# JOURNEYS TO DESTINATIONS: APPLYING BIG DATA AND QUALITATIVE GIS TO UNDERSTAND RECREATIONAL ECOSYSTEM SERVICES AND VISITOR DECISION-MAKING IN PARK AND PROTECTED AREA NETWORKS IN MISSOULA, MT

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# CHAPTER I: INTRODUCTION

Globally, park and protected area (PPA) managers are often tasked with a dual mandate: to protect natural, historic, and cultural values while simultaneously facilitating their use for recreation and tourism (Cessford & Muhar, 2003). To inform management that balances visitor access and ecosystem preservation, PPA managers aim to incorporate a robust understanding of factors related to the biophysical resources present in the landscape, the patterns and distribution of visitation, and how these two factors relate to one another. For any PPA setting where visitation occurs, understanding both the spatial and temporal distribution of visitors across the biophysical landscape is vital (English & Bowker, 2018). Understanding the patterns, outcomes, and quality of visitors' recreation experiences at a PPA starts with the character of the social and the natural resource setting in that PPA (Manning, 2011).

Understanding which of those settings are the most salient to a recreation experience, however, can present a challenge to outdoor recreation researchers and PPA managers. Local PPA visitors often pass through a mosaic of settings – including residential neighborhoods, transportation corridors, exurban development, and the boundaries of multiple trails, parks, or protected areas (Tzoulas & James, 2010). As recreationists traverse different natural resource, managerial, and social settings, their recreation experience is informed by a shifting window of environmental and social interactions; their experience fitting within a broader 'social-ecological complex adaptive system' (Morse, 2020). Therefore, local visitor experiences at PPAs are often a sum of interactions across different social-ecological settings and different phases of the recreation experience (Rice, Newman, et al., 2020). To understand the experiential role of a given park or trail, managers and researchers must recognize the importance of interactions between a given PPA and the settings outside the PPA boundary which combine to provision recreational outcomes (or ecosystem services). Outdoor recreation experiences are foundational in building the human-environment relationship, and experiences in public lands (and the networks of greenspaces that connect them) are an essential ingredient in the development of these relationships (Morse, 2020). A better understanding of visitor behavior across a network of social and ecological settings can support improved management outcomes for both social and ecological settings in PPAs.

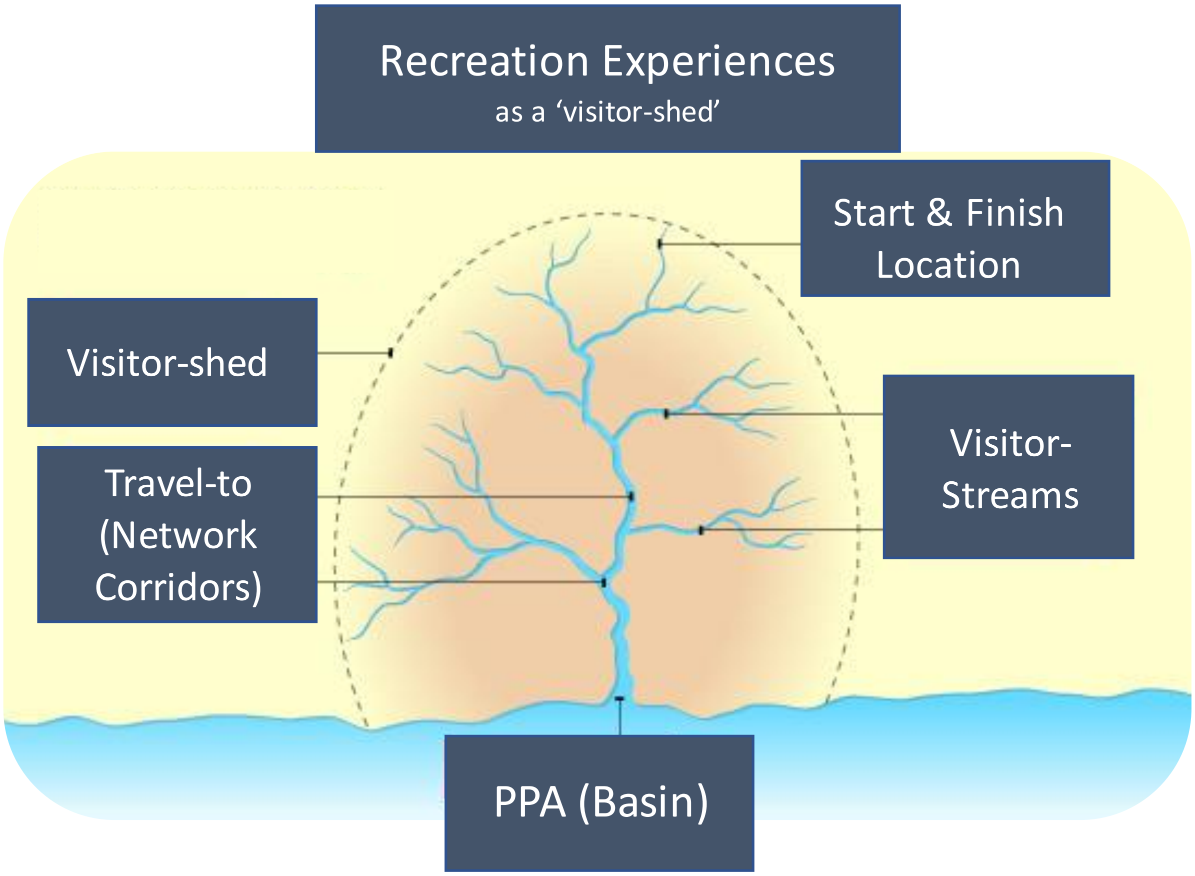



**Figure 1. Representation of the recreation experience as a 'Visitor-Shed'**

This thesis aims to develop an understanding of the visitor experience in PPAs from a systems approach. This approach posits that PPAs, particularly urban-proximate greenspaces that connect the wildland-urban interface, act as porous 'visitor-basins' fed by 'visitor-streams' within a larger 'visitor-shed'. This conceptualization of the recreation experience borrows the terms used to watersheds, where all components of the hydrological landscape are connected in a single system. Figure 1 outlines a conceptual framework for the recreation experience, showing how each individual PPA visitor contributes to a 'visitor-stream' that leads to the PPA 'basin', with all PPA visitors contributing to the total 'visitor-shed'. PPA research has used the concept of a 'visitor-shed', also called a catchment area, to define "the area from which a park attracts a population that uses its services" to examine the social, economic, and health impacts of visitors to PPA's (Guan et al., 2020 p.1; Kupfer et al., 2021; Wu et al., 2018). Just as conservation managers have long recognized the limitations of managing ecological systems as islands of biodiversity (Forman & Godron, 1986; Forman 1995), recreation researchers and managers are beginning to see the limitations of treating PPAs as islands of recreation activity. PPAs, and the benefits they provide through recreational ecosystem services (RES), are connected physically and socially by visitor-streams.

