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Kudos and K.O.M.‚Äôs: The Effect of Strava Use on Evaluations of Social and Managerial Conditions, Perceptions of Ecological Impacts, and Mountain Bike Spatial Behavior

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KUDOS AND K.O.M.'S: THE EFFECT OF STRAVA USE ON EVALUATIONS OF SOCIAL AND MANAGERIAL CONDITIONS, PERCEPTIONS OF ECOLOGICAL IMPACTS, AND MOUNTAIN BIKE SPATIAL BEHAVIOR

by

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ABSTRACT

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The use of social media and self-tracking smartphone fitness applications (apps) like *Strava* is becoming an increasingly pervasive phenomenon in outdoor recreation experiences in parks and protected areas (PPAs). Concurrent in recreation research studies is the use of smartphone GPS tracking (SGT) and volunteered geographic information (VGI) data to study visitor behavior. However, limited research has critically addressed the biases of these data and critically evaluated how behavior and attitudes may be different for visitors when smartphones, connected devices, and the fitness tracking apps they interface with are a focus or mediator of the recreation experience.

The first chapter of this thesis is a literature review of recreation survey and behavior research, social-psychology and technology use theory, gamification, and mountain bike social science and recreation-ecology research. The second chapter is formatted for submission to the Journal of Outdoor Recreation and Tourism and presents results from a survey and global positioning system (GPS) tracking study of visitors to PPAs in Orange County, CA to explore the effect of *Strava* use on visitors' evaluations of

trail, management, and social conditions, ecological knowledge and perceptions of ecological impacts of recreation and differences in spatial behavior of mountain bikers who use *Strava* and those who do not.

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PUBLIC ABSTRACT

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Noah E. Creany

Smartphone based self-tracking fitness applications (apps) like *Strava* are increasingly becoming a part of recreation experiences in parks and protected areas (PPAs). Recreation research has employed smartphone GPS tracking (SGT) and volunteered geographic information (VGI) to study visitor behavior in PPAs, but little is understood about how smartphones or fitness apps affect visitor perceptions and behavior during their experience.

The first chapter of this thesis is a literature review of recreation survey and behavior research, social-psychology and technology use theory, gamification, and mountain bike social science and recreation-ecology research. The second chapter is formatted for submission to the Journal of Outdoor Recreation and Tourism and presents results from a survey and global positioning system (GPS) tracking study of visitors to PPAs in Orange County, CA to explore the effect of *Strava* use on visitors' evaluations of trail, management, and social conditions, ecological knowledge and perceptions of ecological impacts of recreation and differences in spatial behavior of mountain bikers who use *Strava* and those who do not.

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CHAPTER 1

LITERATURE REVIEW AND RESEARCH APPROACH

1. Introduction

Strava, Swedish for “strive”, is a social fitness tracking app that allows users to record and share their recreation activities, like bike rides or runs, with a network of other users on the platform. Among fitness tracking apps *Strava* seems to stand atop the podium with 42 million registered users globally, adding an additional million users each month (Lindsey, 2019). These app users have recorded than 13 trillion data points from more than 2 million activities per week (“Strava Labs,” 2018). According to Lindsey (2019), although Strava was neither the first fitness app nor has the largest number of users, features such as the Segment Leaderboard and integrated social-network platform distinguish the app from others in the fitness app category which has resulted in a dedicated following of users.

Strava is a part of a trend in digital media of self-monitoring or the “Quantified-self” (“Quantified Self”, 2019), which provide affordances to users of connected devices such as smartphones, GPS watches and cycling computers to collect, analyze, and share data created through use of the technology (Lupton, 2016). Further, Lupton (2016), suggests that the data and technologies used to collect it influence users’ behavior and decision making. A qualitative study of Strava users found that the majority of users always record their activity with Strava and that contributing likes and replies to other users' activities on the platform provided positive feedback mechanisms that result in users posting more frequently about their recorded activities (Stragier et al., 2018). In the

context of fitness for physical health, it suggests that these platforms can encourage better health outcomes for its users; however, little research has explored how the use of self-tracking apps affects attitudes and behavior in the parks and protected areas (PPA) settings where many of these activities take place. Understanding the attitudes, perceptions, and behavior of visitors who use these apps can inform recreation management and planning of the social, experiential, and ecological aspects of visitor use.

2. Understanding Visitor Spatial Behavior

2.1. Use of GPS Spatial Data to Understand and Evaluate Visitor Behavior

Global Positioning System (GPS) based tracking emerged in the 2000's as a new approach to examine visitor spatial behavior to understand the relationship between spatial-use patterns, the density of use, and ecological resource impacts (Hallo et al., 2004; Taczanowska et al., 2008). Spatial analysis describing and illustrating the behavioral patterns of visitors to PPAs has been demonstrated to be an effective management tool to determine the use levels of park resources and the extent of the ecological impacts that result from recreation (D'Antonio et al., 2010; D'Antonio & Monz, 2016; Riungu et al., 2018). GPS-based spatial observation provides a less biased tool for collecting spatial data of visitor movement and spatial use and provides researchers insights into behaviors that previously lacked an instrument to adequately quantify. GPS-based tracking also provides insight into behaviors which visitors may be unwilling to divulge or unaware of, such as traveling off designated or formal trail

networks (Wolf et al., 2014; D'Antonio et al., 2010). However, these behavioral patterns are not static and respond to new technologies. For example, in the case of mountain biking, changes in spatial and temporal behavior have resulted from full-suspension frames which afford the ability to travel over rugged terrain, fat-tire bicycles which extend the seasonality and terrain for mountain biking (Monz & Kulmatiski, 2016), and the recent emergence of electric motor-assisted mountain bikes.

The instrument to observe this spatial behavior has primarily been consumer-grade GPS units and data loggers which have been evaluated to determine the validity and reliability of GPS spatial data as for studying behavior, specifically velocity (Hurst & Sinclair, 2013; Varley et al., 2012). Witte and Wilson (2004) compared GPS data to an on-bike cycling computer and found a moderate to high correlation between the collection methods for a range of velocities. GPS accuracy was further evaluated to simulate non-linear trails with small and large curved paths and found a median error of -0.75 m/s and -0.49m/s, respectively. For straight paths, Witte and Wilson (2004) reported that error was normally distributed, and 82% of data within ±0.4 m/s error (Witte & Wilson, 2004, p.1896). Limitations on the accuracy of velocity calculations are influenced by multi-path interference from tree canopies, terrain, and building structures, the number of satellites in orbit, and multi-path error, which all dilute the precision of GPS data collectors. Bauder (2015), acknowledging these constraints on GPS positional accuracy, demonstrated the validity of velocity derived from GPS loggers with ±3m horizontal accuracy in the urban context of Frieberg, Germany, to characterize spatial behavior within the city by mean walking velocity. Moreover, GPS

tracking with recreation grade units provides adequate resolution and data quality to evaluate spatial behavior at trail and park level spatial scales.

The use of volunteered geographic information (VGI), user contributed or generated geospatial information (Goodchild, 2007), to inform the recreation planning of park management has become a growing trend in recreation literature as a methodological development from GPS tracking visitor monitoring and data collection methods. VGI data has been sourced from public geotagged photos (Walden-Schreiner et al., 2018), public-participatory GIS (PPGIS) (Muñoz et al., 2019; Wolf et al., 2014), and opensource or web-share GPS services (Campelo & Nogueira Mendes, 2016; Norman & Pickering, 2017) to utilize large datasets to study spatial and temporal use patterns and trends and provide estimations of visitation to PPAs (Leggett et al., 2017).

Passive and active forms of smartphone GPS Tracking (SGT) have recently emerged as a new source for this spatial data to estimate visitor use levels and spatial behavior (Korpilo et al., 2017, 2018; Monz et al., 2019). Nevertheless, access to SGT data is costly, and data collected via smartphones require added measures during collection, analysis, and data handling to ensure the privacy of subjects. *Strava* Metro is a subsidiary of *Strava* that sells aggregated spatial user data designed for GIS analysis to aid transportation departments in the planning of infrastructure and active transportation plans ("Strava Metro," 2019). Demographic (Sunde, 2019; Garber et al., 2019; Whitfield, 2016) and route preference patterns of Strava users in urban commuting contexts (Boss et al., 2018; Jestico et al., 2016) appear to be relatively representative of the larger bike commuter population, however how consistent this correlation in PPA and recreation

settings has not been evaluated.

At the time of writing, only two recreation studies have used Strava user data to understand spatial behavior in PPA settings (Korpilo et al., 2017; Korpilo et al., 2018). Korpilo et al. (2017) collected SGT data by asking participants in a study in Keskuspuisto Park in Helsinki, Finland to share tracks from Strava, Sports Tracker, Endomondo, HeiaHeia, Garmin, Runkeeper, Suunto Movescount, Attackpoint, Cycle Tracks as well as PPGIS "draw-on-the-map" tracks. While this study did not evaluate differences between spatial behavior based on the source of the data, researchers identified specific use patterns and a higher occurrence of off-trail use by mountain bikers than runners and other use-types within the park.

Strava Heatmaps provides a similar aggregation of user-contributed spatial in a public, free, web-map that allows users to search an area of interest to find trails and visualize the density of use of a park or trail. Rice et al. (2019) demonstrated that Strava Heatmaps could provide useful insights for managers of PPAs to identify use patterns and areas of high use, including informal or non-designated trail use. Moreover, VGI/SGT data can provide a cost-effective and expedient method for gathering data on visitation levels, identification of off designated trail use, and in areas of high visitor density with diffuse entrances which can help managers focus efforts to mitigate the ecological disturbances associated with recreation (Korpilo et al., 2017; Korpilo et al., 2018). However, a limitation of the use of VGI/SGT for spatial-behavioral studies is the absence of contextual information to understand the visitor characteristics, motivations, and attitudes that influence decision making and spatial use (Riungu et al., 2018). Finally,

while SGT/VGI data provides a novel and cost-effective way to gather visitor spatial data limited research has explored how the use of self-tracking apps like *Strava*, potentially mediate spatial behavior in PPAs.

2.2. Paired Survey and GPS Tracking Studies

Surveys instruments have been used in recreation literature to understand attitudes and perceptions, establish normative thresholds of acceptability or tolerance to ecological change, develop visitor motivation typologies, provide demographic information, and answer specific research questions to develop and test theory (Manning, 2010). Pairing a GPS tracking with a visitor survey instrument provides the opportunity to integrate these social dimensions of natural resource use with the theoretical and practical implications of human spatial use of natural resources (Stamberger et al., 2018; Riungu et al., 2018; D'Antonio et al., 2012). Beeco and Hallo (2014) suggest a strength of GPS tracking studies with paired survey instruments is to better understand the motivations and characteristics of visitors that influence spatial use patterns of PPAs (Kidd et al., 2018; Newton, 2016). For example, Becco and Halo (2014) found that self-reported skill or ability level was a significant predictor of total distance of travel and, consequently, and the number of unique areas of a park that were visited. Visitor characteristics such as experience use-history, skill or experience level, and age may provide contextual information to understand the effect of Strava use on spatial behavior. Nevertheless, features within the *Strava* app distinguish it from other fitness tracking apps, namely the competitive and game features within the app which have the potential to influence visitor behavior.

3. Gamification and Technology Use Theory

3.1. Gamification

Strava not only provides its users with a tool to GPS track their activity but provides a platform for competition between users of the app. This competitive element of the *Strava* app, operationalized through gamification techniques distinguishes the app from other fitness tracking apps. Gamification is a technique in digital media design and development that refers to the application of mini-games or challenges, called game elements, to provide motivation and persuasion to complete a task, goal, or desired behavior. Deterding et al. (2011) is widely cited for establishing a definition of gamification as “the use of game design elements in non-game contexts" (p. 2); but also trace its foundations to learning theory and the importance of play for culture, socialization, and learning. Seaborn and Fels (2015) provide a concise summary, "[g]amification has two key ingredients: it is used for non-entertainment purposes, and it draws inspiration from games, particularly the elements that makeup games, without engendering a fully-fledged game"(p.27).

Gamification techniques have been applied in a variety of different contexts, such as education, health, marketing, and social networks, which have led to a plurality of conceptual definitions and theoretical foundations (Seaborn & Fels, 2015). In an attempt to direct future gamification research Putz and Treiblmaier (2015) outline suitable social-psychology theory that has been used to explain and inform the influence of gamification techniques on attitudes, motivation, and behavior including but not limited to the Theory of Reasoned Action (Fishbein & Ajzen, 1975), Theory of Planned Behavior (Ajzen,

1991), Social Learning Theory (Bandura & Walters, 1963)/ Social Cognitive Theory (Bandura, 1986) and Self-Determination Theory (Ryan & Deci, 2000). Furthermore, Putz and Treiblmaier (2015) embrace this multi-theoretical approach because while a growing body of literature supports the effectiveness of gamification in achieving positive outcomes (Hamari et al., 2014), the understanding of the effect of gamification on user's behavior and attitudes is still emerging.

A significant distinction between *Strava* and other fitness tracking apps is the incorporation of game elements, or gamification, into the real-world context of a recreation experience (Chen, 2017). Barret (2017) suggests that while *Strava* has no overt objective to change the behavior of users, the gamification mechanisms imbedded in the app make use of persuasion techniques and social feedback to "[tap] into the basic desires and needs of the users which revolve around the idea of status and achievement" (p. 330). Leaderboards are a well-established game element and central feature of *Strava* that allows users to compete for the fastest time on segments of trail crowning the fastest male or female rider King of the Mountain (KOM) or Queen of the Mountain (QOM), respectively ("What's a segment?," 2012). Sailer et al. (2017), applying Self-Determination Theory to understand the effect of gamification on motivation, found leaderboards and badges increased psychological needs satisfaction of competence, autonomy, and task-meaningfulness.

Additionally, *Strava* features such as trophies, challenges, performance visualizations, and Kudos, which are the *Strava* equivalent of a "Like" on other social platforms, are game elements that trigger motivational mechanisms (Sailer et al., 2013).

Weber et al. (2018) found the workplace cycling social competition Love to Ride that draws upon the aspects of norms, values, and beliefs from the Theory of Planned Behavior and featured points and leaderboards increased levels of cycling participation among new, occasional and regular urban bike commuters in the U.S., U.K., and Australia. Finally, Seaborn and Fels (2015) conducted a meta-analysis of studies that used gamification techniques in a range of contexts and found mostly positive results within social networks and health and wellness contexts.

Barratt (2017), in a qualitative study of gamification of cycling within *Strava*, suggests a new dimension to the mountain bike experience is added through social interaction and competition facilitated by the features of the app. Furthermore, while gamification has been demonstrated to be a useful tool to produce desired outcomes determined by the designer of the app or software, the effect on behavior in PPA settings where these activities often take place and if that behavior is consistent with the goals of management is not well understood.

3.2. Technology Use Theory

The Technology Acceptance Model (TAM) (Davis, 1985) was developed and adapted from the Theory of Reasoned Action (Fishbein & Ajzen, 1975; Fishbein, 1980) to help explain the factors that shape attitudes and barriers to using computer software. Davis (1985) identified perceived usefulness, "the degree to which an individual believes that using a particular system would enhance his or her job performance"(p.26), and perceived ease of use, "the degree to which an individual believes that using a particular system would be free of physical and mental effort" (p.26), as factors that shape attitudes

towards acceptance and use of a new technology. TAM remains a well-cited and useful theory in computer science and digital media literature, however recent studies have contributed additional factors including the hedonic value or enjoyment (van der Heijden, 2004), social ties and motives(Hossain & de Silva, 2009), and perceived utility of self-monitoring and self-regulating aspects of apps (Stragier et al., 2016) to explain technology use. Stragier et al. (2016) integrated these factors in a structural equation model to determine which factors contribute most to habitual *Strava* use between new (<1 year) and experienced (>1 year) users. Stragier et al. found support for the direct, indirect, or moderating effects of all these factors contributing to habitual Strava use, with factors becoming important to explain perceived usefulness for new and experienced users. Self-regulation and monitoring are feedback mechanisms in *Strava*, manifest as performance visualizations and activity summaries, that have been demonstrated to be effective game element techniques in health studies to elicit behavioral change (DiClemente et al., 2001). Nevertheless, this study provides useful insight into what motivates users of *Strava* and suggests there may be differences among *Strava* users depending on how long and how frequently they use the app. The practical implications of how these social and behavioral feedback mechanisms manifest in theory that informs recreation behavior and visitor management strategies in PPA settings warrant further study.

3.3. Integration of Technology and Recreation Theory

Recreation is broadly conceptualized as a multi-phase experience consisting of anticipation, travel-to, on-site, travel-back, and recollection (Clawson, 1963; Hammitt,

1980). Strava appears to acknowledge and leverage these multiple phases; Lindsey (2019) quoting *Strava* CEO James Quarles:

> *"We think Strava plays a role for people not just when they're recording an activity but before and after, right?" he says. "You can find routes, you can find groups to join, people to go with." Then, once you post the activity, you can talk about it, post photos, tag friends, and memorialize and relive the event (p. 2).*

When recreationists incorporate smartphone apps like Strava into their recreation experience, data generated from recording the activity takes on a self-constructed meaning that users use to recall and evaluate the outcomes of the experience (Lupton, 2018). According to Lupton (2018), Strava users find these data provide a more objective summary and evaluation of the experience than their subjective assessment and that these data provide affective responses to "information on their bodies and cycling trips, including feeling part of a community of riders" (p. 661). While this data provides Strava users a functional tool to plan future and recall past experiences, complimenting Clawson's (1963) multi-phase recreation experience model, how these evaluative and affective attributions to self-tracking data of a recreation experience may affect or add a layer of abstraction to the recreation experience is unexplored.

The notion that humans positively benefit from experiences in natural settings is well established in cultural traditions around the world and is supported by evolutionary psychology which asserts that because humans are a product of these settings, they provide a tranquil, restorative experience and a respite from the excessive stimuli the modern era (Berry et al., 2015). Nevertheless, current environmental psychology and outdoor recreation research have sought to qualify and quantify the psychological, social,

and environmental stewardship benefits associated with recreation experiences in natural settings (Holland et al., 2018). While Holland et al. (2018) note it is still unclear whether some of the positive outcomes associated with wildland recreation are dependent on the environmental-setting characteristics another confounding variable to obfuscate these outcomes of the recreation experience is the increasing ubiquity of technology and smartphones interwoven into and mediating these recreation experiences (Martin, 2017).

