area  
 Travel across the Bonneville Salt Flats without roads  
 Find parking spaces without waiting  
 Enjoy the Bonneville Salt Flats without lots of other people  
 Learn about the racing history of the Bonneville Salt Flats  
 Read signs containing information about the area  
 Experience clean air, free of haze, and pollutants  
 Experience a place free of litter  
 Participate in citizen science projects  
 Experience solitude  
 Learn about mining at the Bonneville Salt Flats  
 Take pictures of the Bonneville Salt Flats

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Motivation items derived from semi-structured interviews and evaluated using one Likert-scale question about preference (1 = not important at all; 5 = extremely important) and two rank order questions

Next, we indexed and normalized motivation responses, scaling all responses from 1 to 20 with associated standard deviations (1 = low motivator to visit; 20 = high motivator to visit). Following, to address Hypothesis 4, we evaluated mean differences on these scaled motivation responses across May (ponding surface water), June (moist surface), and July (dry surface), using a one-way ANOVA with a Bonferroni post hoc test using SPSS 24.0. Previous descriptions of data preparation, assumptions, power, and effect size were applied.

## Results

### Description of the Sample

We intercepted 327 visitors at the Bonneville Speedway Access Road and 285 elected to participate, yielding an 87% response rate with no observed patterns of non-response bias. After data cleaning for statistical outliers and GPS error, we elected to reduce the sample to 264, which generated a 6.03% confidence level at the 95% confidence level. Stratified sampling resulted in a sufficient sample size per month based on criteria specified in the pre-study power analysis ( $n_{\text{may}} = 95$ ,  $n_{\text{june}} = 60$ ,  $n_{\text{july}} = 109$ ), which indicates low probability of a Type 2 error. The sample included males (50%) and females (33%), with some participants not identifying their gender. Participants' ages ranged from 18 to 79 with only 8% of participants ranging from 18 to 25 and only 10% age 66 or older. Most respondents identified as white/Caucasian (79%), while Hispanic or Latinx comprised 6% of the sample, and Asian participants 8%. Approximately 63% were residents of the US and the remainder reported citizenship held in one of 23 different countries. While reported annual income was normally

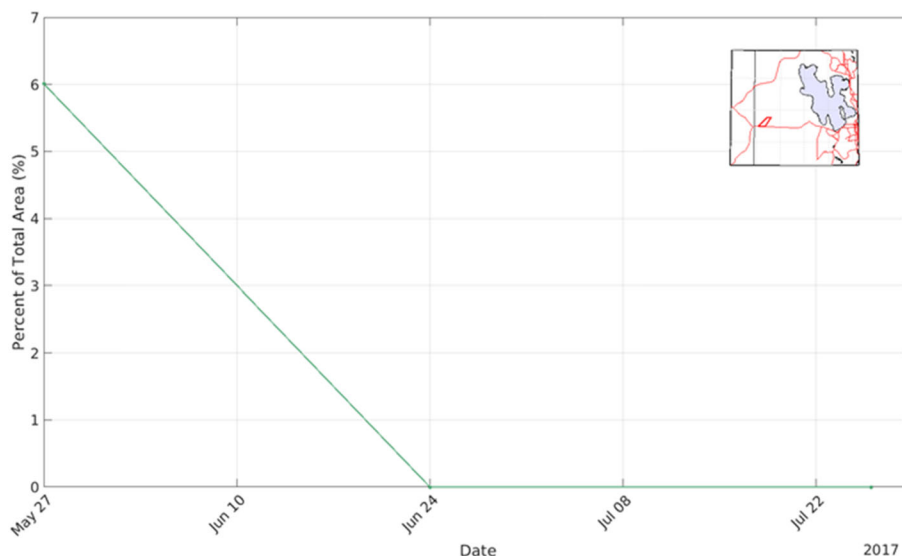
distributed, level of education trended toward the completion of a 4-year college degree or graduate degree (52%).