Elements of this conceptual framework for understanding PPA visitation have been reflected in PPA planning efforts within this study's focus area in Missoula, MT, as shown in Figure 2 (Missoula Parks and Recreation, 2010). Local PPA managers recognize that the greenspace they manage is nested within a larger social and ecological context. PPA managers have oriented strategic planning efforts around this framework for understanding the physical, social, and environmental connectivity between PPAs. This study aims to support those efforts by connecting local data collection and analysis to salient theory in outdoor recreation research and other related fields.

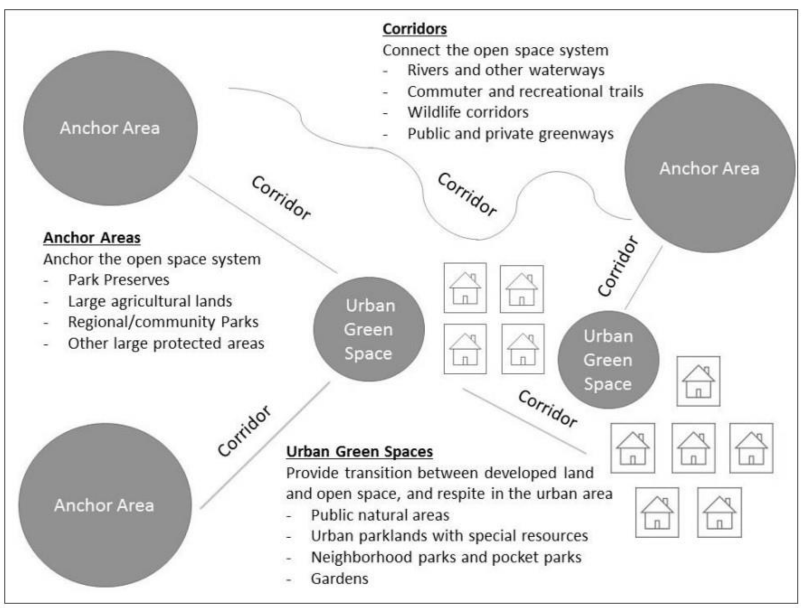



**Figure 2. Model of Open Space in Missoula Urban Area, as presented in the Missoula Urban Area Open Space Plan (City of Missoula and Missoula County, USA). (City of Missoula Parks and Recreation, 2019, p. 5)**

As participation in outdoor recreation activities and PPA-based tourism continues to grow, there is a widespread need for effective and accurate methods of visitor use estimation to inform management decisions and understand user trends (Timmons, 2019; Rice, Newman, et al., 2020). In the past fifteen years, recreation participation has grown across PPA settings: in local and state parks (Smith et al., 2019), at major national park systems in the U.S. (Bergstrom et al., 2020), and across the globe (Balmford et al., 2015), In particular, trends toward intensified uses of local trails and frontcountry experiences highlight the need for a comprehensive understanding of local recreation patterns (Gómez & Hill, 2016). Changes in recreation participation have also brought changes to the demographic composition of PPA visitors, further highlighting the need for managers to assess PPA visitation and to develop management policies that better serve diverse populations, especially in urban-proximate public lands (Wilhelm Stanis et al., 2008; Chavez, 2008). As these visitation trends continue, managers and outdoor recreation research will be challenged to understand how changes in PPA popularity and visitor demographics should influence future PPA policy and management.

A starting point for the future of PPA policy and management is an understanding of the outcomes that visitors receive from their experiences in PPAs. RES provides a useful framework for identifying and mapping the benefits that PPAs and greenspace networks provide. By considering the broader socio-ecological system of recreation experiences, this thesis aims to more fully capture the benefits that recreationists receive across all phases of their experience and describe novel methods to do so (see Clawson & Knetsch, 1966). Where research approaches to RES have typically focused within a single PPA 'basin', the scope of this study is limited to the travel-to phase, or the 'visitor-stream' that leads into the PPA basin. An improved understanding of this distinct phase of the recreation experience contributes to a more wholistic understanding of the benefits provisioned to visitors by local recreation networks. With an improved understanding of these benefits, PPA managers may be able to more effectively communicate with visitors or prioritize interventions. For example, in communications encouraging active transportation to PPA destinations to reduce parking constraints, in determining potential connections to adjacent PPAs to extend trail networks and disperse use to address crowding, or to understand sources of conflict resulting from changes in allowed uses. As the study area includes recreation settings outside of an individual PPA boundary, this thesis nests RES within a broader understanding of the benefits received by recreationists throughout a given experience (e.g., physical health, mental health, pro-social influence, social cohesion). The travel-to phase, from the visitor's front door to the PPA destination, includes many of the benefits, barriers, and constraints presented at other settings within the broader 'visitor-shed' of greenspace networks.

Missoula, Montana provides a case study for the examination of local recreation patterns and decision-making at a wildland-urban interface (WUI) – "where urban lands meet and interact with rural, wild, or undeveloped lands" (Kyle & Graefe, 2007, p. 1). Understanding how visitors interact across a network of greenspaces in the Missoula-area wildland-urban interface, requires measuring spatial visitation patterns that span multiple PPAs. Traditional methods of visitor use estimation have often been constrained within the boundaries of a single, focus PPA (Cessford & Muhar, 2003). These methods of visitor use estimation are based on primary datasets, collected onsite within an individual PPA.

Recently, outdoor recreation research researchers have explored the utility of secondary datasets in PPA visitor use estimation (Monz et at., 2019 & 2020; Heikinheimo et al., 2020; Merrill et al., 2021).Mobile phones, capture geographic location data while in use, leaving a "digital trace" of individual behavior on the landscape (Monz et al., 2019, p. 95). This big data source presents opportunities for unique applications in the PPA context, particularly in answering questions about visitor use and spatial flow in PPAs with unspecific access points or 'porous' boundaries and in areas where visitor use extends beyond the boundaries of any individual PPA 'basin' (Monz et al., 2019). Establishing a Park Service Area (PSA) with mobile phone location data has the potential to provide a representative, cost-effective measure of visitor travel patterns across the landscape (Guan et al, 2020), but it does not provide insight into how recreationists make travel decisions on the ground.

Conducting embodied, 'go-along' interviews (Carpiano, 2009) allows the researcher to probe the recreation experience while it happens; exploring visitor perceptions in the active, ephemeral space that is created during the recreation activity itself. In attempting to understand visitor perceptions of RES during the travel-to phase of the recreation experience, ‘go-along’ interviews allow the researcher and subject to discuss, reflect, and spatially define components of a distinct phase of the recreation experience. Participant decisions and reflections are captured while the visitor is actively engaged in the travel-to phase, responding to changes in microclimate, trail gradient, and social settings as they occur, instead of being filtered through reflections made post-experience (Stevenson & Farrell, 2018). By combining quantitative spatial analysis of mobile phone location data with qualitative GIS analysis of embodied walking interviews, this thesis aims capture a more complete understanding of visitor behavior across the ‘visitor-shed’ system of the recreation experience and inform management that recognizes the context of local use.