Construal-Level Theory (Trope & Liberman, 2010) describes psychological distance as the "subjective experience that something is close or far away from the self, here, and now" (p. 1), and "[objects or events that] are not present in the direct experience of reality" (Liberman et al., 2007, p.353). Application of Construal-Level Theory has primarily focused on interpersonal distance with recent inquiry into the effect of mobile devices on the temporal, spatial, social, and hypothetical dimensions of psychological distance (Norman et al., 2016). Norman et al. (2016) suggest that smartphone use can decrease the perceived distance to a person with whom the smartphone user is communicating yet simultaneously increase the perceived distance to those physically present around them. Additionally, Ward et al. (2017) found that the mere presence of a smartphone in a room reduced the cognitive capacity and diverted consciousness away from an assigned focal task.

Considering the empirical support for the effectiveness of gamification techniques to change behavior within the Strava app, this may have implications for the benefits or outcomes of the recreation experience as well as the psychological distance to the resource. In more concrete terms, Strava users who are focused on the measurable fitness

outcomes or in-app competition with other users during a recreation experience may be less attuned or may not benefit from the psychological restorative aspects of the experience and more importantly may be less sensitive to the ecological impacts associated with their activity as a consequence of their use of a smartphone app mediating their experience.

An emergent theme in qualitative studies of Strava use is the importance of the social aspects of the app and the ability to interact with other users (Smith, 2014). Similarly, Barratt (2017) conducted semi-structured interviews with Strava users in the U.K. and found the sociability and connectedness of Strava to be an important and positive feature of the app to users. Barratt (2017) also notes that Strava users reported that the challenge and competitiveness of the app influence their route choice, frequency of rides, and cycling intensity. According to the Focus Theory of Normative Conduct (Cialdini et al.,1991), these collective and individual perceptions of group conduct are descriptive norms that can influence behavior when they are salient at the time of the behavior (Kallgren et al., 2000). Cialdini et al. (1991) add that evidence of the behavior of others can shape descriptive norms of conduct, adding "If everyone is doing or thinking or believing it, it must be a sensible thing to do or think or believe" (p. 203). The *Strava* Segment Explorer allows users to search for trail segments to compete for the fastest time. However, *Strava* does not manage this aspect of the app, and as a result some of these segments occur on informal trails within PPAs. Further, because the leaderboard hosts records for *Strava* use ("KOMs/QOMs"), the app seems to have the potential to shape *Strava* users' descriptive norms of depreciative behaviors.

The Theory of Planned Behavior (TPB) (Ajzen, 1991; Fishbein & Ajzen, 2011) has been used extensively in recreation research to explain and predict behavior as the product of attitudes, subjective norms, and perceived behavioral control on behavioral intentions, which can be interrupted and influenced by social norms (Fishbein & Manfredo, 1992). While TPB has been only moderately effective in its ability to explain variation in behavior, Miller (2017) suggests research should explore the addition of new predictors and variables to better understand what shapes behavioral intentions and in turn, visitor behavior. Recent research has found factors such as the characteristics of the visitor, which can influence spatial behavior in PPAs (Beeco & Hallo, 2014) and affect perceptions of resource impacts (D'Antonio et al., 2012; Monz, 2009). Finally, Sisneros-Kidd (2018) provided empirical support for adding personal and social factors, which include descriptive norms of behavior, to TPB as interrupting factors that influence visitor spatial behavior.

4. Ecological and Social Impacts of Mountain Biking and Strava

Mountain biking emerged in the 1970s and quickly became the subject of controversy as Sierra Club National issued a policy declaring mountain biking a major problem, and land managers expressed concerns of conflict between mountain bikers and traditional use types (Sprung, 1997). These sensationalized reactions to mountain biking were in part ameliorated throughout the 1990s and the early 2000s, informed by research exploring social dimensions of trail conflict concerns (Ramthun, 1995; Ruff & Mellors, 1993), mountain biker preferences (Symmonds et al., 2000), and visitor management strategies (Chavez, 1993). A second and more recent line of research has sought to better

understand the ecological disturbance specific to mountain biking to soils, plants, and wildlife (Marion & Wimpey, 2007, 2017; Thurston & Reader, 2001; White et al., 2006; Monz & Kulmatiski, 2016).

Mountain biking has experienced a steady increase in participation among Americans growing 29% among young adults 18-24 and 12% for all age groups from 2007 to 2018 (Outdoor Foundation, 2018). Nevertheless, mountain biking remains a concern for land managers as dynamic advances in mountain bike design change and increase the range of terrain of mountain bikes. Fat tire mountain bikes, free-riding on the terrain without trails, and recent emergence of electric-assisted mountain bikes are just a few examples of the dynamic nature of spatial and temporal use-pattern trends of mountain biking that require proactive and evolving visitor management strategies.

4.1. Biophysical Disturbance of Mountain Biking

According to Cole (1989) recreation ecology "studies the impact of recreation on natural and semi-natural environments". Recreation Ecology has explored the disturbances or impacts that result from a range of recreation use-types, however studies focused on mountain biking represent a small proportion of the literature. Nevertheless, these studies have focused study of the biophysical disturbance of mountain biking to plants, soils, and wildlife which will be summarized in this section respectively.

Thurston and Reader (2001) conducted a quasi-experimental trampling study comparing mountain bike and hiking impacts to undisturbed study plots in a forest in Northeast Canada. Authors found that while both use-types reduced vegetation cover and species richness, the nature and extent of disturbances did not significantly differ and add

that "informal trails should not form any more quickly for biking than for hiking" (p.408). However, unique to mountain biking is the creation of technical trail features (TTFs) that involve the harvesting or relocation of local or foreign materials to construct jumps, berms, rock-gardens, which add challenge to a trail (Pickering et al., 2010). Pickering et al. found that TTFs in a peri-urban park in Australia involve removal or damage to existing vegetation and often result in a loss of undergrowth and increased soil exposure.

White et al. (2006) found no significant differences between mountain bike and multi-use trail impacts across a range of common ecological regions of the United States Southwest to trail widening, incision, and erosion. In contrast to motorized use and horses, mountain biking creates less impact on soil displacement and erosion (Marion & Wimpey, 2007). In general, on flat or rolling terrain and sustainably designed trails, mountain biking creates a similar level of disturbance as hiking. However, Wöhrstein (1998) found that downhill and competitive mountain bike race events create more acute erosion impacts in steep, fall-line trail segments. This concern for steep, downhill riding is also reflected in Cessford's (1995) study, which found that hard braking on downhill segments displaces soil downslope and can reroute surface drainage and accelerate erosion. In a study evaluating trail conditions preferences of mountain bikers, researchers found that bumps, jumps, gullies, and indicators of erosion such as exposed rocks and roots contribute to the challenge of the experience of mountain biking (Symmonds et al., 2000). Similar to findings from Farrell et al. (2001), this may suggest that to mountain bikers, resource impacts may present an amenity value, which presents a dilemma for managers who must balance the experiential quality of the trail conditions as well as the

sustainability of the infrastructure.

Trails serve a critical function of concentrating all visitor use types in an already disturbed area, however as a result localized species richness is reduced around the trails and the visitors that use them function as vectors for the transportation of pathogens and invasive plant material that can exponentially increase the natural dispersal range (Marion et al., 1986; Pickering & Mount, 2010). In a grassland area in the Colorado Front Range, Potito and Beatty (2005) found that the percent coverage area of exotic and ruderal species increased with proximity to a trail. Additionally, Frankel et al. (2008), found elevated and spatially correlated soil concentrations of the pathogen *P. ramorum,* which leads to Sudden Oak Death along trail corridors. Frankel, Kliejunas, and Palmieri (2008) also found these correlations to be a function of the level of visitor use of an area, and although the capacity to transmit the pathogen did not significantly differ between hikers and mountain bikers, the most significant factor increasing the likelihood of encountering and distributing the pathogen was the total distance traveled. Because mountain bikes have a greater spatial range than hikers (Pickering et al., 2010), mountain biking may pose an increased risk of distributing soil pathogens across a landscape.

Unsanctioned, informal, or non-designated trails are often unsustainable, and the use of these trails creates far more disturbance because they do not benefit from environmental planning and sustainable design practices that sanctioned or designated trails receive. Newsome and Davies (2009) suggest the creation of informal mountain bike trails are a result of unmet demand for more challenging terrain, short cuts, or connections to other trails. As a result, the ecological response from the creation of these

informal is asymptotic and curvilinear with initial disturbance creating a more significant proportional impact than following use (Hammitt et al., 2015). Informal trails can also fragment habitat (Wimpey & Marion, 2011), reduce biodiversity (Fahrig, 2003), and although these impacts often occur at small spatial scales, when they bisect ecologically sensitive areas and into habitat of species with smaller dispersal ranges the impact is more significant (Gutzwiller et al., 2017).

Hammit et al. (2015) broadly conceptualize the wildlife response to recreation disturbances into two categories; direct disturbance/habitat modification and altered behavior/energy balance. The intensity and spatial and temporal extent of this direct disturbance or habitat modification can lead to altered behavior and energy balance, which can extend the recreation disturbance beyond the species and into the broader ecosystem. While many studies have examined recreation disturbance on wildlife (Steidl & Powell, 2006; Taylor & Knight, 2003a), few have specifically addressed mountain biking. Wisdom et al. (2018) evaluated the disturbance of different use-types on collared elk using minimum separation distance from trails as an avoidance metric. Wisdom et al. found separation distances were largest for ATVs, intermediate for mountain biking, and lowest for hiking and horses. However, In Orange County, CA Patten and Burger (2018) evaluated the influence of human presence in urban proximate parks on the occurrence of twelve medium and large mammals using camera traps and found single-day detections of wildlife were most influenced by pedestrians, followed by mountain biking, motorized vehicles, dogs, and horses while the four year detection patterns did not produce an observable effect from human presence. Similarly, Taylor and Knight (2003b) found no

observable differences in wildlife disturbance between hiking and mountain biking but suggest that because mountain bikers travel further distances their potential for disturbance may be higher per unit time.

4.2. Social Conditions and Perceptions of Ecological Impact

As mountain bikes first began to interface with traditional recreation activity-types on trails, a primary concern for land managers was conflict between users (Chavez, 1993). Two theoretical frameworks, Goal Interference (Jacob & Schreyer, 1980) and Social Value Theory (Vaske et al., 1995), have been employed in studies to evaluate conflicts specific to mountain biking which have generally found low frequencies of conflict but have elucidated the nature and group dynamics of conflict. General themes that emerge from this research are an asymmetric relationship where hikers report higher attribution of conflict towards mountain bikers than mountain bikers attribute to hikers (Mann & Absher, 2008; Ramthun, 1995), and perceived conflicts higher than actual or observed conflicts (Cessford, 2003). Additionally, a small subset of research has explored social values conflict between hikers and mountain bikers and found that while hikers were more likely to report social values, and interpersonal conflicts than mountain bikers (Carothers et al., 2001), values orientations of mountain bikers and hikers are generally similar when compared to the differences between non-motorized and motorized activity types (Rossi et al., 2015).

Recreation research exploring visitor perceptions of ecological impacts has two divergent domains. The first suggests that visitors form judgments and have varying levels of acceptability of ecological impacts that affect the quality of the visitor

experience (Lynn & Brown, 2003; Roggenbuck et al., 1993). This Limits of Acceptable Change framework has been used by managers of PPAs to select meaningful indicators and thresholds of resource impacts to identify standards to maintain and conditions that warrant management action (Hammitt et al., 2015). The second and more nuanced line of research suggests that the visitor experience is not significantly affected by resource impacts, but that visitors are most sensitive to the evident and avoidable resource impacts but may perceive some resource impacts as having an amenity value or positive effect on the experience (Farrell et al., 2001; Monz, 2009). Research exploring this second line of research has explored how visitor characteristics affect these perceptions and have found that a visitor's experience use-history (White et al., 2008), as well as local ecological knowledge and knowledge of minimum impact practices (D'Antonio et al., 2012), are influential factors that affect how a visitor perceives recreation impacts. Limited research has explored how mountain bikers perceive ecological impacts; however, Pickering and Rossi (2016) found that while mountain bikers hold an ecocentric value orientation, very few reported negative perceptions of ecological and resource impacts of their use and other activity types.

5. Research Approach

5.1. Study Background

This study is a part of a multi-year project in Orange County, California in collaboration with the Natural Communities Coalition, a non-profit organization, to develop recreation management strategies for city, county, and state PPAs in Orange

County that integrate the ecological and social dimensions of outdoor recreation into a landscape-scale Habitat and Conservation Plan ("Recreation Management", 2019). Mountain biking is a popular use-type in these PPAs, particularly because of the temperate climate of Southern California, which allows for year-round use.

In the initial scoping for this project, managers indicated visitors were concerned by what they perceived as aggressive mountain biking behavior, which was corroborated by responses from a 2017 survey when visitors were asked what detracted their experience (Sisneros-Kidd et al., 2019). Additionally, among smartphone apps visitors used during their visit to a park, *Strava* was the fitness-tracking app with the highest reported frequency of use. Considering these factors, and informed by a review of the literature that provides empirical support for the effectiveness of gamification techniques to change behavior and the importance of visitor characteristics to understand park behavior and perceptions of ecological impacts, prompted interest to evaluate the effects of *Strava* use on mountain bike behavior and perceptions.

5.2. Research Questions

R.Q. 1 How does the use of Strava affect evaluations of social and management conditions, ecological knowledge, and perceptions of recreation impact?

R.Q. 2 How does the use of Strava affect mountain bike behavior on trails and spatial use of Orange County PPAs?

5.3. Methods

5.3.1. Data Collection Methods

In order to answer the research questions, a paired survey and GPS-tracking methodology were employed in May of 2018. A stratified, random sample of visitors were invited to participate in the study by completing a post-experience survey and visitors whose primary activity types was mountain biking were asked to carry a GPS unit with them during their visit.

The survey instrument (see Appendix A) asked visitors about demographic characteristics, primary activity, and the frequency they participate in the activity, knowledge of park rules about off-trail behavior, knowledge of Leave-No-Trace, local ecological knowledge and their perceptions of the ecological impact of their activity and other activity-types. An additional set of questions were asked only to mountain bikers, including evaluations of management and trail conditions, conflict with other visitors, and if the presence of the GPS unit affected their activity. Finally, visitors were asked how they used their smartphone during their visit. If a visitor selected, "Used *Strava",* they were asked follow up questions which included the frequency they use the app and their primary reason for using the app.

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CHAPTER 2

KUDOS & KOMS: THE EFFECT OF STRAVA USE ON EVALUATIONS OF SOCIAL AND MANAGERIAL CONDITIONS, PERCEPTIONS OF ECOLOGICAL IMPACTS, AND MOUNTAIN BIKE SPATIAL BEHAVIOR

Abstract

The use of social media and self-tracking smartphone fitness applications (apps) like *Strava* is becoming an increasingly pervasive phenomenon in outdoor recreation experiences in parks and protected areas (PPAs). Concurrent in recreation research studies is the use of smartphone GPS tracking (SGT) and volunteered geographic information (VGI) data to study visitor behavior. However, limited research has critically addressed the biases of these data or evaluated how attitudes and behaviors may differ for visitors when smartphone fitness tracking apps are a focus or mediator of the recreation experience. This study draws from a survey of visitors and global positioning system (GPS) tracking of mountain bikers to understand the effect of *Strava* use on perceptions of ecological impacts, evaluations of social and managerial conditions, and mountain bike spatial behavior. *Strava* users were found to have different levels of ecological knowledge and perceptions of social, managerial, and ecological impacts, and trail behavior than counterparts of the same activity type who do not use the app. However, these differences were more pronounced between activity types in this study than between *Strava* users and those who not use the app.

Keywords: *Strava*, gamification, recreation, spatial behavior, self-tracking

1. Introduction

The continually evolving nature of technology and its effect on how visitors behave in PPA settings often outpaces recreation research's understanding of its effect on visitor attitudes and behavior and leaves PPA managers to adapt visitor management strategies in response to changing patterns of visitor use and behavior (Martin, 2017). While smartphones and connected devices like smartwatches offer many benefits and utility to users, emerging research suggests they may affect how visitors interact with the natural environment (Pohl, 2006; Martin & Pope, 2012).

Strava, Swedish for "strive", is a social fitness tracking app that allows users to record and share their recreation activities, like bike rides or runs, with a network of other users on the platform. Among fitness tracking apps *Strava* seems to stand atop the podium with 42 million registered users globally, adding an additional million users each month (Lindsey, 2019). These app users have recorded than 13 trillion data points from more than 2 million activities per week ("Strava Labs," 2018). According to Lindsey (2019), although Strava was neither the first fitness app nor has the largest number of users, features such as the Segment Leaderboard and integrated social-network platform distinguish the app from others in the fitness app category which has resulted in a dedicated following of users.

Concurrently, research in public health and digital media is exploring the effect of smartphones, smartwatches, and how the fitness-tracking applications (apps) they interface with, such as *Strava*, afford users the ability to self-track, monitor, and optimize their activity while receiving feedback from other users (Lupton, 2016; Stragier et al., 2016; Stragier et al., 2018; Barratt, 2017; DiClemente et al., 2001). Findings from this

research indicate that social network platforms function as feedback mechanisms and provide motivation for increased physical activity or behavior change and lead to better health outcomes. However, how these feedback mechanisms affect attitudes towards ecological resources and visitor behavior in PPA settings is not well understood.

The use of smartphone GPS tracking (SGT) and volunteered geographic information (VGI) data collected from users of these platforms has proliferated in recreation literature as a cost-effective method to gather data on visitor behavior (Campelo et al., 2016; Korpilo et al., 2017; Korpilo et al., 2018; Leggett et al., 2017.; Muñoz et al., 2019; Norman & Pickering, 2017; Wolf et al., 2014). However, limited research has explored the representativeness of the population and how users of these fitness tracking apps may be different from visitors to PPAs who do not use these apps.