Results of one-way ANOVAs and non-parametric tests indicate that age, income, race, education, and gender did not differ statistically across May, June, and July ( $p > 0.05$ ). Furthermore, visitors' past use history at the Salt Flats—measured by assessing the number of visits in the last week, month, and year—did not differ significantly by month. Furthermore, 87% of tourists were first-time visitors to the Salt Flats. Importantly, these first-time visitors to the Salt Flats did not differ in their motivation scores from repeat visitors.

### Resource Conditions and Spatiotemporal Distributions of Use: RQ1

Our first research question asked, “How does the presence and distribution of surface water impact the spatiotemporal distribution of visitor use at the Bonneville Salt Flats?” Regarding resource conditions, 2017 was regarded as a relatively wet year at the Salt Flats (Craft and Horel 2019), though surface conditions were still deemed indicative of those resultant from typical quasi-decadal cycles of increased seasonal precipitation that occasionally lead to poor salt-crust conditions and cancellations (Bowen et al. 2018). In addition, the high frequency at which the Salt Flats' surface can cycle between wet and dry—as mentioned previously—lessens the likelihood that the wetter average conditions in 2017 might have an effect of this study's findings. Nonetheless, the level and distribution of ponding surface water varied across May, June, and July resulting in a 6% total net decrease in surface area covered by water over the sampling period (Fig. 2). MODIS/NDWI surface ponding values show more ponding surface water

**Fig. 2** Percent of the Salt Flats covered in water





on the Salt Flats during May, when compared with June and July (Fig. 3).

On an average, when more surface water is present, visitors traveled shorter distances, overall, and were more spatially concentrated—which supports Hypothesis 1. On an average, May visitors traveled 8.49 miles ( $SD = 4.48$ ) compared with June visitors ( $M = 12.01, SD = 6.11$ ) and July visitors ( $M = 13.43; SD = 7.57$ ), resulting in

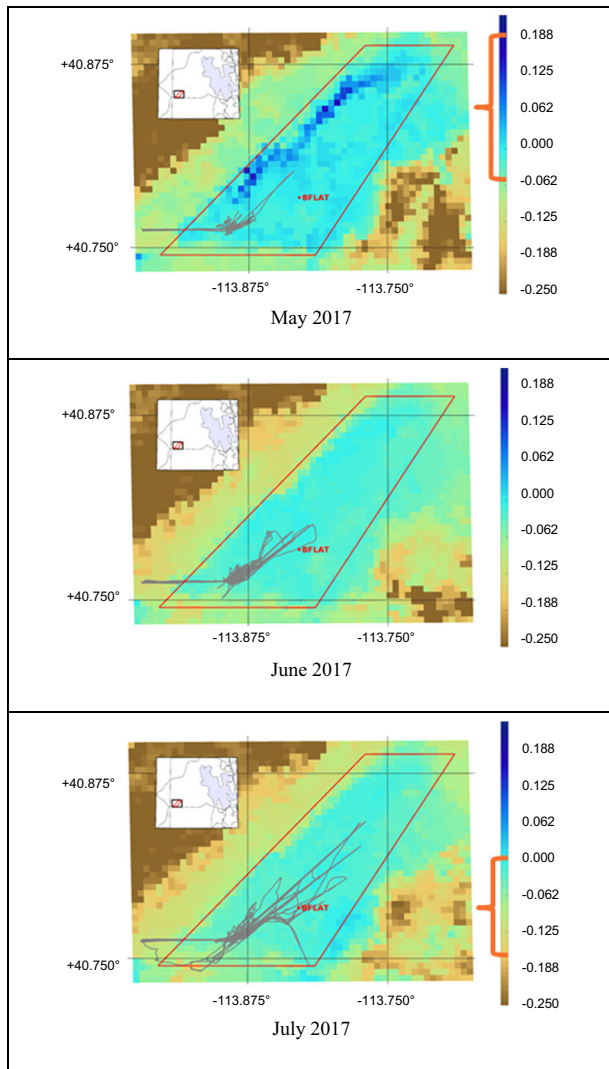
statistically significant difference between May and the other 2 months with a medium to large effect ( $F[2, 264] = 13.58; p < 0.01, \eta^2 = 0.095$ ). The difference in the total distance traveled between June and July was not significant (Table 2).