**Research Questions**

In this study, I applied mobile phone location data, a form of big data, to assess visitor use across management settings in the network of greenspaces leading the Rattlesnake National Recreation Area and Wilderness (RNRAW) in Missoula, Montana. Having identified recreation behaviors across this landscape, I then collected qualitative data through walking interviews to assess the role of recreational ecosystem services (RES) in guiding visitor behavior. Principally, this thesis explores two research questions:

1. How can anonymous, aggregated mobile phone location data be used to conduct a park service area analysis for visitor use monitoring across a *network* of greenspaces?
    a. What visitor-streams to or between PPAs (and their relative density of use) are identified through spatial analysis?

2. How do visitor perceptions of RES vary across space within the travel-to phase of the recreation experience?
    a. What role(s) do recreation ecosystem services play in visitor decision-making in the visitor-streams leading to PPAs (during what is traditionally thought of as the travel-to phase of outdoor recreation)?

# CHAPTER II: LITERATURE REVIEW

This thesis builds on recent (and foundational) research at the intersection outdoor recreation research and research on recreational ecosystem services (RES). Recently, researchers have recognized the need for an integrated framework between these two bodies of literature (Hermes, Van Erkel, et al., 2018; Morse et al., 2022; Rice, Newman, et al. 2020). This research begins with a grounding in the development of literature on visitor use management in different PPA contexts, RES, and proposed methods of analysis. I then apply existing theory and methods from outdoor recreation research, RES, and other related fields of inquiry to improve our understanding of recreation experiences and decision-making within a broader, dynamic social-ecological system.

## Measuring Visitation in Parks and Protected Areas

In the management of PPAs for a balance between natural resource and recreation opportunities, estimates of visitor use and an understanding of the visitor experience are critical baselines (Manning, 2011). In Cessford and Muhar's overview of visitor use monitoring n PPAs (2003), the authors list five primary monitoring categories that are required for comprehensive PPA management: 1) operational (e.g., audits of performance measures and budgets), 2) condition of specific biophysical, historic, or cultural features, 3) visitor numbers and patterns of use, 4) physical impacts of visitor use, and 5) social impact (e.g. visitor conflicts and satisfaction with the quality of their visit). The latter three monitoring contexts, related to visitor use estimation and the impacts of visitors to biophysical and social settings, are studied in visitor use monitoring research (Wilkins et al., 2021). Accurate and reliable visitor use monitoring is essential for a variety of planning tasks in PPA management, including: defining design standards for facilities and services, relating use-levels to social and physical impacts, minimizing user conflicts, identification of trends in use and visitor demand, identifying social, economic, and political significance of recreation, and many more (Hornback & Eagles, 1998; Watson et al., 2000).

Traditional methods of visitor use monitoring in PPAs have approached questions about visitor behavior, demographics, preferences, and experiences in PPAs by using visitor surveys, semi-structured interviews, administrative data, as well as vehicle and trail counters (Leggett et al. 2017). Available methods offer unique benefits and drawbacks, with each technique capturing different kinds of data, at different levels of population representativeness and generalizability. Cessford and Muhar (2003) categorized traditional visitor use monitoring methods into four broad categories of techniques: direct observation, on-site counters, visit registrations, and inferred counts. The review went on to compare the effectives of established techniques in capturing various types of visitation related-data, listing which methods are able measure visitor numbers, date and time, travel direction, route taken, spatial distribution, group size, visitor features, and visitor behavior (from table 5, Gordon & Muhar, 2003, p. 245). Beyond the capabilities of individual methods in deriving accurate estimates of use, researchers and managers have noted the substantial time and financial costs of conducting visitor use monitoring studies. As a result, practical constraints often limit data collection to relatively small geographic scales such as individual parks (Cessford & Muhar, 2003; Wilkins at al., 2021).

In the last decade, researchers have explored the use of large, volunteered geographic datasets, such as those collected through mobile phone location services or social media (e.g., Kim et al., 2019; Walden-Schreiner et al., 2018; Tenkanen et al., 2017). These new methods overcome some of the practical limitations of traditional methods, while providing insights into visitor experiences (Wilkins et al., 2021). These data provide rapid and cost-effective methods of gathering visitation data while, importantly, provisioning each of the data type categories outlined in Gordon and Muhar's (2003) review. In the context of this study, these datasets provide the added advantage of including data related to visitors before, during, and after their time within an individual PPA.

## Visitor Use across PPA Networks

An appreciation for the importance of the context of any individual PPA or greenspace, along with that greenspace's functional impact on human and nonhuman populations (e.g., ecosystem services), has developed across a diverse range of academic fields. Principles of landscape ecology, such as the theory of island biogeography, highlight the positive influence of large, connected, and proximate PPAs on species diversity and ecosystem function (MacArthur & Wilson, 1967). Conservation theory has spurred developments in research and inspired management action in fields beyond conservation biology. In particular, spatial concepts that connect the function of an individual protected area to a broader system have had a lasting influence on landscape architecture, urban greenspace planning, and transportation infrastructure (Goldstein et al., 1983; Jim & Chen, 2003; Schrijnen, 2000).The concept of green infrastructure, defined as "an interconnected network of natural areas and other open spaces that conserves natural ecosystem values and functions, sustains clean air and water, and provides a wide array of benefits to people and wildlife," hinges on an understanding of individual greenspaces as a part of larger network (Benedict & Mcmahon, 2006, p. 1). In the recreation and visitor use context, despite a growth in research on greenspace networks and barriers to greenspace use by visitors, there has been limited research into how individuals use and perceive greenspace networks across a wider landscape context (Bell at al., 2008; Moseley et al., 2013). While inquiry within the 'basin' has yielded a wide body of literature on the PPA visitor experience, taking a step back to examine the whole network or 'visitor-shed' can provide a broader understanding of the recreation experience outcomes.

**Phases of the Recreation Experience**

The frameworks for understanding the temporal component of the recreation experience used in this study borrows from both recreation and tourism research on the nature of visitor experiences. Clawson and Knetsch (1966) outline five phases for any outdoor recreation experience: the anticipation, travel to the site, on-site, travel from the site, and recollection phases. Early research on the phases of recreation experiences defined each of the five phases as uniquely identifiable, needing to be considered as an individual entity, and able to contribute to or detract from satisfaction within an entire outdoor recreation experience (Clawson & Knetsch, 1966; Moore & Driver, 2005). In addition to adopting the five phases of experience, scholars have further segmented the tourism experience into four core experience components:

emotional, informative, practice (e.g. skills development), and transformational (e.g. resulting in a lasting change in state of mind, body, or way of life) experiences (Aho, 2001). These core contents of the tourism experience appear in varying degrees, and often occur simultaneously (Aho, 2001). Outdoor or nature-based recreation is one of the primary ways we choose to interact with our environment, and is foundational in developing human-environment relationships (Morse, 2020). If managers aim to foster positive human-environment relationships through recreation, understanding how that relationship changes across phases within any given recreation experience is paramount. While traditional visitor use monitoring techniques have presented challenges to measuring different phases of the visitor-shed, mobile phone location data provides a unique opportunity to explore this spatial-temporal relationship.