GPS tracking has been demonstrated to be a useful tool to determine density and patterns of visitor spatial use of PPAs (Hallo et al., 2004; Taczanowska et al., 2008) and to inform management of the relationship between patterns of visitor spatial-use and extent of ecological resource impacts (D'Antonio & Monz, 2016; D'Antonio et al., 2010; Riungu et al., 2018; Stamberger et al., 2018). The validity of spatial data have been evaluated to provide adequate resolution to study visitor behavior at both the park level and at small spatial scales (Bauder, 2015; Hurst & Sinclair, 2013; Varley et al., 2012; Witte & Wilson, 2004). When paired with contextual information from survey research, GPS tracking can link the social and human dimensions of spatial-behavioral use of PPAs to the practical implications of ecological resource impacts (D'Antonio et al., 2012; Stamberger et al., 2018; Kidd et al., 2018).

The focus of this study is to understand biases associated with the use of the

fitness tracking app *Strava*, and how use of the app affects evaluations of trail and management conditions, perceptions of ecological resource impacts, and spatial behavior.

1.1. Smartphone Gamification & Technology Use Theory

Gamification, as defined by Deterding et al. (2011), refers to the use of game elements (i.e., leaderboards, points, badges, and “likes”) in non-game contexts, such as a recreation experience in a PPA. Further, Seaborn and Fels (2015) identify two components of gamification, "it is used for non-entertainment purposes, and it draws inspiration from games, particularly the elements that make up games, without engendering a fully-fledged game"(p.27). Gamification techniques have been applied in diverse contexts, including education, marketing, health, and social networks (Seaborn & Fels, 2015). As a result, a plurality of theoretical foundations has formed within research explaining the effects of gamification on behavior (Putz & Treiblmaier, 2015), but include the Theory of Reasoned Action (Fishbein & Ajzen, 1975), Theory of Planned Behavior (Ajzen, 1991), Social Learning Theory (Bandura & Walters, 1963)/ Social Cognitive Theory (Bandura, 1986) and Self-Determination Theory (Ryan & Deci, 2000). Nevertheless, while the understanding of how gamification works is still emerging, a growing body of literature provides empirical support for the effectiveness of gamification in achieving positive outcomes (Hamari et al., 2014), particularly in health and social network contexts (Seaborn & Fels, 2015).

Strava specific studies evaluating the effects of gamification are limited despite the fact that *Strava* features such as the leaderboard, which allows users to compete for the fastest time, badges, which reward users for completing challenges, and kudos, the *Strava* equivalent of a like on other social network platforms, are well established and

effective gamification elements (Sailer et al., 2013; Sailer et al., 2017; Weber et al., 2018). However, Barratt (2017) conducted semi-structured interviews to understand the effect of *Strava* use on the cycling experience and found that the social and competitive features of *Strava* add a new dimension to the mountain biking experience and that *Strava* users reported the app influences their spatial behavior.

The Technology Acceptance Model (TAM) (Davis, 1985) is an adapted theoretical framework from the Theory of Reasoned Action (Fishbein & Ajzen, 1975) that explains adoption of a new technology as a function of the user's attitudes, perceived utility or efficiency gains, and perceived barriers towards the technology. TAM remains a useful and well-cited theoretical framework in current research, but additional factors have been added to better explain technology use such as the hedonic value or enjoyment (van der Heijden, 2004), strong and weak social ties and motivations (Hossain & de Silva, 2009), and the utility of self-regulatory/self-monitoring (Stragier et al., 2016). Stragier et al. (2016) tested an adapted TAM in a structural equation model to understand which factors contribute most to habitual *Strava* use and found that for new *Strava* users (<1 year of use) the self-regulatory and enjoyment motives were most influential, but for habitual *Strava* user (>1 year) the self-regulatory motives remain significant but the social network aspects of *Strava* contribute to the enjoyment and habitual use of the app.

1.2. Integration of Smartphone Use and Recreation Behavior Theory

The recreation experience is broadly conceptualized as a multi-phase experience consisting of anticipation, travel-to, on-site, travel-back, and recollection (Clawson, 1963; Hammitt, 1980). *Strava* allows users to plan their experience by searching for trails and segments on a hosted map within the app, share their run or ride with other users, and

recall past experiences to relive the event. Research exploring the meaning of the self-tracking data that is created through lived experiences has found that it takes on a self-constructed meaning that allows users to recall and evaluate the outcomes of the experience (Lupton, 2018). According to Lupton (2018), *Strava* users perceive the data recorded through the app of their experience providing a more objective summary of their performance than their subjective assessment and sharing the experience on the social platform provides a sense of community with other users.

Recreation experiences in natural settings provide a range of benefits including mental restoration, personal development and learning, environmental stewardship, physical health and well-being (Holland et al., 2018) and provide increased self-control and a perception of slower pace of time (Berry et al., 2015). Nevertheless, with the increasing ubiquity of technology and smartphones interwoven and mediating recreation experiences (Martin, 2017) it is not well understood how these peripherals to the recreation experience affect these benefits and outcomes. However, research evaluating the effects of smartphones on cognition applying Construal Level Theory (Trope & Liberman, 2010) provide some insights. Norman et al. (2016) suggest smartphone use can increase psychological distance and abstraction to the physical surroundings, and the mere presence of a smartphone can decrease cognitive capacity and divert attention from a focal task (Ward et al., 2017). At the time of writing, no research has explicitly explored how smartphone use in natural settings may increase abstraction or psychological distance to the natural resource.

Limited research has specifically studied how cyclists and recreationists who self-track their activity interact with *Strava*. According to Smith (2014) and Barratt (2017),

the social network of *Strava* is an important feature to users that facilitates interaction, support and motivation, and a sense of community. Barratt (2017) also notes that *Strava* cyclists reported that the app influences their route choice, frequency, and the intensity of their ride. These individual perceptions of group behavior, or what everyone else is doing, are descriptive norms according to the Focus Theory of Normative Conduct (Cialdini et al., 1991; Kallgren et al., 2000). When *Strava* users plan their ride, a map provided in the app shows the locations of trail segments where riders can compete for the fastest time. However, *Strava* does not indicate to users whether these segments occur on formal or informal trails, and as a result, the app has the potential to influence descriptive norms of depreciative behavior such as off-designated trail use.

The Theory of Planned Behavior (TPB) (Ajzen, 1991; Fishbein & Ajzen, 2011) has been used extensively in recreation research to predict behavior based as a product of attitudes, subjective norms, perceived behavioral control and intentions, but moderated by social norms (Fishbein & Manfredo, 1992). A critique of TPB in PPA research is its limited effectiveness to predict and explain variation in visitor behavior (Miller, 2017), however recent focus in research has been directed towards understanding the characteristics of the visitor which can influence attitudes and behaviors (Beeco & Hallo, 2014) and perceptions of ecological impacts (D'Antonio et al., 2012; Monz, 2009). Recent research in PPA settings using TPB provides empirical support for the addition of social and personal factors to the theoretical framework, which includes descriptive norms of behavior that influence visitors spatial use of PPAs (Sisneros-Kidd, 2018).

1.3. Perceptions of Ecological Impact

All recreation use results in some level of ecological disturbance (Hammitt et al.,

2015). Within recreation ecology, there are two domains of research on how visitors perceive disturbances or impacts, and its effect on their experience, which have divergent conclusions. The first found that visitors form judgments of resource impacts that affect the quality of their experience (Lynn & Brown, 2003; Roggenbuck et al., 1993). This domain has become the focus of line of research to using a normative approach to determine these thresholds of impacts and provide managers with the relevant indicators to maintain resource conditions and the quality of the visitor experience (Manning, 2010). The second has found that visitors are most affected by unavoidable and noticeable impacts like litter and that some impacts are perceived as positive and provide an amenity value (Farrell et al., 2001; Monz, 2009). With respect to mountain biking, the second domain is supported by Symmonds et al. (2000) who found that impacts that recreation ecologists and land managers would identify - such as exposed roots and rocks from erosion, gullies, and presence of surface water - are perceived by mountain bikers to contribute positively to their experience. Limited research has explored how different use types perceive the ecological and resource impacts of their activity and other use-types. However, Pickering and Rossi (2016) operationalized social values as anthropocentric or ecocentric environmental values orientation and found mountain bikers were more ecocentric, similar to other non-motorized forms of recreation.

1.4. Mountain Biking Social Conditions and Ecological Impacts

As mountain bikes first began to interface with other traditional activity-types on trails in PPAs, land managers and the Sierra Club expressed concerns for social conflicts and the ecological impacts as a result of the new use-type (Sprung, 1997). Over time, these reactions to mountain biking have been in part ameliorated, informed by research

evaluating social conflicts (Ramthun, 1995; Ruff & Mellors, 1993; Pickering & Rossi, 2016), mountain biker trail preferences (Symmonds et al., 2000), and visitor management strategies (Chavez, 1993).

Mountain biking has experienced a steady increase in participation in the United States, growing 29% among young adults 18-24 and 12% for all age groups from 2007 to 2018 (Outdoor Foundation, 2018). Nevertheless, mountain biking remains a concern for land managers as dynamic advances in mountain bike technology and design change and increase the spatial and temporal range of terrain of mountain bikes. Fat tire mountain bikes which can extend the mountain biking riding season into winter, free-riding on the terrain without trails, and recent emergence of electric-assisted mountain bikes are just a few examples of the dynamic nature of spatial and temporal use-pattern trends of mountain biking that require proactive and evolving visitor management strategies.

Recreation research exploring conflicts between activity types has used two theoretical frameworks; Goal-interference (Jacob & Schreyer, 1980) and Social Values Conflict (Vaske et al., 1995). Some general themes that emerge from research applying Goal Interference framework are an asymmetrical attribution of conflict between hikers and mountain bikers (Mann & Absher, 2008; Ramthun, 1995) but perceived conflict higher than actual or observed conflicts (Cessford, 2003). Social-values conflict studies reach a similar conclusion, that although hikers are more likely to report social and interpersonal conflicts than mountain bikers (Carothers et al., 2001), their values orientations are relatively similar compared to the differences between non-motorized and motorized activity types (Rossi et al., 2015).

Concerning the ecological and resource impacts of mountain biking, a subset of

recreation ecology literature has specifically evaluated the recreation use impacts of mountain biking (Marion & Wimpey, 2007, 2017; Thurston & Reader, 2001; White et al., 2006). Thurston and Reader (2001) found that the extent and severity of mountain biking impacts to vegetation cover and species richness were not significantly different from hiking. Similarly, White et al. (2006) found that impacts to soil erosion, trail width, and depth did not significantly differ from hiking in five ecological regions of the Southwest United States. However, when trails occur are steep and aligned with the slope fall-line, the soil impacts are more acute and can accelerate erosion and soil displacement from mountain bike tire cornering and hard braking (Wöhrstein, 1998). Additionally, two significant ecological concerns related to mountain bike use are acknowledged in recreation ecology literature. First, the creation of informal trail features (ITFs) which include jumps, berms, and high-points (Pickering et al., 2010) ; second, non-designated or informal trails because these visitor created trails do not benefit from the sustainable design principles and ecological impact assessments that formal or designated trails receive.

Further, informal trails create additional ecological disturbance by increasing habitat fragmentation (Wimpey & Marion, 2011), reducing biodiversity and species richness (Fahrig, 2003), and when they transect ecologically sensitive habitat of species with small dispersal ranges the disturbance is more pronounced (Gutzwiller et al., 2017). Newsome and Davies (2009) suggest the creation and use of informal trails are a result of unmet demand for the trail type, terrain, style of riding, or challenge that visitors are seeking for their experience. Rice et al., (2019) demonstrated the effectiveness of using *Strava*'s web-based Heatmap to identify the location of informal trails in PPAs and the

examples provided, informal trail use by *Strava* users is more pronounced in settings with mixed and mountain bike only trail settings compared to running only. However, no research has specifically established a connection between *Strava* use and an increased probability of informal trail use, and the only studies that have evaluated the representativeness of *Strava* to broader populations have occurred in urban active-transportation and commuting contexts (Jestico et al., 2016). Further, the proportion of the Strava users that use informal trails is difficult to determine with the aggregated Heatmap data. Nevertheless, the gamification of the recreation experience in *Strava* to race on trail segments, which can occur on informal trails, and empirical evidence of the influence of descriptive on *Strava* users' behavior provide a basis for further exploring the relationship between *Strava* and informal trail use.

This study will explore the effect of *Strava* use on visitor's perceptions of management, social, and ecological evaluations of their park experience, and explore the effect of *Strava* use on spatial use of parks and mountain bike behavior.

2. Methods

2.1. Study Area

Orange County, CA is situated between the metropolitan areas of Los Angeles, CA, and San Diego, CA. The centrally planned development of former agricultural land and ranchos from Mexican Land Grants within the County created large open space parks and preserves that provide critical habitat for coastal migratory birds, as well as for fauna migrating between the coast and the interior Santa Ana Mountains. Additionally, this open space provides year-round recreation opportunities for the nearly 3.2 million residents of Orange County and neighboring communities (U.S. Census Bureau, 2019).

2.2. Study Sites

This study is a part of a larger multi-year project in Orange County, California in collaboration with the Natural Communities Coalition, a non-profit organization, to develop recreation management strategies for city, county, and state PPAs in Orange County that integrate the ecological and social dimensions of outdoor recreation into a landscape-scale Habitat and Conservation Plan ("Recreation Management", 2019). Four urban-proximate PPAs were selected for this study because of high-levels of visitation and mountain bike use (Peter's Canyon Regional Park, Aliso-Wood Canyons Wilderness Park/Top of the World, Whiting Ranch Wilderness Park, and Ridge Park/Crystal Cove State Park) (see Figure 1). Aliso-Wood Canyons/Top of the World are two entrances to the same PPA and are treated as one park in analysis. Similarly, Ridge Park/Crystal Cove State Park are adjoining open space areas but are managed by Orange County Parks and California State Parks, respectively.

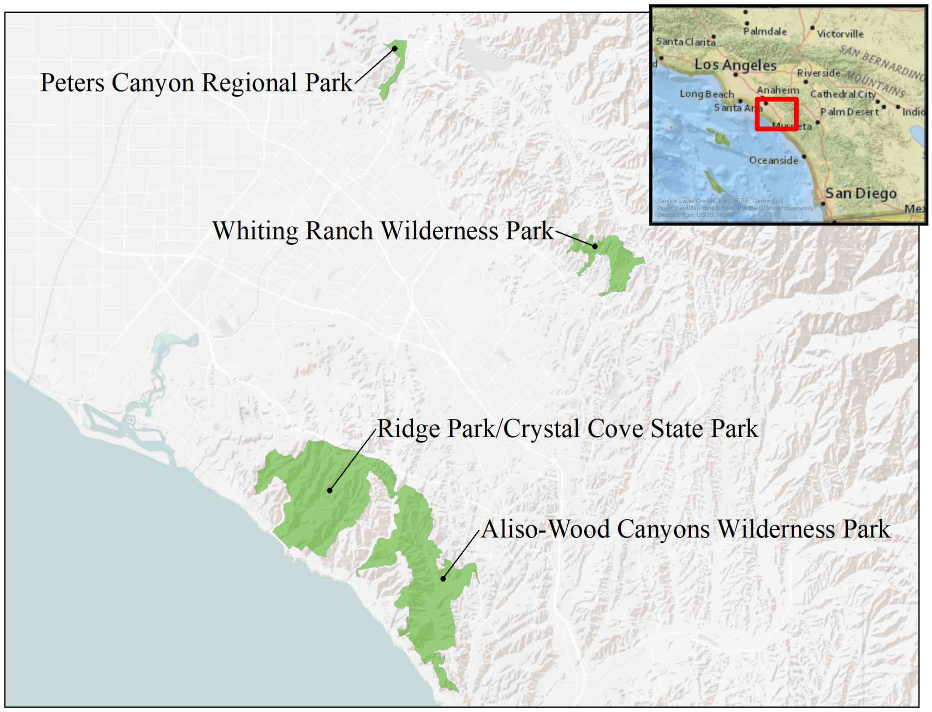


Figure 1: Map of locations of Orange County and California State PPAs in the study.

Two of the parks, Ridge Park/Crystal Cove State Park and Aliso-Wood Canyons Wilderness Park, are located near the Laguna Coast in the San Joaquin Hills, which feature ridge and canyon terrain in a mix of woodland, riparian wetland areas, and meadow landscapes. Whiting Ranch Wilderness Park and Peter's Canyon Regional Park are inland on the wooded foothills of the Santa Ana Mountains. These parks vary in size from 86 ha to 655 ha. The temperate climate of Southern California allows for recreation year-round, with parks closing only during and after significant rain events to prevent erosion of the sandy soil substrate. Many of the parks in this study provide day-use only access for recreation, Crystal Cove State Park provides backcountry camping for overnight use. Motorized use is not permitted in these parks; however, many of the trails within the parks are former ranching roads that are now wide multi-use trails.

2.3.Data Collection

Visitor surveys and GPS tracks were collected in May of 2018. Sampling in each PPA was stratified during weekdays and weekends, multiple entrances to parks, and began when the park opened at either 6:00 am or 7:00 am until approximately 5:00 pm or 6:00 pm. Visitors were intercepted at randomly selected minutes on the hour throughout the sampling period as they entered the park and were invited to participate in the study by completing a post-experience survey. Only visitors whose primary activity was mountain biking were asked to carry a GPS unit (Garmin eTrex 10).

The survey asked socio-demographic information including age, education, and gender identity as well as how frequently they participated in their primary activity (*1=<10 days/year, 2=11-25 days/year, 3= 26-50 days/year, 4= 51+ days/year*) and a self-evaluation of skill or experience level (*1= beginner, 5=expert*). Visitors reported their self-rated local ecological knowledge of natural history and ecological knowledge topics relevant to Orange County PPAs on a three-point scale (*1= no knowledge, 2= somewhat familiar, 3= well informed*) and their knowledge of Leave-No-Trace minimum impact practices from (*1=no knowledge, 6= extensive knowledge*). Visitor perceptions of ecological impacts were assessed on a five-point Likert-scale (*1= no impact, 5= extreme impact*) for common activity types and depreciative behavior in parks including hiking, hiking off-trail, mountain biking, mountain biking off-trail, bird watching, camping, dog walking, horseback riding, and photography. Additionally, visitors were asked about their evaluations of management conditions such as "there are enough trails signs", "there are enough rules", "there are enough trails" on a 5-point Likert-scale (*1=strongly disagree, 5=strongly agree*). Finally, whether the participants were concerned by social conditions

such as "*too many people/large groups*", "*too much noise*", and experiential trail "*too much horse/dog manure*", "*trails too eroded/wide/narrow*", "*litter on trails*", "*informal trails*", "*trails that don't go places I want to go*", and "*trails too difficult/steep*" was asked on a five-point Likert-scale (*1=not a problem at all, and 5=extreme problem*).