We posited that when more surface water was present, visitors would exhibit less total visitation time and less travel time on the Salt Flats, which the results also substantiated (Hypothesis 2). Specifically, May visitors spent an average of 42.4 minutes ( $SD = 35.83$ ) during their visit with only 8.83 ( $SD = 20.41$ ) minutes spent on the Salt Flats, which was statistically significantly different from June ( $M = 55.02$  and 16.78 min) and July ( $M = 63.67$  and 22.33 min), resulting in medium effect sizes ( $F [2, 264] = 7.01$  and 6.93;  $p < 0.01, \eta^2 = 0.069$  and 0.068).

Hypothesis 3 purported that more surface water would result in lower densities of visitor use on the Salt Flats, which the data supported. A visual analysis data provided by GPS loggers reveals substantially more clustering and higher densities of use on the Salt Flats during June and July—shown by the greyish blotches—as compared with May, when more surface water was present (indicated by blue pixels in Fig. 3). May visitors, on an average, spent ~79% of their total visit time on the access road compared with June and July visitors (69% and 64%, respectively). In addition, we layered GPS tracks with resource conditions segmented across sampling months to compare spatial distribution with areas of ponding (Fig. 3). The spatial distribution of use during May suggests visitors avoid areas of ponding surface water (Fig. 4).

**Resource Conditions and Motivation Stability: RQ2**

Research Question 2 asked, “How stable are visitors’ motivations for different experiences as changes occur in the level and distribution of ponding water at the Bonneville Salt Flats?” To answer, we indexed the 18 motivation items from the questionnaire and evaluated visitors’ reported importance across May, June, and July. Results indicate that the following five motivations are the most important for Salt Flat visitation (listed in order of reported importance): (1) taking pictures of the Salt Flats, (2) being away from crowds of people, (3) enjoying long



**Fig. 3** GPS tracks and surface water conditions across months

**Table 2** Spatiotemporal distributions of use by month

Month ( <i>n</i> )	Total distance <i>M</i> <sub>miles</sub> (sd)	Total time <i>M</i> <sub>minutes</sub> (sd)	Time on road <i>M</i> <sub>minutes</sub> (sd)	Time on flats <i>M</i> <sub>minutes</sub> (sd)
May (95)	8.49 <sup>a</sup> (4.4)	42.4 <sup>a</sup> (35.83)	33.57 <sup>a</sup> (29.70)	8.83 <sup>a</sup> (20.41)
June (60)	12.01 <sup>b</sup> (6.11)	55.02 <sup>b</sup> (30.80)	38.24 <sup>b</sup> (24.12)	16.78 <sup>b</sup> (16.09)
July (109)	13.43 <sup>b</sup> (7.57)	63.67 <sup>b</sup> (32.11)	41.33 <sup>b</sup> (23.33)	22.33 <sup>b</sup> (21.15)
<i>F</i> (2, 264)	13.58**	7.01**	2.93*	6.93**

Mean scores with different superscripts (a and b) within each column are statistically different