**Visitor Use Monitoring with Mobile Phone Data**

Big, spatial data on PPA visitor behaviors before they arrive at their PPA destination allows research to define visitor use across temporal phases and across a network of PPAs. In recent years, a rapidly expanding body of literature has established new methods for using anonymous, aggregated mobile phone location data that is "passively" collected from large samples of mobile device users in PPAs (e.g., Merrill et al., 2020, Kupfer et al., 2021, Juang & Carrasco, 2020). This application of big data represents a significant opportunity for PPA managers and researchers to measure visitor use across time, recreation and tourism behaviors, and demographic attributes (Monz et al., 2019). The term 'big data' has been given a variety of definitions across different fields of study, but it's original definition describes the "Three V's" that characterize a big data set: volume, variety, and velocity (Laney, 2001). A fourth "V" was later added to the definition of big data to introduce the concept of value to describe the validity and utility of big datasets (Gants & Reinsel, 2011). The application of big datasets to recreation and tourism research has continued to grow in recent years, including the specific application of mobile phone location data (Li, Xu, et al., 2018, Whitney et al., 2023).

Mobile phone location data has been used to measure park visitation across scales – from individual trails (e.g., Heikinheimo et al., 2020), to single PPAs (e.g., Monz et al., 2020), to networks of PPAs or regional or country-wide analysis of park visitation (e.g., Merrill et al., 2021). In the U.S., mobile phone location data is purchased, aggregated, and anonymized from cell phones with GPS capabilities by a number of private vendors (for example, AirSage, SafeGraph, Near, and Streetlight), who then provide location data to customers from “a sample of about 30% of U.S. cell phone users” (Lawson, 2021, p. 30). Pulling from such a large sample size, vendors such as Near are able to “provide estimates for visitor use and visitor demographics with very high levels of confidence” (Rice et al., 2022, p. 49).

Until recently, research involving mobile phone location data in PPAs has often relied on “active” participation of users, where visitors use a specific mobile app or actively post information (often photos) to social media (e.g., Kim et al., 2019; Walden-Schreiner et al., 2018). Social media platforms such as Instagram, Flickr, and Twitter have been used to catalog user-submitted photographs, providing datasets in research related to visitor use and protected area management (see Sonter et al., 2016; Tenkanen et al., 2017). However, the participatory nature of data submission to social media or sport-specific GPS tracking apps constrains researcher attempts to gather data that is representative of the general population. These social media data sources represent only a fraction of the public (i.e., those that actively post to a particular platform), and can lack adequate spatial and temporal resolutions (Ekbia et al., 2015; Merrill et al., 2020). Other phone-driven, active data collection methods have proved limiting as well. Miyasaka et al. (2019) found low participation rates (15%) and participation biases towards younger, more technology-friendly, first-time visitors that were staying for longer periods and coming from a greater distance when investigating the sociodemographic attributes of participants and non-participants in a participatory mapping exercise and survey using respondent’s own mobile phones at Nikko National Park, Japan. Many of the limitations associated with other phone-derived big data sets (e.g., social media content or data collected through a specific application), can be addressed through the use of anonymous, aggregated mobile phone location data.

Passively collected mobile phone location data present advantages that are unique among methodologies utilizing mobile phone technology for visitor use monitoring. Initial studies aimed to establish the accuracy of visitor monitoring using mobile phone location data by comparing big data results to traditional survey methods (e.g., Monz et al., 2019). Subsequent studies have used mobile phone location data to answer questions that combine dig data sources (e.g., Guan et al., 2021), or to explore connections between disparate parks where other forms of visitor monitoring would not have been feasible (e.g., Kupfer et al 2021; Rice & Pan, 2021). As the methods have developed further, other researchers have approached the analysis of networks of proximate PPAs. Li and Yang (2021) refined the application of mobile phone location data to assessing park performance, conducting a visitor use monitoring study across 141 parks in Tucson, AZ to establish visitation per day and per month using solely mobile phone location data.

**Mobile Phone Location Data-derived Park Service Area**

The concept of a Park Service Area (PSA) can be used to measure various aspects of accessibility to PPAs, as applied to a diversity of research fields—from urban and regional planning to healthcare access (Axelrod et al., 2010; Church & Marston, 2003; Higgs, 2004). A common application of 'Park Service Area' in PPA research has been the "area from which a park attracts a population that uses its services," helping researchers and managers understand who is recreating in a given PPA, where they live, and how far they travel to reach their PPA basin destination (Guan et al., 2020; Lee & Hong, 2013). PSA analyses utilize geographic information systems (GIS) to quantify the level of access to a given park across a local population of interest (Lee & Hong, 2013). Service area analysis (a similar form of analysis is termed catchment area analysis) has been used widely outside of the PPA context to measure relative access to a given amenity, infrastructure, or service by comparing the spatial distribution of the a given population to a given public amenity or service (e.g., Xiong & Luo, 2017). For example, measuring accessibility for people with physical disabilities (Church & Marston, 2003) or measuring access to healthcare facilities (Higgs, 2004).

Over time, PSA analysis has been refined to include a number of factors that influence variation in accessibility of PPAs. For example, Oh and Jeong (2007) conducted a PSA analysis to quantify accessibility to parks in the Seoul metropolitan area by examining a road network-based PSA that adjusted for the specific regional distribution of urban parks & relative population, where previous studies had relied on per capita index, which is derived by dividing the individual park's area by the total population in it's given governmental or jurisdictional boundary. As mobile phone location data research has developed, researchers have advanced the PSA concept by utilizing location data obtained from mobile phones to measure park accessibility (Li, Chen, et al., 2021), park performance (Li, Yang, et al., 2021), and differences in PSA results across time (Guan et al., 2021). However, generally, mobile phone location data provides only a descriptive understanding of visitor use within PSA (i.e., where hot spots of use exist, demographics of visitors, time spent within a park). Evaluative data, if paired with this descriptive data source, would provide a more actionable understanding of the park visitor experience for managers (Manning, 2011).