Visitors whose primary activity was mountain biking were asked an additional series of questions assessed using a five-point Likert-scale (*1= strongly disagree, 5= strongly agree*) to understand if the trail conditions provide enough challenge, satisfy their riding style, whether the trail quality is satisfactory, and whether they experience conflict with other use-types within the park. Visitors who indicated they use Strava in the survey were asked an additional set of questions; how frequently they use Strava (*1= never, 5= always*) and a list of reasons for using Strava with the option of an open-ended response.

GPS units were programmed to record the visitor's location every 10 seconds to balance the resolution of their behavior and the size of the dataset. In cases where a mountain biker did not have a backpack or pocket to carry the unit, researchers provided tape to affix the unit to the handlebars or top-tube of the bike. All GPS units were returned to researchers.

2.4.Data Processing and Analysis

2.4.1. Survey Data

Survey responses were collected through Qualtrics (Qualtrics, Provo, UT 2019), processed using Microsoft Excel (Microsoft Corporation, Bellevue, WA 2019), and statistical analysis was carried out in SPSS (v. 25, IBM Corp., Armonk, NY 2017). All GPS tracks and spatial analyses were performed in ArcMap (v.10.6, Environmental

Systems Research Institute, Redlands, CA 2018).

Visitors were asked how they used their smartphones during their visit, and if they selected "Used *Strava*" a follow-up question asked them how frequently they use the app. Valid responses from visitors who did not use Strava were coded into a new Strava use frequency variable as "Don't use *Strava*". Scores for visitors' self-reported knowledge of natural history and ecological topics were summed into a single local ecological knowledge variable. Additionally, visitor activity type and whether they use *Strava* were combined into a single variable (i.e. Mountain biker, Strava Mountain Biker, Runner, Strava Runner, etc.) to analyze local ecological knowledge, Leave-No-Trace practices, perceptions of ecological impact, and social and managerial conditions to understand differences in responses based on activity type and *Strava* use. Because dog walking and "other" activity types were underrepresented in the sample, they were excluded from analysis. The summed local ecological knowledge variable and perceptions of ecological impacts from recreation were assessed for consistency using Cronbach's α. In order to satisfy the assumptions of the analysis, survey variables were tested for normal distributions using Shapiro-Wilk W-test at the $p<.05$ level. Apart from age, the assumption of normal distributions was not met for all variables, and non-parametric Mann-Whitney U and Kruskal Wallis-H tests were selected for the analysis.

2.4.2. Spatial Data

All GPS tracks were projected in California State Plane Coordinate System Zone 6 ("NAD83(2011) / California zone 6—EPSG:6425", 2019) and processed to remove points where the GPS unit was given to the visitor and returned to researchers to include only points of the visitor's movement. A unique alpha-numeric code provided the ability

to link survey responses to mountain bike GPS tracks and to determine whether a mountain biker used *Strava* and to form *Strava* and Non-*Strava* groups from the sample for this comparative analysis. Velocity was calculated for each point within a track from projected (X,Y) coordinates and timestamps within the attribute tables stored in the GPS track.

In order to compare behavior between *Strava* and Non-*Strava* mountain bikers, trails were identified based on the sample size from the park and relatively even proportions of use between *Strava* and non-*Strava* users and selected for analysis between the groups. Peter's Canyon Regional Park had very few mountain bike tracks and a low proportion of Strava users, so it was excluded from this comparative analysis. Eight trails were then selected by searching for *Strava* segments ("Segment Explore | Strava", 2019) within these parks where users compete for the fastest times. Three trails from Aliso-Wood Canyon (Wilderness Park, Cholla, Mathis, and Meadows) and Ridge Park/Crystal Cove State Park (Lizard, Old Emerald, and Willow) and two from Whiting Ranch (Borrego-Mustard-Dreaded Hill and Cactus Hill) were selected. Data for trail segment velocity were collected by creating a 5-meter buffer around the aforementioned trails' centerline from a shapefile provided by Orange County Parks to filter out erroneous GPS points (Bauder, 2015). Velocity values for these trail segments below 0.5 m/s, which was determined by the author as the slowest speed possible to remain moving while still upright on a bicycle, were filtered out from the dataset and analysis to remove the effect of stopping behavior where it was present. Trail velocities did not meet the assumption of normality, and because there was an interest in evaluating the full variation in the data beyond the central tendency, non-parametric Mann-Whitney U tests were

selected to determine if there were differences in the distributions between *Strava* and non-*Strava* mountain bikers.

Maximum, median, and mean velocities for each of the 244 GPS tracks were calculated and associated with the unique survey alpha-numeric code to predict these aggregate measures of velocity from whether a mountain biker used *Strava*, their self-reported skill or ability level, frequency of *Strava* use, and a dummy variable for the park where the GPS track was recorded. Initial exploratory analysis plotting the dependent velocity variables indicated they did not follow a normal distribution. Distributions of maximum and mean velocity were very left-skewed but median velocity somewhat closer to a normal distribution but still slightly left skewed. A log-transformation was chosen to resolve this issue and applied to all three velocity variables to maintain consistency across our dependent variables in the analysis and make interpretation across the models more straightforward. Visual inspection of QQ-plots and histograms of the residual values of the log-transformed dependent variables indicated that the model satisfied the assumption of normal distribution of residuals and numerical tests confirmed the models did not indicate any concerns with multi-collinearity of predictors.

Finally, in order to understand differences in spatial use of parks a kernel density analysis was conducted to visualize patterns of use between *Strava* and non-*Strava* mountain bike GPS tracks. Additionally, a buffer analysis was conducted on known informal trails within the study areas to understand if *Strava* use has an effect on informal trail use.

3. Results

The response rate for the survey was 72% with 977 usable survey responses and

82% for GPS tracking, which resulted in 244 usable GPS tracks (Strava n=110, non-Strava n=127). Approximately 10% of the total sample of mountain bikers did not have a GPS track associated with their survey response either from refusing to carry a GPS unit or because there were no GPS units available. A Mann-Whitney U test was run to determine if there were differences between *Strava* and non-*Strava* users in education, gender, experience level, activity frequency and an independent samples T-test run for age among mountain bikers and all activity types, (Table 1).

Among all activity types, distributions were similar for age and education but different for gender, activity use frequency, and experience level. With respect to gender identity, 22.5% of *Strava* users identify as female compared to the 44.5% of non-*Strava* users, U=49,274.5,z=-4.667,p<.001. *Strava* users tend to participate more frequently (i.e., days per year) in their primary activity (Mdn= 4) than non-*Strava* users (Mdn = 3), U=84,409.5, z=6.206, p<.001. Finally, *Strava* users tend to have a higher self-reported experience level in their primary activity (Mdn=4)compared to non-*Strava* users (Mdn=3), U=78,663.5, z=5.043, p<.001. Among mountain bikers, responses were similar between groups for all variables except activity use frequency, where *Strava* mountain bikers reported more frequent participation days per year than mountain bikers who do not use *Strava*, U=9316, z=2.043, p=.042.

Table 1: Descriptive characteristics of *Strava* and non-*Strava* visitors.

	All Activity Types				Mountain Bikers			
	Non-*Strava* *n=797*	*Strava* *n=156*	Test Statistic		Non-*Strava* *n=145*	*Strava* *n=114*	Test Statistic	
Age			t	df			t	df
Mean	42.6 (15.25)	43.8 (10.94)	-0.906**	944	47.05 (11.84)	44.4 (10.99)	1.804	246
Highest Level of Ed.			U	z			U	z
<High School	0.0%	0.0%			0.0%	0.0%		
Some H.S.	0.5%	0.7%			0.7%	0.9%		
H.S. Grad	6.2%	2.6%			9.8%	3.6%		
Voc./Trade Cert.	1.9%	7.9%			3.5%	9.1%		
Some College	13.3%	15.2%			14.0%	15.5%		
Two Year College	7.8%	8.6%			5.6%	10.0%		
B.A./B.S.	43.1%	41.1%			45.5%	38.2%		
M.S./Graduate	17.4%	15.9%			11.9%	16.4%		
Ph.D., M.D.,J.D	9.8%	7.9%			9.1%	6.4%		
Median	7.00	7.00	58,256.00	-1.302	7.00	7.00	7,725.00	-0.253
Gender Identity								
Male	55.2%	76.2%			86.5%	85.5%		
Female	44.4%	22.5%			13.5%	13.6%		
Other	0.4%	1.3%			0%	0.9%		
Median	1.00	1.00	49,274.00	-4.667**	1.00	1.00	7,847.50	0.270
Activity Use Frequency								
1-10	15.8%	5.8%			6.8%	5.3%		
11-25	15.7%	3.8%			8.2%	1.8%		
26-50	20.0%	16.0%			20.5%	17.5%		
51+	48.5%	74.4%			64.4%	75.4%		
Median	3.00	4.00	84,409.50	6.206**	4.00	4.00	9,316.00	2.032*
Experience Level								
Beginner	7.4%	0.6%			3.4%	0.9%		
Novice	13.2%	7.8%			7.6%	8.8%		
Intermediate	45.9%	40.9%			36.6%	40.4%		
Advanced	28.4%	37.7%			44.1%	37.7%		
Expert	5.1%	13.0%			8.3%	12.3%		
Median	3.00	4.00	78,663.50	5.043**	4.00	3.50	8351.5	0.155

Note: 1 *=p≤.05, **=p≤.001. Standard Deviations appear in parentheses below means.

Strava use is most frequent among mountain bikers, followed by runners and walkers (Table 2). *Strava* users who indicated in survey responses that their primary activity was dog walking, presumably use the app when they participate in some other activity type in the park.

Table 2: Activity-Type and Strava Use

Activity Type	n[1] (% of total N)	Number of *Strava* Users (n)
Walking	591 (59.3%)	15
Running	120 (12.0%)	22
Biking	260 (26.1%)	114
Dog Walking	14 (1.4 %)	3
Other	12 (1.2%)	2

[1]Total N=977

While *Strava* users represented only 15.9% of the total sample, those who do use *Strava* use it frequently. Further mountain bikers use *Strava* more frequently than other use types with approximately 41% of mountain bikers using *Strava* at least often or always (Table 3).

Table 3: Strava Use Frequency

How often do you use *Strava*?	All Activity Types n (Valid % of All Activity Types)	Mountain Bikers n (Valid % of Mountain Bikers)
Don't use *Strava*	695 (94.3%)	146 (56.2%)
Rarely	2 (0.3%)	2 (0.8%)
Sometimes	7 (0.9%)	6 (2.3%)
Often	12 (1.6%)	27 (10.4%)
Always	21 (2.8%)	79 (30.4%)

When *Strava* users were asked to select all of the primary reasons they have for using the app, 89.1% responded to tracking and analyzing fitness and performance, 48.7% to follow friends or groups on the app and share achievements, and 26.3% to compete against self and others (Table 4). Only eight *Strava* users selected the "Other" open-ended response, and of those three contributed text responses of their reasons which included "Track miles on various bicycles that I own", "mileage & elevation", and "Beacon service".

Table 4: *Strava* users' primary motivations for using the app

Primary Reasons for Using Strava	Valid %
To follow friends/group and share achievements	48.7%
To track and analyze fitness performance goals	89.1%
To compete against self and others	26.3%

Strava use among mountain bikers is also more prevalent in some PPAs than others. At Whiting Ranch Wilderness Park, *Strava* mountain bikers outnumber non-

Strava mountain bikers nearly 60:40, while in Peter's Canyon Regional Park *Strava* mountain bikers are a small minority (Table 5). Aliso-Wood Canyons Wilderness Park/Top of the World and Ridge Park/Crystal Cove State Park are popular mountain bike destinations, and proportion of *Strava* and non-*Strava* users is similar.

Table 5: *Strava* use among mountain bikers by Park

Park	Non-*Strava* n=146		*Strava* n=114	
	n	% by Park	n	% by Park
Aliso-Wood Canyons Wilderness Park/Top of the World	45	60.0%	30	40.0%
Ridge Park/ Crystal Cove State Park	46	56.1%	36	43.9%
Whiting Ranch Wilderness Park	29	40.3%	43	59.7%
Peter's Canyon Regional Park	27	84.4%	5	15.6%

3.1.How does the use of Strava affect ecological knowledge, and perceptions of recreation impact, and evaluations of social and management conditions?

3.1.1. Ecological Knowledge and Perceptions of Recreation Impacts

Reliability analysis of the visitors self-rated natural, historical, and ecological knowledge returned a high internal consistency (α=.95). A Kruskal Wallis-H test was run to determine if there were differences in local ecological knowledge between activity types and *Strava* use. Local ecological knowledge scores were different between groups $\chi 2$ (5)=32.793, p<.001 (Figure 2). Statistical significance of pairwise comparisons using Dunn's (1964) procedure was accepted at p=.003 . Walkers (mean rank=425.11) had significantly different and lower scores than mountain bikers (mean rank=548.25)(p<.001).

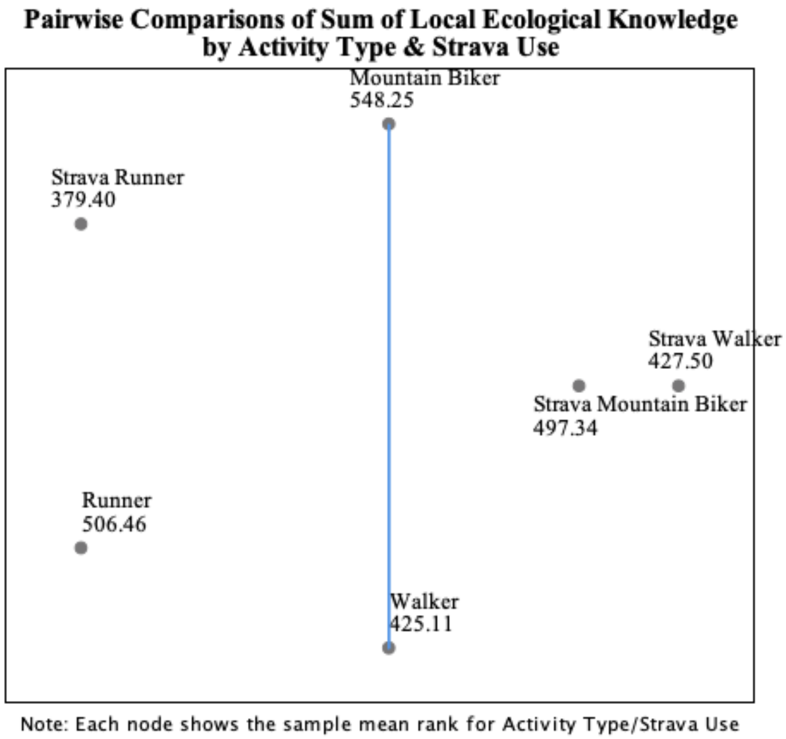


Figure 2: Results of Kruskal-Wallis pairwise comparisons for Local Ecological Knowledge Scores by Activity Type and *Strava* Use

A Kruskal-Wallis H test was run to determine if there were differences in visitors' self-rated knowledge of minimum impact Leave No Trace practices based on activity types and *Strava* use. Knowledge scores were significantly different between groups $\chi 2$ (5)=19.205, p=.002 (Figure 3). Statistical significance of pairwise comparisons using Dunn's (1964) procedure was accepted at p=.003. Again, walkers (mean rank=458.05) had significantly different and lower scores than mountain bikers (mean rank=536.59)(p=.002) and *Strava* mountain bikers (mean rank=556.96)(p<.001).

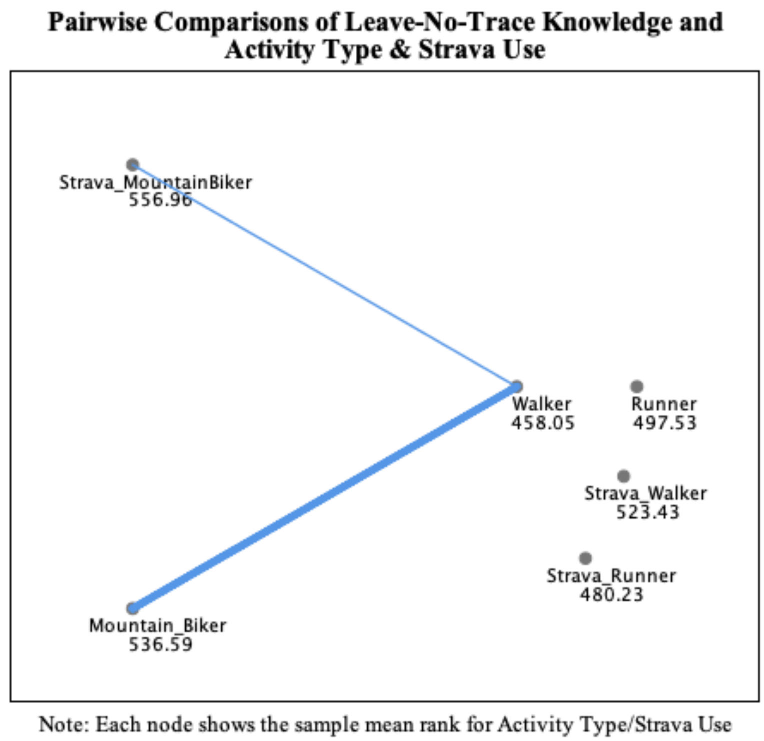


Figure 3: Results of Kruskal-Wallis pairwise comparisons for knowledge of Leave-No-Trace Practices by Activity Type & Strava Use

Reliability analysis of the visitors' perceived levels of the ecological impact of different activity types and depreciative behaviors returned a high internal consistency (α=.87). A Kruskal-Wallis H test was run to determine if visitors perceived the level of ecological impacts differently based on their activity type and *Strava* use. Mountain biking (on formal trails) $\chi 2$ (5)=51.820, p<.001 (Figure 4) and horseback riding $\chi 2$ (5)=15.682, p=.008 were activity types that visitors perceived different levels of impact., however for horseback riding there were no statistically significant pairwise comparisons using Dunn's (1964) procedure when significance was accepted at p=.003. For perceptions of mountain biking impacts, *Strava* mountain bikers (mean rank=370.95) had

lower scores than walkers (mean rank=519.54)(p<.001) and runners (mean rank=533.13)(p<.001). Similarly, mountain bikers (mean rank=396.54) scores were lower than walkers (mean rank=519.54)(p<.001) and runners (mean rank=533.13)(p=.001).