\* $p < 0.05$ ; \*\* $p < 0.01$

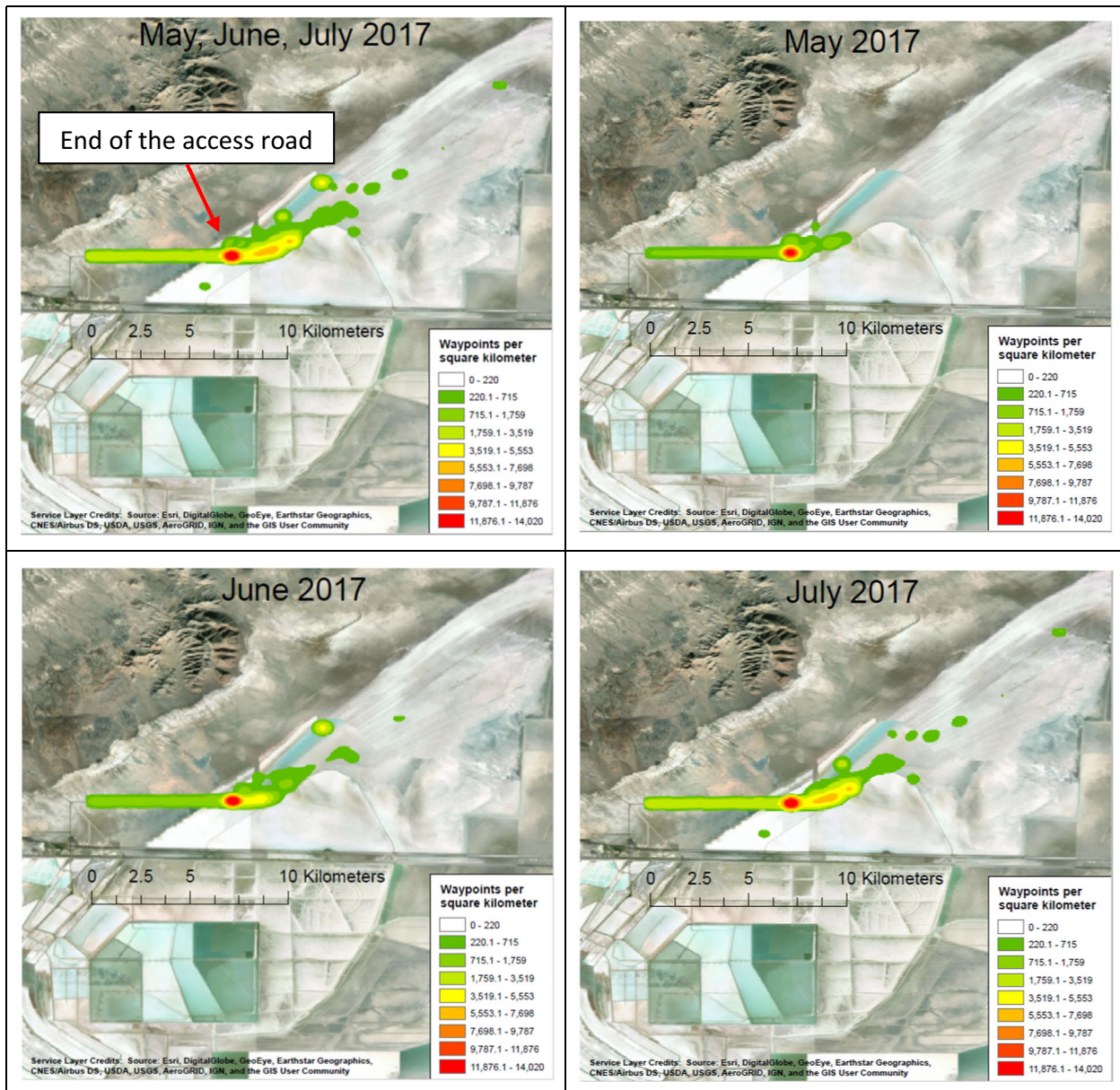


Fig. 4 Point density results across months

open space without obstructions or structures, (4) enjoying natural views without human structures within sight, (5) traveling across the Salt Flats without roads (Table 3). Overall, four of these five remained relatively stable, regardless of changing resource conditions ( $F [2, 264] = 1.88, 1.94, 2.32, 3.08; p > 0.05$ ). The other 13 less important motivations did not vary statistically across months. However, a significant difference was discovered between the importance of taking pictures in May (12.19,  $SD = 7.11$ ), June (15.98,  $SD = 9.17$ ), and July (15.38,  $SD = 8.14$ ), resulting in a low to medium effect size ( $F [2, 264] = 4.92; p < 0.01, \eta^2 = 0.041$ ). Overall, these results suggest that four of the top five motivations

remained relatively stable as the resource rapidly changed. Our third hypothesis, that visitors would express more motivation for stationary-oriented experiences during periods of ponding water, was not supported by the data.