**Understanding PPA Visitation through Recreational Ecosystem Services**

Any form of proper recreation management within PPAs requires, at some level, an understanding of the visitor experience. This idea, establishing an understanding and measuring what the visitor is experiencing and how they perceive their experience, can be a difficult concept to capture in outdoor recreation research. Early approaches to measuring recreation experiences used a "commodity metaphor" to map the relationship between the PPA manager's role in providing for recreation activities and select resource, social, and managerial settings and visitor's experience of those activities and settings, ultimately resulting in a level of visitor satisfaction (Anderson & Brown, 1984; Manning, 2011). Borrie and Birzell (2001) reviewed the major approaches to measuring quality in recreation experiences, including experience-based analysis, meaning-based analysis, outcomes-based analysis, and satisfaction-based analysis. Outcomes-focused management, which applies outcomes-based to management frameworks, outlines possible positive outcomes from recreation (e.g. benefits) and outlines management strategies to support visitors in attaining those outcomes (Driver, 2008). Over time, outcomes-focused analysis and management has become the most widely adopted by PPA managers (Rice, Taff, et al., 2020). While an outcomes-focused framework for understanding or managing visitor experiences creates space for the wide range of visitors and visitor experiences (e.g. both positive and negative experiences), researchers have pointed out its inability to account for the temporally dynamic nature of recreation experiences (Roggenbuck, 2000). Visitor perceptions of their recreation experience can vary across time—such as in the time between the various stages of their recreation experience, or between their immediate experience and their reflection upon that experience. In the application of theory to visitor behavior, Gómez and Malega (2007) called for more studies that explore the relationship between perceived benefits of recreation and park use. Johnson and Glover (2013) noted the importance for researchers to explore the ways in which individuals perceive public space in order to "contribute a better understanding and contextual representation of leisure and its relation to… quality of life in urban society" (p. 194).

A research focus on urban-proximate greenspace networks, incorporating visitor-streams into the visitor-shed, clarifies the connections between PPAs, outdoor recreation, and public health outcomes. Schultz et al.'s (2016) *Potential Measures for Linking Park and Trail Systems to Public Health* emphasized the important role that parks and trails play in developing a sense of place and community (as found with the Residential Environment Assessment Tool (REAT) in Dunstan et al., 2005) and facilitating pro-social behaviors and community cohesion (as in Kuo, 2010). Findings support the idea that perceptions of neighborhood qualities, such as neighborhood walkability, safety, and access to walking destinations, are then positively associated with more walking participation (King et al., 2000; King et al., 2003). Further studies on this effect have been extended to other pro-social perceptions, including a Fisher et al. (2004) study that found that neighborhood social cohesion was associated with differences in average walking behavior of elderly populations between comparable neighborhoods (Mendes De Leon et al., 2009). Research that extends the outdoor recreation research and RES research focus outside of just the 'basin' of individual PPAs can connect components of the recreation experience to related research in community and public health outcomes.

The concept of ecosystem services, or the benefits that people receive from ecosystems, provides a link between the health of ecological systems and the health of human systems (Millennium Ecosystem Assessment, 2005; Costanza, 2020), The Millennium Ecosystem Assessment provides a benchmark for research and policy related to ecosystem services—segmenting the types of ecosystem services into supporting, provisioning, regulating, and cultural services (Millennium Ecosystem Assessment, 2005). Most relevant to the field of outdoor recreation research are cultural ecosystem services (CES), defined as "the non-material benefits that people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences" (Millennium Ecosystem Assessment, 2005, p. 58). CES include a wide range of services that play a central role in PPA use and management, including cultural identity, heritage, spirituality, inspiration, education, knowledge systems, aesthetics, sense of place, social relations, and recreation and tourism (Millennium Ecosystem Assessment, 2005). As a subset of CES, researchers and managers have advanced the idea of recreation ecosystem services (RES).

Recreational Ecosystem Services are defined as "the natural environment's contribution to the range of leisure and recreational opportunities and experiences enjoyed by human societies" (Hermes et al., 2018, p. 290). Nested within CES, RES are closely linked to multiple aspects of human well-being; common examples include connections to health (e.g., exercise), social relations (e.g., social connections, following local traditions), and recreation-based provisioning services (e.g. gathering wild food materials) (Hermes et al., 2018). Further research has explored the specific role that development and human systems play in tandem with natural environmental to provision RES, such as the benefits provided through human-constructed infrastructure and agricultural development. Responding in part to conflicting applications of RES, Rice, Newman, et al. (2020) advanced a RES interpretive framework; clarifying the Millennium Ecosystem Assessment definition of RES as "the outcomes people obtain from ecosystems *through* recreation [*Emphasis added*]" (Rice, Newman, et al., 2020, p. 894).

Morse et al. (2022) note the prevalence of economic theory in much of the RES literature, where supply (locations with recreation potential) are identified and linked to demand (visitation information or proximity to local population centers). Much of the RES literature is relevant to urban-proximate greenspace networks: including studies that found that both recreation and conservation values are positively correlated with more heterogeneous landscapes (Hahn et al., 2018), and research that concludes that RES are not just defined by landscape potential, but also the presence of recreation facilities that correlates with recreation use (Kulcyk et al., 2018). Kulczyk et al. (2018) treat RES as "the delivery of services, conditioned by recreational use" (p. 1), where the act of recreating is a requisite for a RES to be provisioned, and visitor demand for RES is informed by natural potential and recreational infrastructure. Therefore, RES can be seen as the combination of landscape potential, recreational infrastructure, and visitor use (Kulczyk et al., 2018). This combination of factors occurs at any given setting (location) in a PPA, but we also know that recreation experiences are often a sum of a visitor's interactions with different settings and different phases throughout their experience (Tzoulas & James, 2010; Rice, Newman, et al., 2020). Therefore, as it relates to this thesis, I assert that that perceived and provisioned RES are the sum of experiences across the each of the phases of a recreation activity – not just within the PPA itself.

**Mapping Recreation Ecosystem Services**

**RES Mapping Using Big Data**

PPA managers use maps to identify recreation management goals, opportunities, regulations, and constraints (Hornback & Eagles, 1998; English & Bowker, 2018; Jim & Chen, 2003). Maps are also essential in visitor use monitoring, communicating spatial patterns in visitor behavior, recreation impacts, and perceptions (Riungu et al., 2019). Maps have also been used to designate management zones (Thomas & Middleton, 2003) and classes of recreational opportunities (Clark & Stankey, 1979) in PPAs. Spatial assessments of RES have developed substantially over the past decade, both in applications that utilize theoretically-derived spatial indicators and those that utilize big, user-generated datasets (Morse et al., 2022; Hermes et al, 2018). While expert-based approaches to mapping RES in PPAs have proven useful in guiding management, there has been a growing effort to more accurately represent spatially-specific RES values by utilizing participatory-GIS data generated by visitors to identify visitation, values, and motivations (Tenkanen et al., 2017; Oteros-Rozas et al., 2017; Rice et al., 2020). Researchers and managers have used RES to provide management frameworks that can help to balance the needs, motivations, and outcomes of visitors against other ecosystem services present in PPAs (Buckhard et al, 2014; Von Haaren et al., 2014). Authors have built on this theoretical foundation to outline specific management components related to RES. For example, Kulczyk et al (2018), provide a three-dimensional evaluation criterion for assessing the 1) landscape potential, 2) availability of recreational facilities, and 3) recreationist demand when planning for RES in PPA settings. Theory-informed spatial indicators, such as the landscape aesthetic quality index presented by Hermes et al. (2018) or the expert-based tool that is cross-referenced with user preferences advanced by Rabe et al. (2018), aim to provide generalizable tools that could be applied at various spatial scales (Hermes et al., 2018).