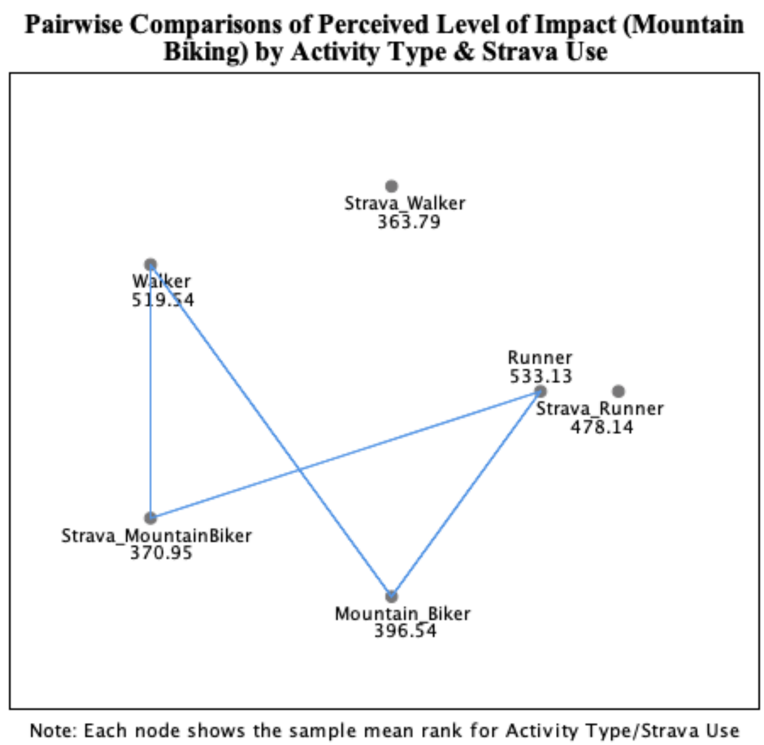


Figure 4: Results of Kruskal-Wallis pairwise comparisons for perceived level of ecological impact from mountain biking by activity type and Strava use.

Finally, A Mann-Whitney U test was run to determine if mountain bikers who used *Strava* and those that do not have differences in perceptions of the ecological impact of various activity types and depreciative behaviors and returned no statistically significant differences in perceptions between *Strava* and non-*Strava* mountain bikers. A Kruskal-Wallis H test was run to determine if there were differences in perceptions of ecological impact based on the frequency a mountain biker uses *Strava*. Distributions of

perceptions were dissimilar for camping $\chi2(4)=10.249$, p=.036, but there were no statistically significant between groups when statistical significance was accepted at p=.005.

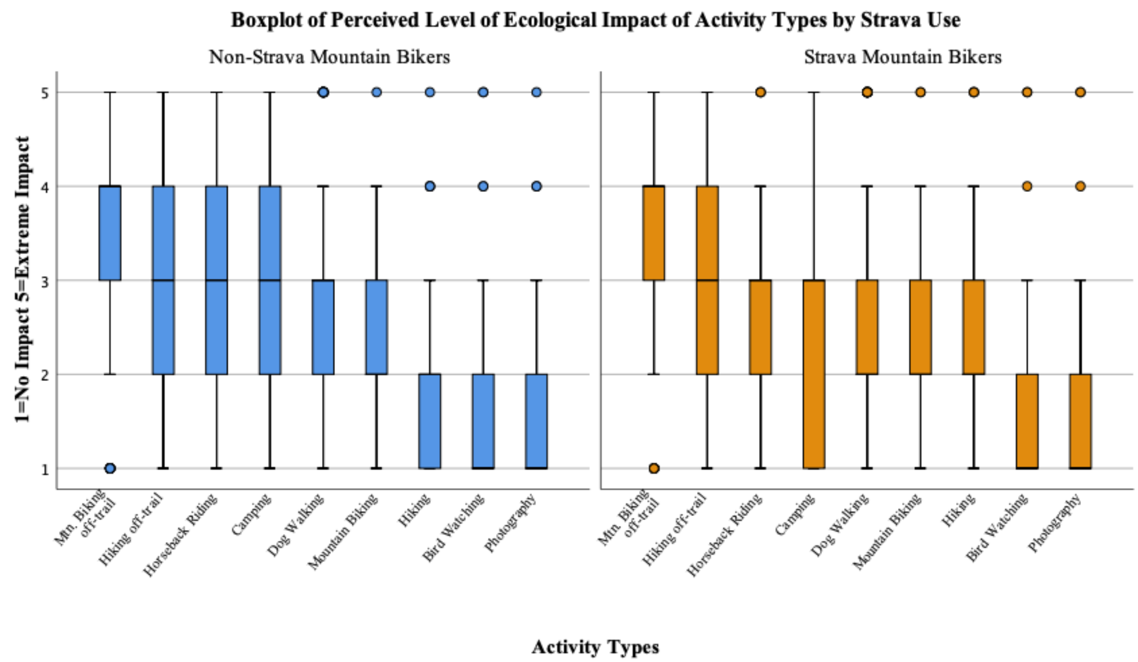


Figure 5: Boxplot of Mountain Bike Perceptions of Ecological Impact of Activity-Types

3.1.2. Social and Management Conditions

A Kruskal-Wallis H test was run to determine if there were differences in visitor evaluations of trail conditions and park management and their concerns for crowding, activity type conflict, visitor-related depreciative behavior and impacts based on their activity type and *Strava* use. Distributions were dissimilar for “There are enough trail signs” $\chi2$ (5)=11.474, p=.043, “There are enough trails” $\chi2$ (5)=50.668, p<.001, “There are too many people/large groups” $\chi2$ (5)=66.103, p<.001, “There are too many mountain bikers” $\chi2$ (5)=47.585, p<.001, and whether they evaluated “Informal trails (visitor created trails) as a problem $\chi2$ (5)=16.607, p=.005. Pairwise comparisons were

only significantly different for “there are enough trails”, “there are too many people/large groups”, and “there are too many mountain bikers” when statistical significance was determined using Dunn’s (1964) procedure at p=.003.

With respect to how much a visitors disagreed or agreed there were enough trails (Figure 6), mountain bikers (mean rank=402.54) had lower and different scores than walkers(mean rank=532.78)(p<.001), *Strava* runners (mean rank=615.86)(p<.001) and runners(mean rank=556.02)(p<.001). Similarly, *Strava* mountain bikers (mean rank=413.65) had lower and different scores than walkers (mean rank=532.78)(p<.001), *Strava* runners (mean rank=615.86)(p=.001) and runners (mean rank=556.02)(p<.001).

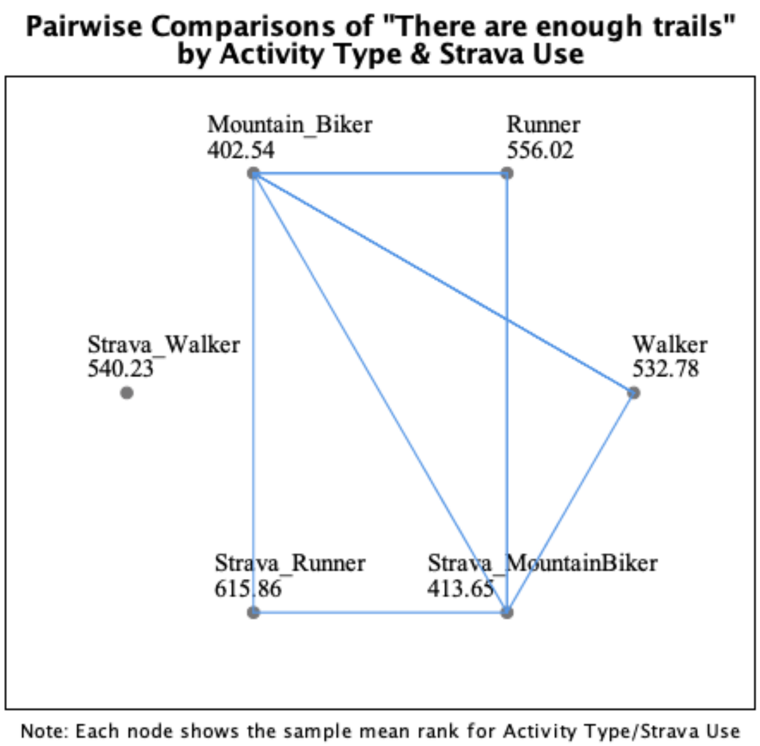


Figure 6: Results of Kruskal-Wallis pairwise comparisons for "There are enough trails" by activity type & *Strava* use

When visitors were asked how much they agreed or disagreed that there were too many people and large groups on the trails (Figure 7), mountain bikers (mean rank=612.92) had higher and significantly different scores than walkers (mean rank=457.93)(p<.001) and runners (mean rank=509.61)(p=.002). Strava mountain bikers (mean rank=619.35) had higher and significantly different scores than walkers (mean rank=457.93)(p<.001) and runners (mean rank=509.61)(p=.003).

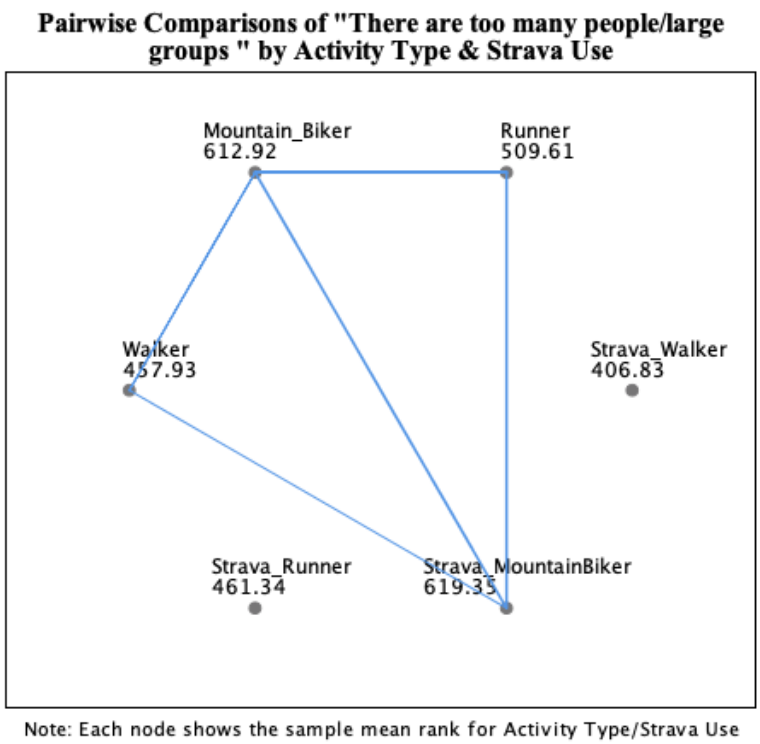


Figure 7: Results of Kruskal-Wallis pairwise comparisons for "There are too many people/large groups" by activity type & *Strava* use

When visitors were asked how much they agreed or disagreed that there were too many mountain bikers on the trails (Figure 8), mountain bikers (mean rank=420.66) had lower scores than walkers (mean rank=540.14)(p<.001) and runners (mean

rank=547.43)(p<.001). Similarly, *Strava* mountain bikers (mean rank=413.19) had lower scores than walkers (mean rank 540.14)(p<.001) and runners (mean rank=547.43)(p<.001).

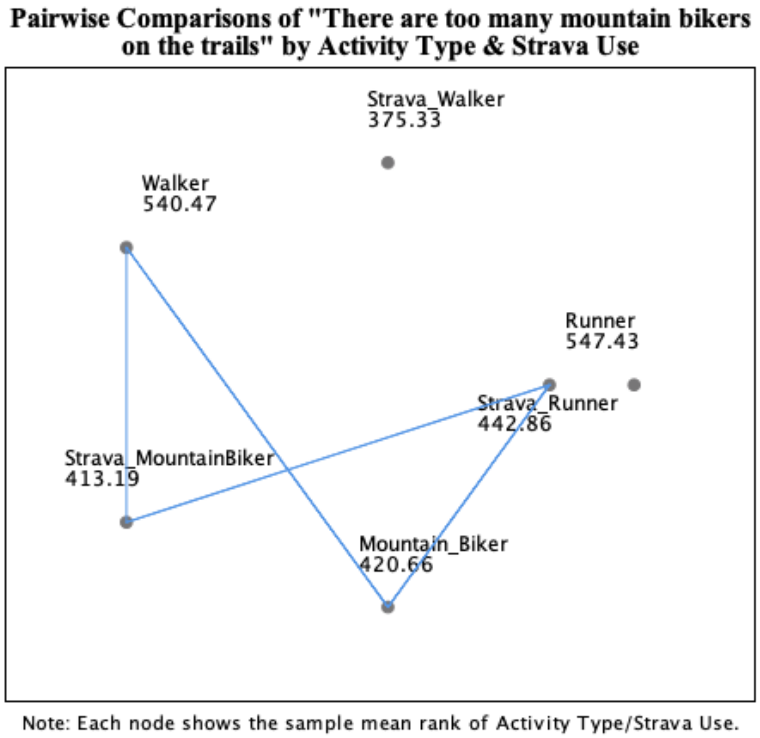


Figure 8: Results of Kruskal-Wallis pairwise comparisons "There are too many mountain bikers on the trails" by activity type & *Strava* use

The next set of questions were only asked to all mountain bikers in the study, whether they used *Strava* or not, to understand if responses vary between *Strava* and non-*Strava* mountain bikers when evaluating satisfaction with trail types “Trails provide enough challenge”/”Trails satisfy my preferred riding style” and conditions “Trail quality or condition is satisfactory” and if that may inform analysis of spatial behavior and informal trail use. Additionally, mountain bikers were asked if they experienced conflict with other bikers, other-non-bike visitors, or if other non-bike visitors had conflicts with

them. A Mann-Whitney U test was run to determine if responses to evaluations of trail types and conditions were different between *Strava* and non-*Strava* users, but the test returned no significant differences in responses for all questions (Table 6).

Table 6: Results of Mann-Whitney U test of mountain bike evaluations of trail and social conditions by *Strava* use

Survey Question	U	z	p
Trails provide enough challenge	8,462	1.099	.272
Trails satisfy my preferred riding style	8,758	1.434	.152
The quality/condition of the trails is satisfactory	8798.5	1.388	.165
Conflict with other bikers	7,553	-.916	.360
Conflict with other non-bike visitors	7,662.5	-.557	.557
Non-bike visitors have conflict with you	8,208	.289	.773

Subsequently, a Kruskal-Wallis-H test was run to determine if there are differences in the evaluations to these same questions based on the frequency that a mountain biker used *Strava* and returned non-significant differences in responses for all questions (Table 7).

Table 7: Results of Kruskal-Wallis H test of mountain bike evaluations of trail and social conditions by *Strava* use frequency

Survey Question	$\chi2$ (4)	p
Trails provide enough challenge	6.216	.184
Trails satisfy my preferred riding style	5.135	.274
The quality/condition of the trails is satisfactory	6.870	.143
Conflict with other bikers	5.269	.261
Conflict with other non-bike visitors	3.808	.433
Non-bike visitors have conflict with you	2.808	.590

Finally, mountain bikers were asked if they were aware of park rules about going off the designated trail, if they left the designated trail at any point during their visit and if the presence of the researcher's GPS unit affected their activity. A Mann-Whitney U test was run to determine if there were differences in responses between mountain bikers who used *Strava* and those who did not and returned non-significant differences in responses

for all questions (Table 8).

Table 8: Results of Mann-Whitney U test of mountain bike off-trail knowledge/behavior, and if GPS affected behavior by *Strava* use

Survey Question	U	z	p
To your knowledge does the park you are visiting have rules about visitors going off the trail?	7,842.5	-.592	.554
Did you go off the designated trail at any point during your visit?	7,989	-.082	.934
Did the presence of the GPS unit affect your activity?	8,358	.427	.670

Subsequently, a Kruskal-Wallis-H test was run to determine if there are differences in the responses to these same questions based on the frequency that a mountain biker used *Strava* and returned non-significant differences in responses for all questions (Table 9).

Table 9: Results of Kruskal-Wallis H test of mountain bike off-trail knowledge/behavior and if GPS affected behavior by *Strava* use frequency

Survey Question	$\chi2$ (4)	p
To your knowledge does the park you are visiting have rules about visitors going off the trail?	4.710	.318
Did you go off the designated trail at any point during your visit?	.573	.966
Did the presence of the GPS unit affect your activity?	3.336	.503

Table 10: Descriptive statistics of mountain bike off-trail knowledge/behavior and if GPS affected behavior by Strava use frequency

Survey Question	Yes (Valid %)	No (Valid %)	Unsure (Valid %)
To your knowledge does the park you are visiting have rules about visitors going off the trail?	84.7%	3.0%	12.3%
Did you go off the designated trail at any point during your visit?	2.6%	94.7%	2.6%
Did the presence of the GPS unit affect your activity?	4.8%	95.2%	-

3.2. *How does the use of Strava affect mountain bike behavior on trails?*

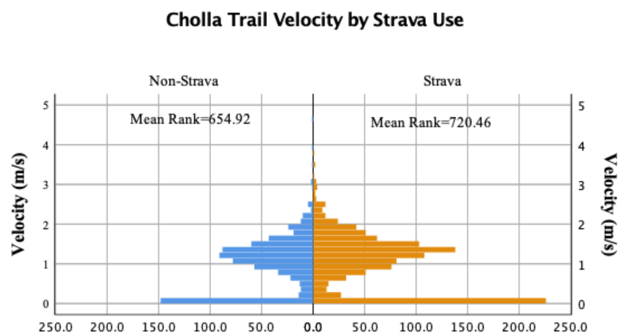
A series of Mann-Whitney U tests were run to determine if there are differences in velocity based on whether a mountain biker used *Strava* or not. Results from these

tests were statistically significant for seven of the eight trails (Figures 9 &10).