## Discussion

In most SES studies, the relationships between short-term, rapid, seasonal resource changes, human behavior, and individual perceptions have lacked evaluation. To address this deficit, we evaluated how relatively rapid alterations in the level and location of salt-crust moisture and ponding

**Table 3** Differences in visitor motivations by month

Month ( <i>n</i> )	Take pictures <i>M</i> (sd)	Avoid crowds <i>M</i> (sd)	Open space <i>M</i> (sd)	Natural views <i>M</i> (sd)	Roadless travel <i>M</i> (sd)
All months (264)	14.41 (7.99)	11.12 (2.49)	11.01 (5.46)	10.64 (5.76)	10.09 (6.07)
May (95)	12.19 <sup>a</sup> (7.11)	11.85 <sup>a</sup> (3.29)	12.51 <sup>a</sup> (6.41)	11.83 <sup>a</sup> (6.62)	11.38 <sup>a</sup> (7.47)
June (60)	15.98 <sup>b</sup> (9.17)	11.04 <sup>a</sup> (1.71)	11.19 <sup>a</sup> (4.54)	10.09 <sup>a</sup> (3.62)	9.34 <sup>a</sup> (6.53)
July (109)	15.38 <sup>b</sup> (8.14)	11.08 <sup>a</sup> (2.93)	10.76 <sup>a</sup> (5.17)	9.74 <sup>a</sup> (5.87)	9.55 <sup>a</sup> (7.06)
<i>F</i> (2, 264)	4.92**	1.94	2.32	3.08	1.88

Mean scores with different superscripts within column are statistically different; Score range is 1–20

\* $p < 0.05$ ; \*\* $p < 0.01$

water at the Bonneville Salt Flats influenced visitors' spatiotemporal distribution of use and motivations for visitation. Using reflectance land surface modeling techniques, GPS visitor tracking, and quantitative visitor surveys allowed us to illuminate the relationships. The findings indicate that visitors travel more distance, spend more time recreating, and use the Salt Flats in higher densities during dry conditions. However, the results also highlight that motivations to visit remained relatively stable regardless of changes in salt-crust moisture and ponding water. These findings offer numerous points for discussion, several of which we present here while addressing Research Question 3 (How can modeling and displaying relationships between changing resource conditions, visitor behavior, and visitors' motivations inform management and understandings of complex SESs?).

This study's findings show a direct connection between recreation patterns and resource conditions at the Salt Flats that—while seemingly obvious at first glance—have the potential to reveal unexpected evidence of complex reciprocities. Specifically, despite the limitation that the salt crust's surface wetness imposed upon travel patterns, the quality of visitors' experience was—by their own testimony—undiminished. We suggest several potential explanations. First, perhaps simply being present at the Salt Flats and witnessing the existence of such an environment was a rewarding, satisfying, or fulfilling experience. Second, for some visitors at least, there may be no need to venture very far onto the salt to feel immersed in the Salt Flats' otherworldly environment (e.g., attention restoration theory; Kaplan and Kaplan 1989). This has implications for the necessary size of parks and protected areas that—aside from ecological requirements such as the minimum area for certain species' viability—may nonetheless provide restorative experiences despite their small size (e.g., Stack and Shultis 2013). Third, perhaps by remaining closer to the access road, visitors felt safer than they would have if they ventured many miles onto the salt crust to where their perceived level of isolation leaned more toward worrisome discomfort than recreational satisfaction (e.g., Appleton 1984; Ruddell and Hammit 1987; Andrews and Gateleben 2010). This has implications for understanding