Geolocated social media data, especially big datasets of geotagged photos from sites such as Flickr, Instagram, and Twitter, have supported a rapid proliferation of spatial CES research (Figueroa-Alfaro & Tang, 2016; Richards & Friess, 2015; Tenkanen et al., 2017). In a 2020 review, Zhang et al. found 58 peer-reviewed publications that had used geolocated social media data to spatially define components of cultural ecosystem services. Other user-created big data, such as geocache game location data (e.g., geolocated data that is obtained through submissions from geocache game players, a worldwide outdoor game where people can hide and look for 'caches' with GPS technology), have been used to map RES (as in Cord et al, 2015).

In the right setting, these data sources allow faster, larger scale, and more cost-effective CES evaluation than traditional data sources (Zhang et al., 2020). Even in data-sparse environments, geolocated social media data can identify and characterize locations of high recreational value (as in Schirpke et al., 2018; Van Berkel et al., 2018). However, notable limitations have been attributed to this data. First, social media data often lacks reliable social and demographic information about users, which limits control of sample representation and generalizability (Wilkins et al., 2021). Overall, social media content tends to bias towards younger, better educated, higher income, more-likely females, professionals, urban residents, and tech-savvy users (Zhang et al., 2020; Miyasaka et al., 2019). Finally, data availability can vary based on private platform operation, privacy policies, and popularity among users (Zhang et al., 2020; Tenerelli et al., 2016). While valuable contributions have been made through the analysis of geolocated social media posts, mobile phone location data provides many of the same benefits while addressing many of the stated limitations of social media data. By combining mobile phone location data with interview data, this thesis aims to provide a more complete picture of RES influences on visitor decision-making.

### RES Mapping using Embodied, "Go-Along" Interviews and Qualitative Geographic Information Systems (GIS)

This study pairs aggregated recreation behavior, quantified through mobile phone location data, with the embodied, active recreation experience of individuals. Introduced to interview research by Carpiano (2009), the 'go-along' interview enables a more natural exploration of people's experiences and decision-spaces while they are engaged in the active, embodied, ephemeral space created as they participate in an activity. Using this method, researchers accompany participants as they travel across different environments, often walking, while following a semi-structured interview guide; leaving space for divergent discussions, reflections, and co-creating experiences (Carpiano, 2009; Kusenbach, 2003). This process can highlight embodied aspects and sensory experiences in response to changes in the weather conditions or gradient of the path, components that may not make it into a post-experience interview or survey.

This method is well-suited to answer the second set of research questions of this thesis, helping to capture heterogenous values across a relatively small area while addressing some of the limitations of other research that has aimed to collect qualitative GIS information on RES. Researchers have pointed to the variation in settings, rhythm and exertion of movement as contributing to participants ability to articulate their attitudes and feelings during a 'go-along' (also called walking) interview, resulting in longer interviews, more place-specific data, and more spatially focused responses (Evan & Jones, 2011). Reflections are captured in the moment, not mediated by post-walk consideration of the overall experience of the completed walk (Stevenson & Farrell, 2018). The physicality of the activity supports the development of a particular consciousness, rising from the "experiential flow of successive moments of detachment and attachment, physical immersion and mental wandering, memory, recognition and strangeness" (Edensor, 2010, p. 70; see also Anderson, 2004). Importantly, researchers have found that go-along interviews offer opportunities for under-represented and/or oppressed people to better express themselves and relate their experiences outside of traditional, institutional research facilities or academic spaces (Harris, 2016; Warren, 2017). However, certain limitations are associated with walking interviews and should be considered, most notably the potential restriction of the sample population to those that are able and willing to participate in the walking route chosen for the interview (e.g. participants may need to be able bodied and comfortable outdoors) and the potential for participants to be uncomfortable sharing sensitive information in a more public venue (Harris, 2016).

‘Go-along’ interviews have been used widely in ethnographic, geographic, and urban planning contexts, mostly to explore connections between urban spaces and social-cultural identities and experiences (e.g., Adams and Guy, 2007; Anderson, 2004; Kusenbach, 2003). Applications that are specific to natural areas, however, are relatively few and recent. Central to the development of this thesis’ methods is Teff-Seker et al.’s (2022) examination of the use of embodied walking interviews to identify both generalizable and local (site-specific) themes of CES across Europe and the Middle East. In this thesis, go-along interviews, whether walking, jogging, or biking, aim to explore the role of RES in visitor decision-making across a variety of PPA and managerial settings while travelling-to PPA destinations with visitors.

By asking visitors where and when they perceive RES and how RES values influence their recreation decision-making while maintaining a spatial record of the interview, this thesis utilizes qualitative GIS methods and theory to produce a “spatial interview transcript” (Evans & Jones, 2011). Broadly defined, qualitative GIS is the identification of spatial patterns associated with qualitative data (Steinberg & Steinberg, 2015). As advances were made in GIS technology in the 1990s, researchers also began to expand their understanding of ‘place’ using participatory mapping methods (Brown et al., 2020). GIS software, designed to display either raster or vector quantitative datasets, has been adapted to qualitative research using three main approaches—transformations, hyperlinks, and software extensions (Elwood, 2006). Epistemologically, though, qualitative GIS has maintained an interpretivist grounding that creates, thrives on, and ultimately speaks from a reordering of messiness (Cope & Elwood, 2009). The participatory mapping of place values has grown significantly since then in both research and practice in outdoor recreation research, with researchers across the globe working with research subjects to explore the “where” of ecosystem services (Zhang, Gao, 2019; Chen et al., 2019; Fagerholm et al., 2019; Blake et al., 2017). Over time, participatory mapping has become one of the most-utilized qualitative GIS tools, with studies often opting to employ both quantitative and qualitative GIS methods (Davies & Dwyer, 2008; Brown, et al., 2020; Garcia et al., 2018).

Qualitative GIS researchers have collected data variety of ways and at different scales, including: archival data (Steinberg & Steinberg, 2015), participatory mapping (Rice et al., 2020), exploring metadata of spatial attributes (Schuurman, 2009), focus groups (Lowery & Morse, 2013), and semi-structured interviews (Stevenson & Farrell, 2018). Qualitative GIS is inclusive of a number of analytical approaches as well, including: content analysis (Garcia et al., 2018), inductive coding (Stevenson & Farrell, 2018; Rice at al., 2020), grounded theory (Knigge & Cope, 2006). As Cope & Elwood (2009) write:

> Mixed methods research such as qualitative GIS can enhance the rigor of knowledge production, not only because of its reflexive, critical traditions, but also because a critical mixed method approach makes it harder for a researcher to be complacent about a single version of 'the truth'. (p. 172)

By exploring recreationist behavior throughout the visitor-shed with both the lens of recorded spatial behavior (e.g. mobile phone location data) and active, embodied decision-making (‘go-along interviews’), this thesis aims to provide a more robust, complete picture of recreation in greenspace networks.