The *Strava* segments that were selected to compare trail velocity indicate the direction of travel along the trail that *Strava* users to compete for a position on the leaderboard. These segments represented uphill, downhill, and in some instances, segments were in both directions. When comparing the velocity distributions in Figures 9 and 10, where the distributions of velocity are relatively similar for the two groups it can be inferred that direction of travel was consistent between the two groups as is the case for Cholla, Mathis, Lizard, Willow, Borrego-Mustard-Dreaded Hill, and Cactus. However, when these distributions are very dissimilar, as is the case for Meadows and Old Emerald, the direction of travel is mixed within and between groups given the bimodal or inverse distribution of velocities. Results of the Mann Whitney U tests were statistically significant for Cholla, Meadows, Lizard, Old Emerald, Willow, Borrego-Mustard-Dreaded Hill, and Cactus Hill. Of the trails that had both similar distributions of velocity between the groups and statistical significance, *Strava* mountain bikers traveled faster than non-*Strava* mountain bikers on four out of five of these trails.

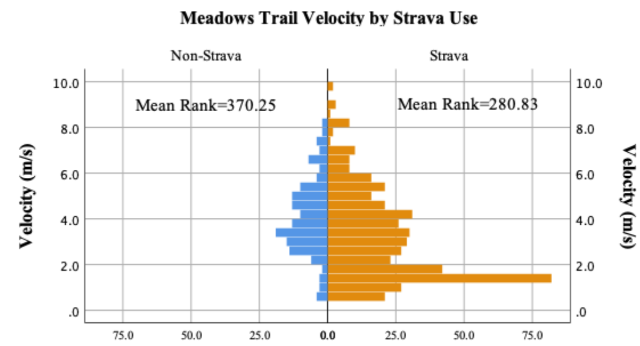
Aliso -Wood Canyon – Cholla

n=1387
U= 253,446
p=.003
z=2.99



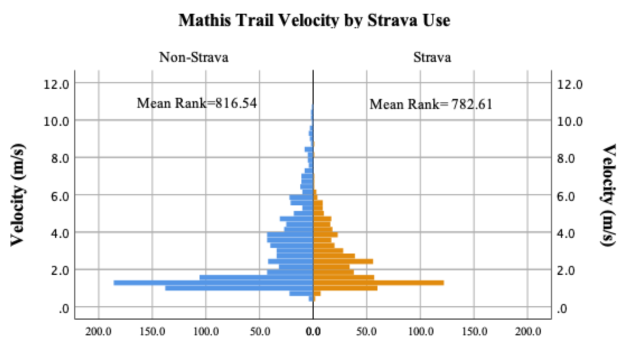
Aliso -Wood Canyon – Meadows

n=605
U=24,037
p<0.001
z=-5.433



Aliso -Wood Canyon – Mathis

n=1607
U=288,154
p=.157
z=-1.415



Ridge Park- Lizard

n=1370
U=204,499
p <0.001
z=-3.798

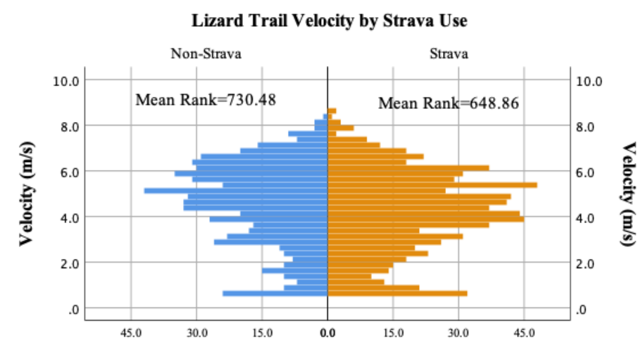
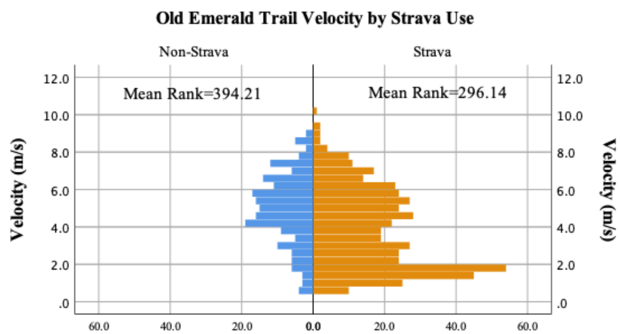


Figure 9:Trail velocity distributions between Strava and non-Strava Mountain Bikers

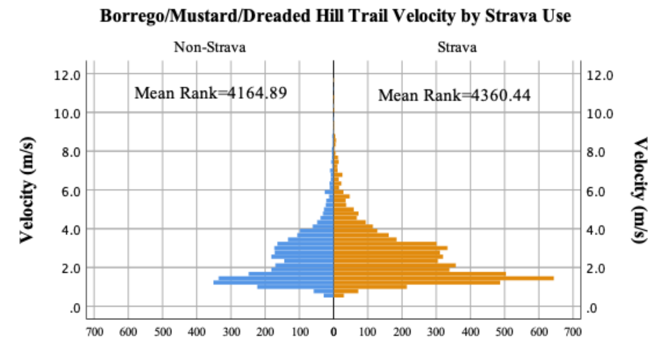
Ridge Park- Old Emerald

n=649
U=30,519
p=<0.001
z=-6.073



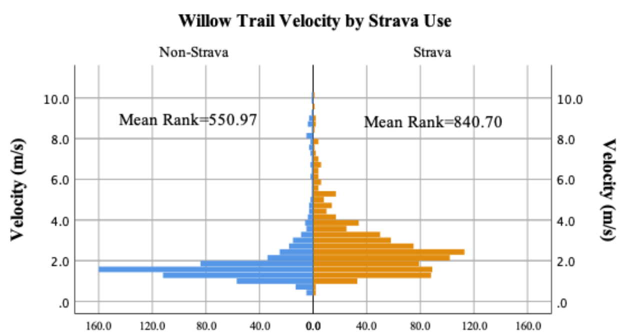
Whiting Ranch -Borrego/Mustard/Dreaded Hill

n=8576
U=8,941,619
p<0.002
z=3.527



Ridge Park-Willow

n=1445
U=352,806
p<0.001
z=12.963



Whiting Ranch – Cactus Hill

n=914
U=108,448
p=.001
z=3.37

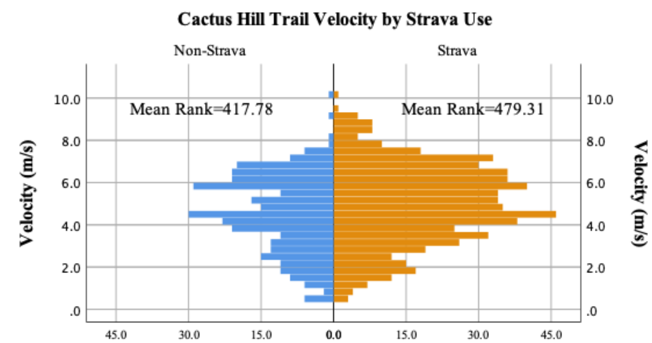


Figure 10: Trail velocity distributions between Strava and non-Strava Mountain Bikers

A multiple regression was performed to predict maximum, mean, and median velocity of GPS tracks from *Strava* use, experience level, the frequency respondents participated in their primary activity (activity days/year), and a dummy variable for the park where the GPS track was recorded. The survey asked visitors to self-rate their experience level, and the frequency they participated in their primary activity which measure different metrics of activity specialization so both measures were included in the regression model. Linearity was assessed by visual inspection of partial regression plots and homoscedasticity from scatterplots of studentized residuals against unstandardized predicted values. Independence of residuals were assessed using the Durbin-Watson statistic (maximum velocity=2.312, mean velocity=2.198, mean velocity=2.063). There was no evidence of multicollinearity in any of the three models, as assessed by tolerance and VIF values. Studentized deleted residuals were inspected to identify outliers, which returned two observations above 3.0 for maximum velocity and one observation for mean velocity which were ultimately retained in the final models. Finally, the assumption of normal distribution of residuals was met based on visual inspection of histograms and Q-Q plots. The multiple regression resulted in statistically significantly linear models for maximum velocity $F(8,232) = 9.583$, $p<.001$(Table 11), mean velocity $F(8,232)=5.439$, $p<.001$ (Table 12), and median velocity $F(8,232) = 5.064$, $p<.001$ (Table 13). These models were considered highly acceptable, explaining 24.8% of the variation in maximum velocity, 39.7% of the variation in mean velocity, and 38.5% of the variation in median velocity.

Table 11: Multiple regression of maximum velocity of mountain bike GPS tracks

Variable	*B*	95% CI *LL*	95% CI *UL*	*β*	t	*p*
Intercept	2.244	2.103	2.384		31.563	<.001
Activity Days/Year	.003	-0.028	0.035	.013	.219	.827
Experience Level	.052	0.021	0.083	.200	3.318	.001
Strava Use Frequency	.027	0.013	0.041	.222	3.710	<.001
Park = ALWO	-.215	-0.282	-0.149	-.422	-6.372	<.001
Park=TOWO	.022	-0.374	0.418	.006	.108	.914
Park=WHRA	-.148	-0.213	-0.083	-.300	-4.497	<.001
Park=PECA	-.123	-0.215	-0.032	-.170	-2.670	.008
Park=MORO	-.130	-0.364	0.104	-.064	-1.092	.276

Note: R^2 = .248 (N=241, p<.001), CI= confidence interval for *B*, *LL*= lower limit, *UL*=upper limit.

Table 12: Multiple regression of mean velocity of mountain bike GPS tracks

Variable	*B*	95% CI *LL*	95% CI *UL*	*β*	t	*p*
Intercept	.575	.385	.766		5.943	<.001
Activity Days/Year	.024	-.018	.066	.071	1.119	.264
Experience Level	.076	.034	.118	.226	3.546	<.001
Strava Use Frequency	.036	.017	.056	.232	3.675	<.001
Park = ALWO	.119	.029	.21	.182	2.596	.01
Park=TOWO	-.037	-.576	.503	-.008	-.134	.893
Park=WHRA	.061	-.028	.149	.096	1.356	.177
Park=PECA	.134	.012	.257	.146	2.158	.032
Park=MORO	-.057	-.376	.262	-.022	-.353	.725

Note: R^2 = .397 (N=241, p<.001), CI= confidence interval for *B*, *LL*= lower limit, *UL*=upper limit.

Table 13: Multiple regression of median velocity of mountain bike GPS tracks

Variable	*B*	95% CI *LL*	95% CI *UL*	*β*	t	*p*
Intercept	.258	-.032	.547		1.752	.081
Activity Days/Year	.028	-.036	.092	.055	.858	.392
Experience Level	.083	.019	.147	.163	2.553	.011
Strava Use Frequency	.051	.022	.081	.217	3.405	.001
Park = ALWO	.287	.149	.424	.289	4.105	<.001
Park=TOWO	.18	-.639	.999	.026	.433	.665
Park=WHRA	.084	-.051	.218	.087	1.227	.221
Park=PECA	.272	.086	.458	.196	2.881	.004
Park=MORO	.012	-.472	.497	.003	.051	.96

Note: R^2 = .385 (N=241, p<.001), CI= confidence interval for *B*, *LL*= lower limit, *UL*=upper limit.

3.2.1. How does Strava use affect visitor spatial use of parks?

A shapefile of trails within the PPAs provided by Orange County Parks was combined with a shapefile collected in 2019 during a trail assessment. These shapefiles indicated the location of known informal trails within the PPAs, which focused the analysis of informal trail use to Aliso-Wood Canyon Wilderness Park and Ridge Park/Crystal Cove State Park because there were no known informal trails in Whiting Ranch Wilderness Park. A 10m buffer was created around these informal trails to identify instances of informal trail use and Strava and non-Strava mountain bike GPS tracks were clipped to these buffer zones. Ridge Park/Crystal Cove State Park was the only PPA where mountain bikers left the formal trail, with one *Strava* mountain biker and three non-*Strava* mountain bikers' GPS tracks intersecting the 10m informal trail buffers. The *Strava* mountain biker and one of the non-*Strava* mountain bikers used a short 130m trail that shortcut a bend before returning to the formal trail. The *Strava* mountain biker had high scores for trail quality and satisfaction, but indicated they were unsure if they left the designated trail during their visit. The non-*Strava* mountain biker similarly had high scores for trail quality and satisfaction but indicated they did not leave the designated trail during their visit.

The other two non-*Strava* mountain bikers used two informal trails known as "Repoman" and "Marie Calendar". The "Repoman" trail user had high scores for trail quality and satisfaction, considered informal trail use to be an extreme problem, that the GPS unit did affect their activity, but did not report leaving the designated trail during their visit. The "Marie Calendar" trail user had high scores for trail satisfaction, considered informal trails not to be a problem, reported the GPS unit did affect their

activity, but also did not report leaving the designated trail during their visit. Figures 3, 4, & 5 display the Kernel Density of Strava and non-Strava mountain bike tracks overlaid on the formal trail network for each park. These Kernel Densities show relatively similar use patterns of low, medium, and high use-levels for both groups in each park.

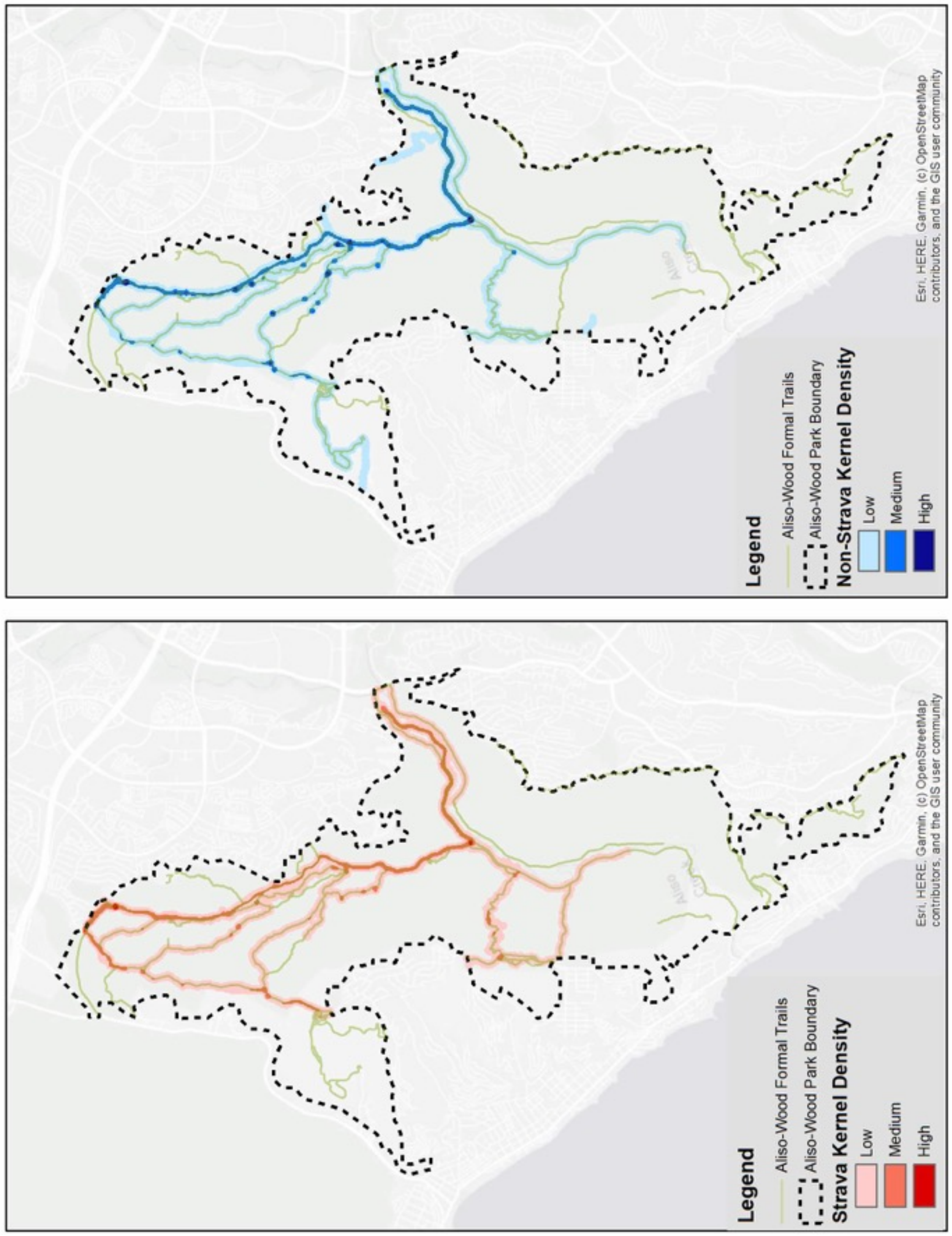
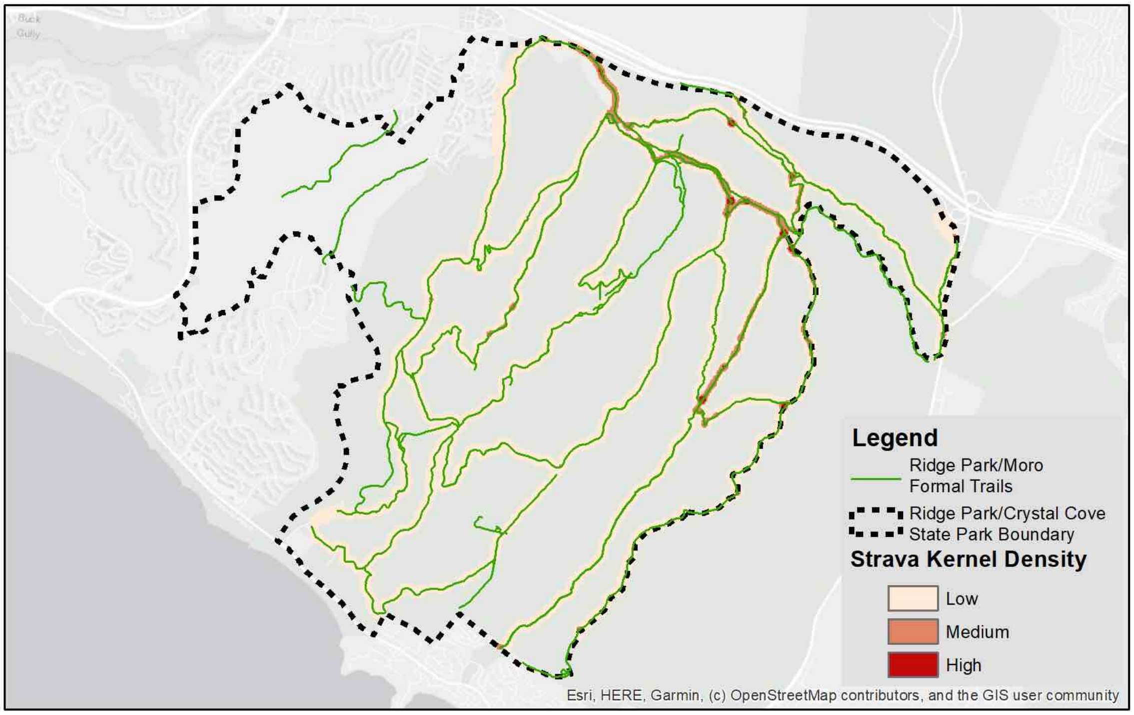


Figure 11: Aliso-Wood Canyons Wilderness Park Kernel Density of GPS tracks from Strava and non-Strava mountain bikers.