what makes visitors feel safe or threatened in a landscape; unlimited visibility may be an acutely double-edged sword, with the discomfort of exposure outweighing the comfort or fascination regarding unlimited views. Fourth, perhaps the isolation and monochromatic landscape at the Salt Flats is simply not that interesting to visitors aside from the novelty of its barren expanse. It may simply lack the obvious complexity in which many people seek and find fascination—this is perhaps another reason that a future study might consider the allure of the Salt Flats' "infinitely mirrored" surface during the wet season. Fifth, and perhaps most far reaching, is the possibility that many protected areas don't warrant as much human access as many people believe, as even getting taste of these amazing places is enough to encourage people to support their protection.

### Spatiotemporal Use Changes with Resource Conditions

The Salt Flats are unique because they offer a relatively free-choice, dispersed recreation experience in an isolated and inimitable environment with limited restrictions imposed by management (BLM). Although the BLM recommends that visitors do not travel on the Salt Flats when ponding water is present, visitors are rarely observed for compliant behavior outside of permitted racing events in late August and September. Consequently, the opportunity for management influence on visitor behavior appears limited. However, in this study, the influential factor on visitor behavior appears to be rapidly changing resource conditions: as salt-crust conditions became increasingly dry, visitors spent more time on the Salt Flats while extending their travel distance. This influence indicates that off-highway vehicle use on the Salt Flats, outside of permitted racing events, is at least partially resource and climate-dependent with visitors changing spatiotemporal behavior as resource conditions change. Although such a finding may seem logical in other PPAs (e.g., ski touring occurs in winter months), it is an important finding and the first empirical evidence of recreation-related resource dependency outside racing events on a rapidly changing salt-pan.

As identified in the results, visitors spent ~21–36% of their total visit time on the Salt Flats, as opposed to the access road, regardless of the level of ponding water and salt-crust moisture. This is an important finding because driving on the salt during ponding water events or times of high moisture could impact salt-crust formation (Bowen 2017; Penrod 2016). The research community is currently examining the scope of this possible impact and striving to ascertain the degree of impact that recreational driving during wet periods has on salt-crust condition and formation. This is an important question as motorsports enthusiasts. The surface conditions influence the racing experience, particularly the capability of the salt to support a racing event and the ability of the racers to achieve desirable speeds. In 2014 and 2015, races were canceled on the Salt Flats due to an unusual summer flooding and unfavorable salt-crust conditions (Bowen et al. 2018). It appears that understanding the impact of casual, off-highway recreational driving on the Salt Flats would be useful to ascertain one potential influencer in this complex SES.

### Motivation Stability vs. Seasonal Resource Change

The findings of this study display a paradox—as resource conditions change, crucial motivators for visiting do not. Although researchers have used the concept of norm or threshold stability to explain such phenomena in other PPAs, the time-period for these investigations (10–41 years; e.g., Hall and Davidson 2013) are substantially longer than the investigation period in this study (<3 months). Also, previous studies did not investigate motivation or indicator stability or evaluate short-term or incremental resource change as a primary variable. Similar to the longitudinal norm stability studies conducted previously, evidence from our current study provides support for motivation and indicator stability at the Salt Flats, as the importance of motivation items remained relatively stable regardless of month-to-month changes in resource conditions. This finding is important because the stability of visitors' opinions in a PPA means that data derived from similar investigations (e.g., Krymkowski et al. 2009) may be quite useful for informing management decisions. In the case of the Bonneville Salt Flats, this finding provides evidence for managers that indicators formulated from these motivation items could be used for managing and monitoring visitor experiences outside of permitted racing events.