## CHAPTER III: METHODS

### Study Area

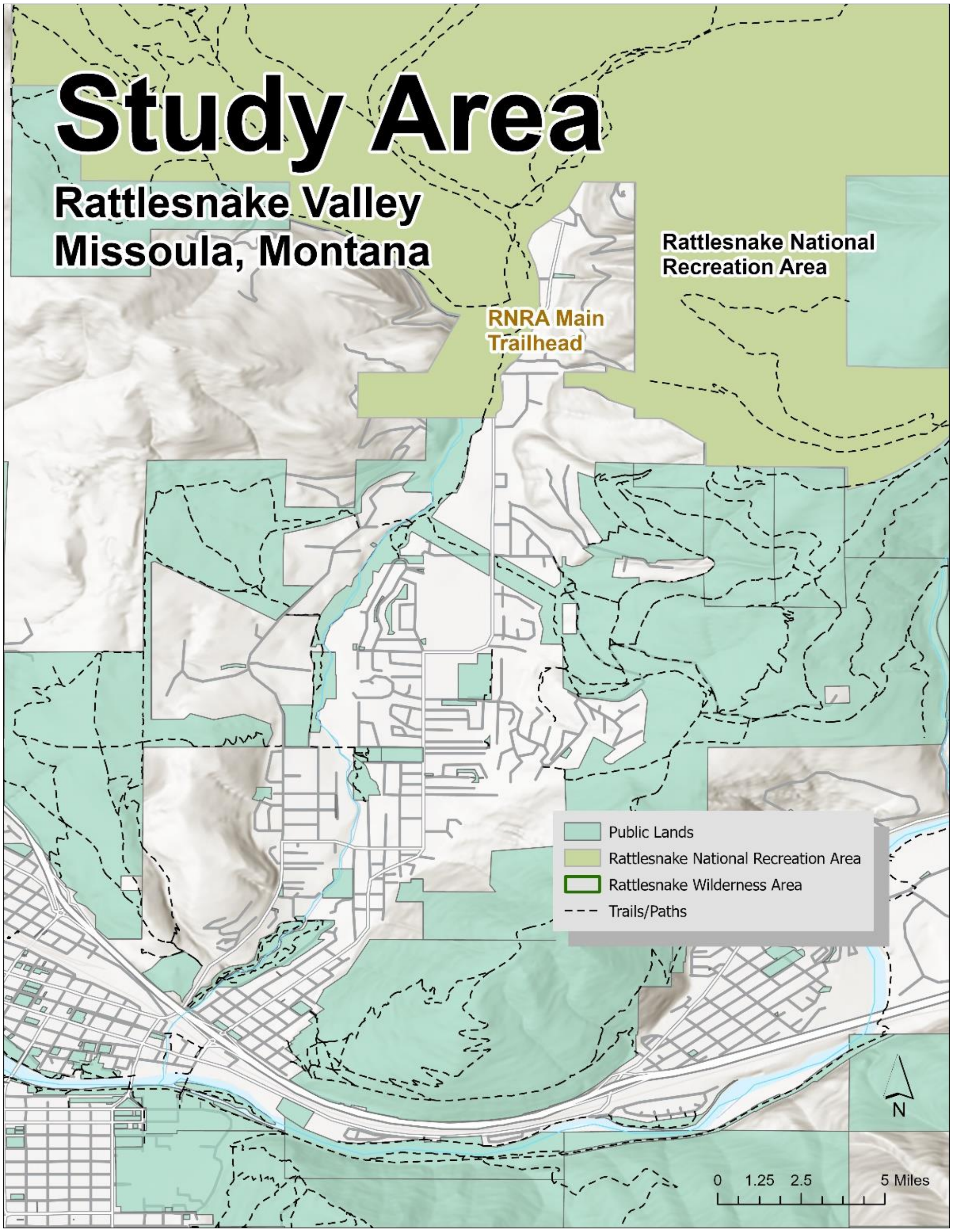



**Figure 3. Study Area – The Rattlesnake Valley and the Rattlesnake National Recreation Area.**

*This study area and the University of Montana are located in the ancestral territories of the Salish and Kalispel people. This thesis examines recreation behavior on lands that are currently managed by federal, state, and municipal government agencies, non-governmental organizations, and private landowners. The author recognizes that the study area's present-day management is the outcome of land ownership obtained through a system of settler-colonialist occupation that continues to this day.*

This research was conducted in the Rattlesnake Creek watershed, focusing on the pedestrian active transportation corridors leading to the Rattlesnake National Recreation Area and Wilderness (RNRAW) in Missoula, Montana. The RNRAW, established in 1980 and managed by the Missoula Ranger District of the Lolo National Forest, serves as a gateway to a large complex of connected protected areas that extended from all sides of the RNRAW boundary, including areas managed by the Confederated Salish & Kootenai Tribal Natural Resource Department, the Bureau of Land Management, non-governmental conservation organizations, the U.S. Forest Service, the State of Montana, and the City of Missoula. The Main Trailhead of the RNRAW is located 5 miles north of downtown Missoula, MT, providing access to a range of recreation opportunities across over 73 miles of trails throughout RNRAW's 60,081 acres (USDA Forest Service, n.d.). RNRAW has a notable history of outdoor recreation research, and the U.S. Forest Service manages visitor recreation experiences in the National Recreation Area and Wilderness with a Limits of Acceptable Change (LAC) management framework. LAC zones stratify visitor experiences into six opportunity classes (Stankey et al., 1984) across RNRAW's 60,081 acres (USDA Forest Service, n.d.). As Missoula's population has grown, and as recreation demand has increased, the RNRAW and nearby City of Missoula Open Space lands are faced with an increasing number of management challenges, including increased recreation density, parking scarcity, and impacts to visitors' recreation experiences (Missoula Parks and Recreation, 2019).