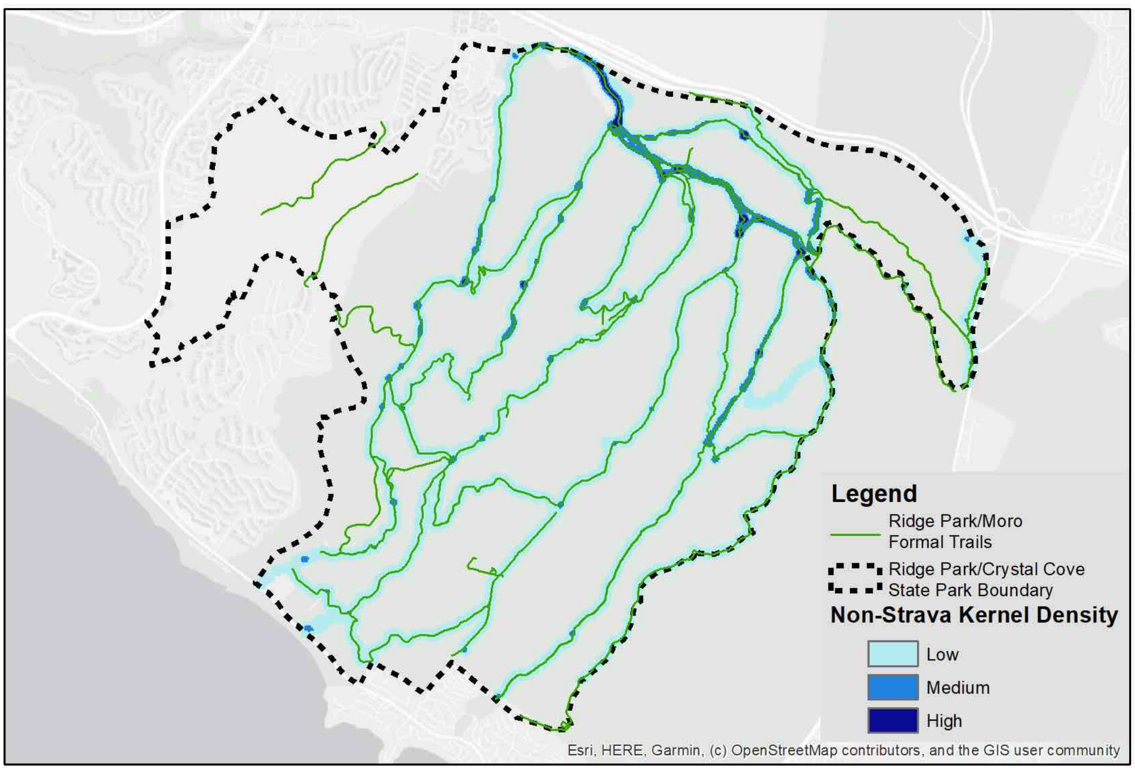


Figure 12: (Ridge Park/Crystal Cove State Park) Kernel Density of GPS tracks from Strava and non-Strava mountain bikers.

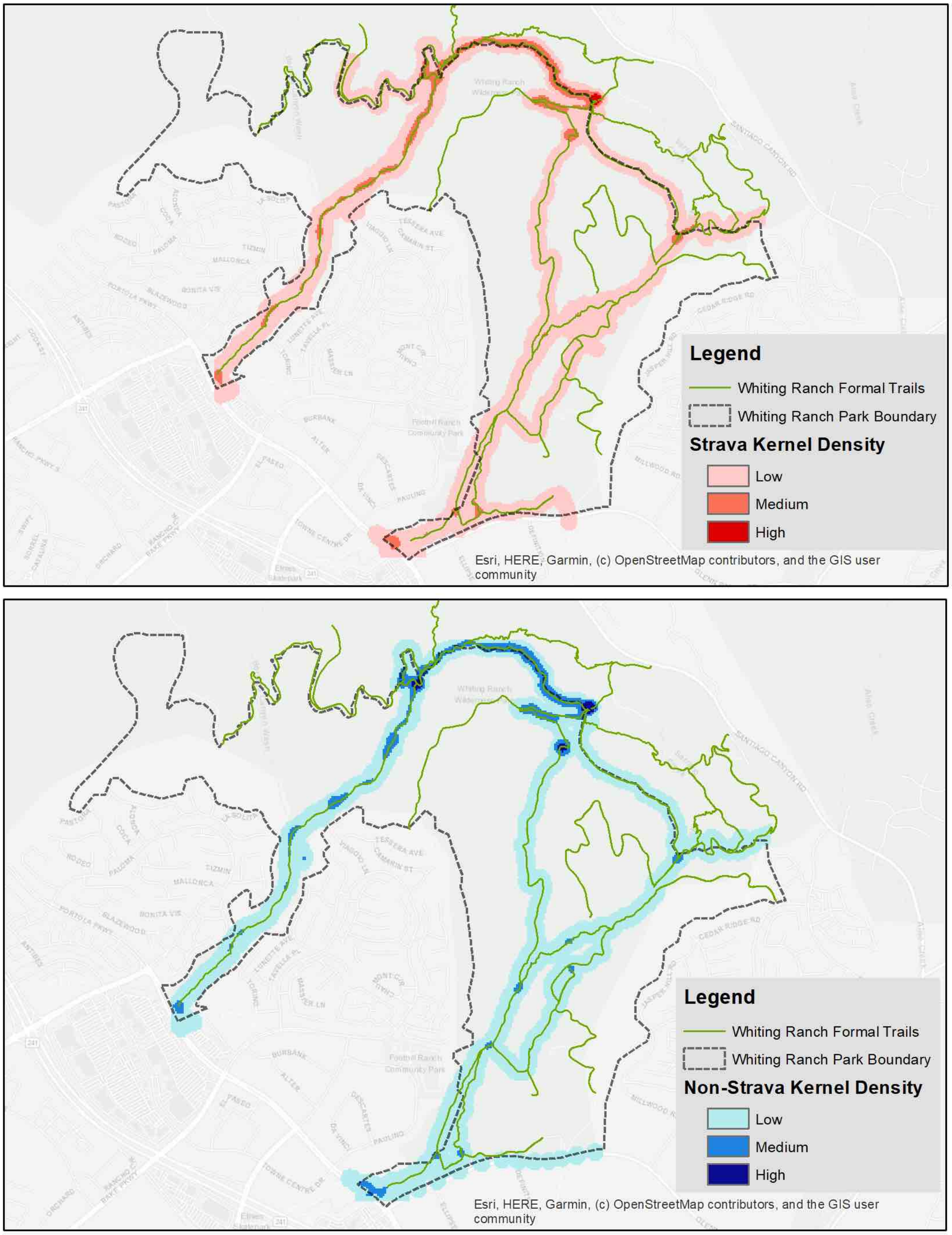


Figure 13: Whiting Ranch Wilderness Park Kernel Density of GPS tracks from Strava and non-Strava mountain bikers

4. Discussion

In both survey responses and GPS tracking, significant differences in *Strava* users' perceptions, attitudes, and spatial behavior were observed. Socio-demographic differences among *Strava* and non-*Strava* users are more pronounced when comparing *Strava* users against all use types. *Strava* users are more likely to identify as male, have higher activity specialization participating in their primary activity more frequently, and have higher self-evaluations of their experience level. Additionally, *Strava* use is more frequent among activity types like mountain biking and running, and less frequent for walkers or hikers. A trend across all survey responses was a high degree of similarity between *Strava* mountain bikers and non-*Strava* mountain bikers. Among mountain bikers, whether they use *Strava* or not, mountain bikers were generally college-educated, middle-aged males that are intermediate to advanced mountain bikers. These findings are consistent with other studies that have found a gender bias among cyclists (Barrie et al., 2019). Additionally, this corroborates with other survey research comparing mountain bikers with other use types that found mountain bikers to be a generally homogenous group (Pickering & Rossi, 2016). The only significant difference among *Strava* and non-*Strava* mountain bikers is the frequency at which they participate in the activity. Health and behavior studies have observed gamified *Strava* features and fitness apps like it to provide motivation to users and significantly increase the rate of physical activity of users and habitual use of these apps (Sailer et al., 2017; Weber et al., 2018). How representative this sample reflects the population of *Strava* users for these socio-demographic variables is difficult to determine because existing literature evaluating the similarity of *Strava* data to the broader population are limited to urban, active

transportation and communing contexts (Sunde, 2019; Whitfield, 2016).

Strava users' responses to the primary reasons for using the app compliment Stragier et al. (2016) where 89.1% of users in this study reported the self-regulatory motives to "track and analyze fitness performance goals" as most important to the 40.8% of habitual *Strava* users who use the app at least often or always. The next most frequent reason was the social motives to follow friends/group and share achievements (48.7%), which aligns with the Stragier et al. (2016) structural equation model and has been validated through qualitative research as an important feature of social fitness communities (Stragier et al., 2018).

The proportion of *Strava* use by PPA is generally similar for three of the PPAs in the study, Aliso-Wood Canyons Wilderness Park/Top of the World, Ridge-Park/Crystal Cove State Park, and Whiting Ranch Wilderness Park which are popular destinations for mountain bikers among Orange County open-space areas. Peter's Canyon had fewer mountain bikers overall and very few *Strava* users. Prior research of the larger project found demographic characteristics and motivations of visitors to Peter's Canyon to be significantly different from other PPAs sampled in 2017 (Sisneros-Kidd et al., 2019).

4.1. Ecological Knowledge and Perceptions of Recreation Impact

Mean ranks of local ecological knowledge between the same activity type were lower for all *Strava* users except *Strava* walkers who were very similar to walkers mean rank. However, the only statistically significant pairwise comparison between activity type mean ranks was between walkers and non-*Strava* mountain bikers. Pairwise comparisons of Leave No Trace knowledge by activity-type and *Strava* use were generally similar for walkers, runners, *Strava*-runners, and *Strava*-walkers but mountain

bikers and *Strava*-mountain bikers were significantly different than the other activity types. Taken together, *Strava* users tend to have less local ecological knowledge but their self-evaluations of their knowledge of Leave No Trace were higher than those who don't use *Strava*.

Interestingly, there was a high degree of similarity between all use types and whether a visitor used *Strava* or not in perceptions of ecological impact for five of the seven activity types and both of the depreciative behaviors of hiking off-trail and mountain biking off-trail. Mountain biking was the only use-type where pairwise comparisons were statistically significantly different, and all *Strava* users' perceptions of mountain biking impact were lower than their activity-type counterparts who did not use *Strava*. However, *Strava* and non-*Strava* mountain bikers' self-rated knowledge of local ecological knowledge and Leave-No-Trace practices were higher than all other groups and their evaluations of the ecological impact of their activity were lower than all other groups except for *Strava* walkers. Recreation ecology studies that have specifically evaluated mountain biking resource impacts to vegetation and soils (Thurston & Reader, 2001), trail conditions (White et al., 2006), and wildlife in these same parks (Patten & Burger, 2018) conclude that there is a similar level of ecological disturbance from mountain biking and many of the other activity types visitors evaluated. There were no statistically significant differences between *Strava* and non-*Strava* mountain bikers' perceptions of ecological impacts, but distributions of their perceptions for all activity-types indicate subtle differences. Median scores are generally similar between groups, but *Strava* distributions are dissimilar for horseback riding, camping, hiking. These perceptions are complex, subjective, and challenging to measure and compare results

between groups within the same study, let alone other studies without a standardized survey instrument. Nevertheless, these results are different from Symmonds et al. (2000), who found that mountain bikers perceived the impact of their use type to create significantly more ecological disturbance than walkers or hikers, but less than horseback riding and motorized use. Conversely, these results more closely align with Pickering and Rossi (2016), who measured perceptions differently, but found mountain bikers to be less sensitive to impacts of their activity-type and the impact of other activity-types. These results may suggest an additional nuance to the Farrell et al. (2001) and Monz (2009) framework of visitor characteristics and perceptions of resource impacts; that visitors may perceive the resource impacts of their activity as creating less disturbance than other activity types.

4.2. Social and Management Conditions

The contrasts in visitor evaluations of management of trail conditions require some context from the setting. Because many of these PPAs were formerly used for ranching, many of the trails in these PPAs were previously roads that have been adapted into wide, multi-use trails and single-track trails are less commonplace. While other use types and *Strava* users had high satisfaction with the trail infrastructure, which may be well suited for their use-type and desired trail experience, both *Strava* and non-*Strava* mountain bikers have lower satisfaction with number of trails in the parks. However, this study did not specifically explore the desired trail characteristics if a visitor was dissatisfied with the availability of experiences from the current trail network.

The mean ranks of visitor of perceptions of "too many people/large groups" indicated mountain bikers and *Strava* mountain bikers felt most strongly that there were

too many people on trails, followed closely by runners who do not use *Strava*. However, these perceptions should not be used as a proxy for an assessment of crowding or displacement, as there are more well developed, standardized, and robust normative and contingent evaluation methods used to assess these social dimensions of PPA. Additionally, these assessments of crowding must take into consideration a non-response bias of visitors who were already displaced if they felt the PPAs were too crowded.

Visitor perceptions of "too many mountain bikers on trails" clearly biases comparisons between mountain bikers and non-mountain bikers because other activity types were not framed in the same fashion to visitors as a problem or concern. Nevertheless, while the only significant differences were between *Strava*/non-*Strava* mountain bikers and walkers and between *Strava*/non-*Strava* mountain bikers and runners, all *Strava* activity-types had lower mean ranks than their non-*Strava* counterparts.

When survey analysis was focused to questions asked only to mountain bikers, there were no significant differences between groups with the dichotomous variable (*Strava*/non-*Strava*) or the ordinal variable *Strava* use frequency ("Don't use *Strava*" to "Always use *Strava*"). Nevertheless, in their assessments of trail types and conditions distributions for both *Strava* and non-*Strava* mountain bikers were skewed towards "strongly agree" that trails provided enough challenge, satisfied their preferred riding style, were satisfactory in quality and condition. When these assessments of trail conditions were analyzed by how frequently a mountain biker used *Strava*, the trends were consistent with the distributions of the dichotomous *Strava*/non-*Strava* variable.

When mountain bikers were asked if they experienced conflict with non-bike

visitors, distributions for both *Strava* and non-*Strava* mountain bikers were highly skewed towards "strongly disagree” and when asked if non-bike visitors had conflicts with mountain bikers, distributions were slightly less skewed but also trended towards "strongly disagree" for both *Strava* and non-*Strava* mountain bikers. When these assessments of conflict were analyzed by how frequently a mountain biker used *Strava*, distributions were bimodal with distributions similar for mountain bikers who "don't" and "always" use *Strava* reporting slightly higher perceptions of conflict than those who "rarely", "sometimes", or "often" used *Strava*. Because hikers or walkers were not asked how they perceive conflict with mountain bikers, there is no data to compare these attributions of conflict. Nevertheless, while the differences in the direction of conflict is subtle, these results are opposite of Mann & Absher (2008) and Ramthun (1995) who found hikers to attribute more conflict with mountain bikers than mountain bikers attribute to hikers.

Finally, there were no significant differences between *Strava* and non-*Strava* users or the frequency of *Strava* use in responses to knowledge of park rules about going off the designated trail, reporting off-trail behavior, and if the presence of the GPS unit affected behavior. While 84.7% were aware of park rules about going off-trail, 94.7% of mountain bikers reported they did not leave the designated trail during their visit. Finally, a sizable majority (95.2%) of mountain bikers responded that the GPS unit did not affect their behavior.

4.3. Trail and PPA Spatial Behavior

The most notable differences as a result of *Strava* use were in visitor behavior observed in the velocity along *Strava* segments and aggregate measures of velocity. The *Strava* segments selected to compare trail velocities provided a sample of trail types and when the direction of travel was consistent between *Strava* and non-*Strava* users, *Strava* mountain bikers traveled faster than non-*Strava* mountain bikers on four out of five of these trails. Further, results from the multiple regression indicate that *Strava* use was the most influential variable to predict maximum, mean, and median velocity aside from the park where the GPS track was recorded. Further, *Strava* use better predicts higher velocities of mountain bikers than their experience level or the frequency at which they participate in the activity.

The results of the analysis of off-trail use revealed only four of the 244 GPS tracks, three non-*Strava* mountain bikers and one-*Strava* mountain biker, used an informal trail and occurred in Ridge Park/Crystal Cove State Park. Of those four, all had high satisfaction with trail quality and conditions and none of the mountain bikers reported leaving the designated trail during their visit but in one case, reported being unsure. These results suggest that to mountain bike visitors, the status of whether a trail designated or not may be unclear which may account for the 4.2% of mountain bikers who reported they left the designated trail or were unsure but did not leave a designated trail when their GPS tracks were analyzed. It is not known if these trails had signage that indicated the closure or designation status, however even in National Park settings prominent trail signage can be inconspicuous to visitors (Kidd et al., 2015). Additionally, like other recreation studies that have used paired GPS and survey methods (D'Antonio et

al., 2010), there were discrepancies and inconsistencies in visitors stated versus actual behavior.