In addition, this divergent effect of changing resource conditions—motivation stability but spatiotemporal use changes—has the opportunity to further influence our knowledge regarding the affective, cognitive, and behavioral dimensions of weather dependency (Verbos and Brownlee 2017). Results from this study contribute to the

growing literature focused on the broader role of weather and climate influencing the experiences of recreationists and visitors to PPAs. From ski tourism (Scott et al. 2008) to visitation of the Great Barrier Reef (Marshall et al. 2013), variable resource conditions—affected by seasonal climate, weather variation, or global climate change—influence tourists' relationships with specific sites. Verbos et al. (2017) refer to the measurement of the impact of climate and weather on the tourism experience in specific protected area contexts as a component of resource dependency, which assess “individuals' sensitivity to changes in resource conditions” (p 13). These “sensitivities” may come in the form of spatiotemporal changes behavioral change (i.e., decreases in snowmobiling due to decreased snowpack; Perry et al. 2018), as well as changes in perceptions about the recreational opportunities afforded or conditions within by specific resources (i.e., different perceptions of seasonal carrying capacity across winter and summer months; Görner and Čihař 2011). However, the results from this study indicate these changes do not always covary; in other words, while spatiotemporal driving behavior on the Salt Flats changes in accordance with changing resources conditions, visitor motivations do not. Future research would do well to further explore the cognitive predictors for this disconnect, as they conflict with various rational models for cognition and behavior (e.g., Cognitive Consistency, Theory of Planned Behavior; Kollmus and Agyeman 2002).

### Study Limitations

The findings of this study broaden our knowledge regarding the influence of short-term resource changes on spatiotemporal visitor behaviors and the stability of perceptions of important resource element at the Bonneville Salt Flats. These findings are, however, not without their limitations. First, this study provides a cross-sectional view off-highway use of the Salt Flats during a sample of non-racing months (May to July). Off-highway visitor spatiotemporal behavior and motivations to visit may deviate during other non-race months (November to April), when ponded water is more reliably present on the Salt Flats. It is possible that, for some visitors, their motivations and desired experience with the resource reflects these seasonally ponded conditions. In addition, future research should investigate visitor type (i.e., off-highway enthusiast vs. casual visitor) through cluster analyses or other common social science methods. Next, the reliability of questionnaire and GPS data deserves mention. Response bias surrounding specific items (e.g., travel across the Bonneville Salt Flats without roads) may have suppressed mean values during ponded months, as respondents could have been concerned about social sanctions from the research team due to indicating an interest in traveling on

the Salt Flats. GPS tracker data during these months, particularly May, could also potentially reflect visitors' altered behavior due to perceptions of surveillance (e.g., Sandbrook et al. 2018) with GPS tracks from the research team of BLM managers. In addition, the potential of visitors to exit their vehicles without the GPS tracker device limits our understanding of their entire travel experience. Though we informed all respondents to keep the tracker on their person at all time and not deviate from their intended travel plans or change their responses based on our presence, it is possible our presence had an effect.

Finally, more information on overall, off-season use, including monthly visitor counts and demographics, would be useful to further understand the representativeness of our survey population and generalizability of the results. As this is the first peer-reviewed visitor-use study of the Salt Flats, this data, until now, has thus far been lacking. Future research would do well to further understand the different visitor segments that frequent the Salt Flats during non-race times both to understand the economic impact to Tooele County, Utah and Wendover, Nevada of visitation, as well as further represent the various stakeholders of this unique resource.

## Conclusion

This study sought to leverage both ecological and social data to help identify key linkages at an iconic protected area with rapidly changing resource conditions. Illuminating such linkages is important because most natural resource issues in society are not solely ecological or social in nature but characterized by deeper enmeshment between the two. Numerous spatial, temporal, social, and ecological attributes motivate visitation within the dynamic landscapes in protected areas. Consequently, SES science-based approaches that probe the dynamic interactions among the social and ecological phenomena will continue to be increasingly important as the complexity of society and our understanding of resources both evolve. This study provides one step in this direction where we evidenced resource-specific recreational behaviors, motivations, and indicators or experiential quality to illuminate certain aspects of complexity with changing SESs.

## Compliance with Ethical Standards

**Conflict of Interest** The authors declare that they have no conflict of interest.

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