Nevertheless, while the number of visitors who used an informal trail was minimal, it raises the question of whether the GPS unit may have affected the trails and routes mountain bikers used during their visit particularly in the PPAs where the 2019 trail impact assessment showed signs of use on informal trails and where the *Strava* Heatmap was used to identify the locations of these trails. While GPS units have been used extensively in recreation research to understand visitor behavior, no studies have addressed an observation effect on visitor behavior. The mismatch in informal trail use on *Strava* Heatmap and the *Strava* users' patterns of use in this study presents some uncertainties about mountain bike users in this study. First, because mountain bikers reported that the GPS unit did not affect their behavior, this may indicate that there was a non-response bias for both *Strava* and non-*Strava* mountain bikers who mountain bike on informal trails to participate in this study. Alternatively, this may suggest the sample of *Strava* users was significantly different than the aggregated data on *Strava* Heatmaps. However, because of the random sampling visitor interception technique and high response rate the latter is unlikely and the *Strava* users in this study are likely the majority of *Strava* users whose PPA use is predominately limited to formal trails. Moreover, when the high degree of similarity between *Strava* mountain bikers and non-*Strava* mountain bikers survey responses are taken together, it suggests that *Strava* users may be no more predisposed to use informal trails than non-*Strava* users. Further, the proportions of informal use evidenced on the *Strava* Heatmap may reflect the proportion of the total population of mountain bikers that use informal

trails, and as Rice et al. (2019) suggest *Strava* Heatmaps can be a resource for managers of these PPAs to monitor informal trail use.

5. Conclusion

A limitation of this study was not using spatial data collected from the *Strava* app, and a significant assumption about *Strava* users in this study is that their behavior is consistent with PPA use while self-tracking their activity through the *Strava* app. However, the GPS units in this study provided a standardized instrument to evaluate spatial behavior and further analysis is necessary to compare these GPS tracks with aggregated *Strava* user data. The characteristics of *Strava* users in this study complement existing literature concerning gender bias, activity specialization and use frequency, and primary motivations for using the app. Survey responses indicate that *Strava* users have high levels of self-rated knowledge of local ecological knowledge but perceive the ecological impacts of recreation to be lower than those who don't use the app. While there are no studies that have explicitly explored how smartphone or fitness app use in PPAs affects visitor perceptions of resource impacts, these results suggest additional research is warranted to better understand how smartphones affect psychological distance, abstraction or construal, and its effect on attitudes towards the natural environment.

Mountain bike visitors' survey responses were significantly different than other activity types in the analysis, which presents an opportunity for further research to better understand the values that set this group apart from other activity types. Normative methods to assess thresholds of crowding and ecological resource impacts between *Strava* and non-*Strava* are necessary to confirm the findings in this study.

Although questions related to trail conflict were only asked to mountain bikers, the significant differences in responses to assessments of trail and managerial conditions from other activity types suggests there may be implications for managers of these PPAs. When visitors perceive other activity types as incompatible with their own use type, direct management interventions such as spatial and temporal zoning strategies are often employed to reduce conflict between activity types. Additionally, in order to accomplish the habitat and resource conservation goals of these PPAs, the lack of certainty about rules and inconsistency of responses to off-trail use presents an opportunity for managers to engage visitors with interpretation that indicates behavior consistent with those conservation goals. While the vast majority of *Strava* users remained on designated trails within the PPAs, *Strava* and fitness apps like it should communicate to users the ethic and behavior that is consistent with the conservation goals of PPAs where app users recreate.

Finally, there were some signs in the trail segment velocity analysis of differences in the direction of trail use between *Strava* and non-*Strava* mountain bikers. Network analysis or Graph Theory has scarcely been used in recreation spatial behavior studies, but can provide an indication of this functional use of trail networks and be used to understand the homogeneity or heterogeneity of use along links and between nodes for different activity types or app users (Taczanowska et al., 2017). These types of analysis can provide managers a data-driven method to determine where trail conflicts are likely to occur and be used for planning for spatial or temporal zoning that results in the least amount of disturbance to patterns of PPA spatial-use between groups.

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APPENDICES

APPENDIX A. 2018 VISITOR SURVEY

Q1 By continuing on to the survey, you agree to participate in this study. You indicate that you understand the risks and benefits of participation, and that you know what you will be asked to do. You also agree that you have asked any questions you might have, and are clear on how to stop your participation in the study if you choose to do so. Please be sure to retain a copy of this form for your records.

Q2 Would you like to participate in this survey?

○ Yes

○ No

Q3 GPS track label

____

Q4 What park are you visiting today?

○ Aliso-Wood Canyon

○ Top of the World

○ Ridge Park

○ Whiting Ranch

○ Peter's Canyon

○ Crystal Cove State Park

Q5 What was the primary activity you planned to participate in on your visit today?

○ Walking/Hiking

○ Running

○ Biking

○ Dog Walking

○ Horseback Riding

○ Other (Please Specify)

____

Q6 On average how many days/year do you participate in [activity in Q5] ?

○ 0-10

○ 11-25

○ 26-50

○ 51+

Q7 Please rate your current experience level in [activity in Q5]. Please mark only one.

○ Beginner

○ Novice

○ Intermediate

○ Advanced

○ Expert

Q8 [Non-Response] What was your primary constraint for not participating in this survey?

____

____

____

____

____

Many visitors to open space areas in Orange County are looking for experiences being immersed in nature or exercising outdoors. What was your primary motivation for visiting the park today?

- ○ Nature immersion
- ○ Nature immersion and outdoor exercise, but mostly nature immersion
- ○ Outdoor exercise
- ○ Outdoor exercise and nature immersion, but mostly outdoor exercise
- ○ Other (Please specify)

____

Q10 Why did you [and your personal group] decide to get out on the trails you did today? Select all that apply.

- ☐ To get away from the demands of life
- ☐ To be away from crowds
- ☐ To learn about plants & wildlife
- ☐ To be in touch with my spiritual values
- ☐ To test my abilities
- ☐ To get some exercise
- ☐ To feel safe while in the outdoors
- ☐ To spend time with friends

Q11 What did you most enjoy about your recreation experience today? (Please tell us up

to three things you enjoyed most.)

- ◯ 1 ____
- ◯ 2 ____
- ◯ 3 ____

Q12 What did you least enjoy about your recreation experience today? (Please tell us up to three things you enjoyed least.)

- ◯ 1 ____
- ◯ 2 ____
- ◯ 3 ____

Q13 Please indicate your level of satisfaction concerning your ability to achieve the

following experiences on trails within [Park selected in Q4] today.

	Extremely dissatisfied	Somewhat dissatisfied	Neither satisfied nor dissatisfied	Somewhat satisfied	Extremely satisfied
To get away from the demands of life	○	○	○	○	○
To be away from crowds	○	○	○	○	○
To learn about plants & wildlife	○	○	○	○	○
To be in touch with my spiritual values	○	○	○	○	○
To test my abilities	○	○	○	○	○
To get some exercise	○	○	○	○	○
To feel safe while in the outdoors	○	○	○	○	○
To spend time with friends	○	○	○	○	○

Q14 To your knowledge, does the park you visited today have any rules about visitors going off the trail? Please select only one response.

○ Yes, visitors are not supposed to go off the trail.

○ No, visitors are allowed to go off the trail.

○ I'm not sure if there is a rule about going off the trail.

Q15 The following statements ask for your evaluation of the management and conditions within [Park selected in Q4]. Please indicate the extent to which you agree or disagree

with each of the following statements.

	Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
There is enough parking	○	○	○	○	○
There are enough road signs	○	○	○	○	○
There are enough trail signs	○	○	○	○	○
There are enough rules	○	○	○	○	○
There are enough trails	○	○	○	○	○
There is enough info about plants & animals I might see at the park	○	○	○	○	○
There is enough info about historical and cultural significance of the park	○	○	○	○	○
There is enough info about conservation initiatives at the park	○	○	○	○	○
There is enough info about having a safe experience at the park	○	○	○	○	○

Q16 Thinking about your trip, would you have liked to have seen more of, the same, or

less of each of the following facilities? Please select one response for each item.

	Less	Same	More
Trails for hiking	○	○	○
Trails for biking	○	○	○
Trails for horseback riding	○	○	○
Universal Access (e.g., for wheelchairs) sites and facilities	○	○	○
Other (please specify)	○	○	○

Q17 Please indicate how much you agree or disagree with the following statement regarding your concerns while using the trails. Please mark only one response per

question.

	Not at all a problem	Slight problem	Moderate problem	Serious problem	Extreme problem
Too many people/large groups on the trails	○	○	○	○	○
Too many mountain bikers on the trails	○	○	○	○	○
Too much noise (traffic/helicopter/music).	○	○	○	○	○
Too much horse/dog manure on the trails	○	○	○	○	○
Trail surface quality (too deeply eroded, muddy, rough, uneven, too wide, too narrow)	○	○	○	○	○
Litter on the trail	○	○	○	○	○
Informal trails (visitor created trails)	○	○	○	○	○
Trails that don't go to the places I want to go	○	○	○	○	○
Trails too difficult (too many hills/too steep)	○	○	○	○	○
Other (Please specify):	○	○	○	○	○

Q18 Were there any places or times you avoided because of conditions you have encountered in the past?

○ No

○ Yes - Please describe the conditions you wanted to avoid.

____

Q19 On this visit to Aliso & Wood Canyon Wilderness Park, which was the first entrance

you used to enter the park?

- ◯ Main entrance (parking lot)
- ◯ Top of the World
- ◯ Hunwut Trail
- ◯ Moulton Meadows
- ◯ Other Neighborhood

Q20 On this visit to Aliso & Wood Canyon Wilderness Park, through which location will you leave on your final exit from the park?

- ◯ Main entrance (parking lot)
- ◯ Top of the World
- ◯ Hunwut Trail
- ◯ Moulton Meadows
- ◯ Other Neighborhood

Q21 On this visit to Whiting Ranch, which was the first entrance you used to enter the park?

- ◯ Market Street (Borrego Trail)
- ◯ Glen Ranch Road
- ◯ Parking near Wahoo's (Serrano Creek Trail)
- ◯ Concourse Park
- ◯ Other Neighborhood

Q22 On this visit to Whiting Ranch, through which location will you leave on your final exit from the park?

- ◯ Market Street (Borrego Trail)
- ◯ Glen Ranch Road
- ◯ Parking near Wahoo's (Serrano Creek Trail)
- ◯ Concourse Park
- ◯ Other Neighborhood

Q23 On this visit to Top of the World, which was the first entrance you used to enter the park?

- ◯ Alta Laguna Boulevard
- ◯ Stairsteps Trail
- ◯ Park Avenue Trail
- ◯ Canyon Acres Drive

Q24 On this visit to Top of the World, through which location will you leave on your final exit from the park?

- ◯ Alta Laguna Boulevard
- ◯ Stairsteps Trail
- ◯ Park Avenue Trail
- ◯ Canyon Acres Drive

Q25 On this visit to Crystal Cove State Park, which was the first entrance you used to

enter the park?

- ◯ Lower parking area (Moro Canyon Trail)
- ◯ Upper parking area (No-Dogs Trail near Ranger Station)
- ◯ Pacific Coast Highway to Moro Ridge Trail
- ◯ Muddy Canyon
- ◯ Ridge Park
- ◯ Bommer Canyon

Q26 On this visit to Crystal Cove State Park, through which location will you leave on your final exit from the park?

- ◯ Lower parking area (Moro Canyon Trail)
- ◯ Upper parking area (No-Dogs Trail near Ranger Station)
- ◯ Pacific Coast Highway to Moro Ridge Trail
- ◯ Muddy Canyon
- ◯ Ridge Park
- ◯ Bommer Canyon

Q27 On this visit to Ridge Park, which was the first entrance you used to enter the park?

- ◯ Crystal Cove State Park
- ◯ Bommer Canyon
- ◯ Ridge Park Rd.
- ◯ Laguna Coast Wilderness Park
- ◯ Other Neighborhood

Q28 On this visit to Ridge Park, through which location will you leave on your final exit from the park?

- ◯ Crystal Cove State Park
- ◯ Bommer Canyon
- ◯ Ridge Park Rd.
- ◯ Laguna Coast Wilderness Park
- ◯ Other Neighborhood

Q29 On this visit to Peter's Canyon, which was the first entrance you used to enter the park?

- ◯ Canyon View Parking Lot
- ◯ Peter's Canyon Rd
- ◯ Canyon View & Jamboree Entrance
- ◯ Other Neighborhood

Q30 On this visit to Peter's Canyon, through which location will you leave on your final exit from the park?

- ◯ Canyon View Parking Lot
- ◯ Peter's Canyon Rd
- ◯ Canyon View & Jamboree Entrance
- ◯ Other Neighborhood

Q31 During your visit today, how did you use your Smartphone (cell phone, iPad,

tablet)? (Please select all that apply)

- ☐ Do not own a smartphone
- ☐ Did not use my smartphone
- ☐ Used Facebook
- ☐ Used Instagram
- ☐ Used Snapchat
- ☐ Used Twitter
- ☐ Used Strava
- ☐ Used MapMyRun
- ☐ Used EndoMondo
- ☐ Used eBird or iNaturalist
- ☐ Other (Please Specify)

____

Q32 How frequently do you use Strava?

- ○ Never
- ○ Rarely
- ○ Sometimes
- ○ Often
- ○ Always

Q33 What is the primary reason(s) that you use Strava?

- ☐ Follow friends/group and share achievements
- ☐ Track and analyze personal fitness performance and goals
- ☐ Compete against friends/self/others
- ☐ Other (Please Specify) ________________

Q34 We would like to know how you feel about biking on trails in [Park selected in Q4]. For each item below please rate how much you think it describes the experience of riding

on trails [Park selected in Q4] -wide.

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
Trails here provide enough challenge for you	○	○	○	○	○
Trails here satisfy your preferred riding style	○	○	○	○	○
The quality/condition of trails is satisfactory	○	○	○	○	○
You experience conflict with < other bikers	○	○	○	○	○
You experience conflict with other non-bike visitors	○	○	○	○	○
Other non-bike users have conflicts with you	○	○	○	○	○

Q35 Did the presence of a researcher administered GPS unit affect your activity?

○ No

○ Yes (Please specify) ____

Q36 Did you go off the designated trail at any point on your visit today? If yes, please

describe in several words why you travelled off the designated trail today.

◯ No

◯ Yes ____

◯ Unsure

Q37 Has anything impacted your ability to engage in [Activity selected in Q5] safely?

◯ No

◯ Yes (Please Specify) ____

Q38 On this visit did you [and your personal group] feel prepared for common safety situations that you may have encountered at [Park selected in Q4]?

	Yes	No
Exposure to sun	◯	◯
Heat	◯	◯
Access to drinking water	◯	◯
Proper equipment (i.e., footwear)	◯	◯
Encounters with hazardous plants and animals (e.g. Poison Oak, Rattlesnakes)	◯	◯
Other (Please Specify)	◯	◯

Q39 How crowded did you feel while [Activity selected in Q5] at [Park selected in Q4]

today?

- ◯ Not at all crowded
- ◯ Slightly crowded
- ◯ Moderately crowded
- ◯ Very crowded
- ◯ Extremely crowded

Q40 Do you feel like the number of other people around you has increased your risk or any member of your party's risk of being injured at any point during your visit today?

- ◯ Yes, and it impacted my participation
- ◯ Yes, I felt this way all of the time but it did not impact my participation
- ◯ Yes, I felt this way some of the time but it did not impact my participation
- ◯ No, I did not feel this way

Q41 We would like to know more about your knowledge of some natural history and ecological issues in [Park selected in Q4]. For each item below, please rank your knowledge of this topic as it relates to Orange County Open Spaces by checking the

appropriate.

	No Knowledge	Somewhat Familiar	Well Informed
Wildlife	○	○	○
Plants	○	○	○
Insects	○	○	○
Historical and cultural significance of the area	○	○	○
Habitat Conservation	○	○	○
Habitat Restoration	○	○	○
Water Quality	○	○	○
Water Management	○	○	○
Air Quality	○	○	○
Fire Management	○	○	○
Fuel Management	○	○	○
Invasive Species Management	○	○	○

Q42 How would you describe your current knowledge of "Leave No Trace" practices?

Please select only one choice.

- ◯ No knowledge
- ◯ Very limited
- ◯ Limited
- ◯ Fair
- ◯ Above average
- ◯ Extensive

Q43 In your opinion, how does each of the following recreational activities impact the natural environment of [Park selected in Q4].

	No impact	Slight impact	Moderate impact	High impact	Extreme impact
Hiking	◯	◯	◯	◯	◯
Hiking (Off-trail)	◯	◯	◯	◯	◯
Mountain biking	◯	◯	◯	◯	◯
Mountain biking (Off-trail)	◯	◯	◯	◯	◯
Bird watching	◯	◯	◯	◯	◯
Camping	◯	◯	◯	◯	◯
Dog walking	◯	◯	◯	◯	◯
Horseback riding	◯	◯	◯	◯	◯
Photography	◯	◯	◯	◯	◯

Q44 What is your age?

____

Q45 Are you a permanent resident or citizen of the United States?

○ Yes-(What is your Zip Code?) ____

○ No-(What is your Country of Origin?) ____

Q46 What is the highest level of education you have completed? Please select only one response.

○ Less than high school

○ Some high school

○ High school graduate

○ Vocational/trade school certificate

○ Some College

○ Two-year college degree

○ Four-year college degree [or Bachelor's degree]

○ Master's Degree [or Graduate Degree]

○ Ph.D., M.D., J.D., or equivalent

Q47 What gender do you identify with?

◯ Male

◯ Female

◯ Other

Q48 For you only, are you Hispanic or Latino?

◯ No

◯ Yes

Q49 When visiting [Park selected in Q4], what languages do you and most members of your personal group prefer to use for the following?

	Other(Specify)	English
Speaking		◯
Reading		◯