Missoula County, encompassing the Missoula Metropolitan Area, has a population of 119,533 (U.S. Census Bureau, 2020) and is located in the Northern Rockies of Montana. Surrounded by seven wilderness areas and at the confluence of three rivers, Missoula is known and advertised for its access to outdoor recreation (Destination Missoula, 2022). The population of Missoula County grew 9.3% between 2010 and 2019 (U.S. Census Bureau, 2020), and residents and managers have reported the impacts of increased use of the local open space and surrounding public lands (Missoula Parks and Rec. Department, 2010). As a gateway to public lands and situated in a region previously dependent on resource extractive industries, Western U.S. towns like Missoula, MT, Bend, OR, and Lake Tahoe, CA, are often pointed to as examples for centers of amenity migration (Kruger et al., 2008). Amenity migration describes the movement of people to places with attractive recreation opportunities, environmental and cultural resources (McCool and Kruger, 2003). PPAs that provide urban-proximate access to public lands, recreation opportunities, and Wilderness Area designations, all of which describe RNRAW, are a central driver of amenity migration (Kruger et al., 2008). As local populations grow, driven in part by demand for PPAs like the RNRAW, local managers face a number of challenges related to visitor use, including: increased recreation density, wildlife impacts, spread of invasive species, social trail development and soil erosion, parking scarcity, and impacts to visitors' recreation experiences (Missoula Parks and Rec. Department, 2010; Gicklhom et al., 2021). Missoula, MT presents a case study for metropolitan area that is both likely to continue to experience increased recreation demand and visitor use impacts related to local population and contains a network of urban-proximate PPAs across a gradient of the wildland-urban interface.

Urban-proximate PPAs are broadly defined as natural areas "located outside of a city, but accessible to a major population center" (Gómez & Hill, 2016, p. 70). The U.S. Departments of Agriculture and Interior defines the wildland-urban interface as "the area where houses meet or intermingle with undeveloped wildland vegetation'' (Glickman & Babbit, 2001). In research and in federal policy, wildland-urban interfaces are further subdivided into two categories: "…intermix WUI (area > 6.17 housing units/km$^2$, with > 50% wildland vegetation), and interface WUI (area > 6.17 housing units/km$^2$, with < 50% wildland vegetation)" (Glickman & Babbit, 2001, p. 800; Radeloff et al., 2005). In this study area, PPA networks provide recreationists with transportation corridors, whether through specific recreation infrastructure or road systems, that connect the wildland-urban interface: from urban center, to interface and intermix wildland-urban interface, to Wilderness areas. Thus, this thesis examines visitor behavior and perceptions of RES across a diversity of biophysical settings, landowners, and management contexts in the visitor-shed of greenspaces leading to the RNRAW in Missoula, MT.

**Data Collection: Research Question 1**

To answer the first research question, RNRAW visitation was assessed with a Park Service Area (PSA) and visitation density analyses, using mobile phone location data acquired from the Near VISTA platform. Recent studies using mobile phone location data to conduct PSA analysis have promising implications for a range of academic fields and applied problem-solving, including visitor use monitoring in PPAs (Li, Chen, et al., 2021; Jaung & Carrasco, 2020). However, the literature has yet to examine *networks* of PPAs and greenspace through a PSA analysis. This thesis builds on recent examples of PSA analysis using mobile phone location data, applying established methods to a novel setting (greenspace networks). In particular, the PSA methods presented in a pair of studies by Guan et al. (2020; 2021) will inform PSA in this thesis.

Device-level spatial data, representing individual visitors to the RNRAW, were used for pathing and PSA analysis. From this data, two components of the Near mobile phone location dataset were used in analysis: pathing data (defining movement *to/from* and *within* PPAs and greenspace networks) and Common Evening Location (CEL) data (defining proxy-home locations, connecting to visitor demographics at the census block level) (Ubermedia, 2021a, 2021b). Near (formerly Ubermedia), a mobile phone location data vendor, provides location data through its VISTA platform to customers after purchasing, organizing, anonymizing, and packaging raw batch location data from major cell carriers in the U.S. The exact steps and comprehensive list of sources of location data varies between data vendors, with some proprietary processes having limited information available. Among current mobile phone location data vendors in the U.S., Near advertises itself as a research-grade data provider with transparent data procurement and cleaning processes (UberMedia, 2021a).

The location data are captured at the device level, collected by software in applications or mobile browser pages access via mobile phone that have location services enabled (UberMedia, 2021a). Near's dataset is derived from location-collecting software packages, embedded into pop-up ads, apps, and webpages by software developers, included in over 100,000 mobile phone applications (UberMedia, 2021a). The Near dataset used to produce the sample for this study is obtained through a paid subscription account, which provides access to the VISTA platform. Data queries through VISTA include mobile phone location data from four data sources: ~50% of data was "second-party" data (gathered by other location-data providers and shared with Near), ~48% of data was "bid stream data" (collected through software embedded into banner and video advertisements), ~1% of the aggregated data was provided by "first-party" apps (those developed with publishers that have a direct relationship with Near), and ~1% gathered through apps created by Near (UberMedia, 2021c). Mobile phone location data, as a form of big data, has especially large volume and variability (Li et al., 2018). To address the statistical noise that could be introduced by these two "V's", Near applies three general layers of data screening processes to its long-term dataset, which was utilized to create this study's sample. Basic screening removes faulty data reporting from individual devices, "power law" screening removes implausibly high levels of device requests or device density, and fraudulent data created by "bad actor" devices is removed. Additional levels of screening include audit-based data testing and other report-based screening methods (Near 2021a). These raw data are aggregated and screened for accuracy and quality by Near, and then provided based on query parameters submitted by Near customers through the VISTA software portal (for example, a query of devices with location points that entered RNRAW in a given time period (UberMedia, 2021a).

While the application of this data in visitor use monitoring research is relatively new, several studies provided validity assessments and methodological guidance for the use of mobile phone location data to conduct visitor density analysis at different locations (e.g. at trailheads, on trails) in PPAs (Monz et al., 2019; Heikhinheimo et al., 2020; Creany et al., 2021). Creany et al (2021) compared validity of mobile phone location data visitor use estimates to traditional methods of visitor use estimation (on-trail counters and parking lot counts). The study compared visitor use estimates derived from Streetlight location data (mobile phone location data vendor) and Trafx devices (on-trail infrared or magnetometer devices), finding:

1) no significant difference between vehicle and bicycle counts at trailheads, and 2) significant moderate to very strong positive correlations between estimates of spatial distribution and density for pedestrian and bicycle trail users across four urban-proximate PPA's. Following analysis, the study found the results "suggested a high degree of face validity in the spatial patterns and density estimates in the Streetlight and GPS" data (Creany et al., 2021, p. 4, tables 1-3 and Figures 3-6). A growing body of literature is now using Near VISTA data is a similar way (e.g., Rice et al., 2022; Linnell et al., 2023).

Once queried by the customer, Near mobile phone location data are provided as tabular (spreadsheet) documents, separated by the type of location data that is exported (e.g. pathing data vs. common evening location data). Near defines visitor home locations by their "Common Evening Location" (CEL), which is "estimated by determining where a device most frequently appears during the 'non-work' hours" (UberMedia, 2021a, p. 2). "Non-work hours" are defined as between 18:00 and 08:00 on Mondays through Fridays and all day on Saturdays and Sundays (UberMedia, 2021a). The defined common evening location is then geomasked or "jittered [by] 50 m [meters] a random direction" to "help maintain the de-identification of device-level data" (UberMedia, 2021a). To quantify demographic composition of the sample, these CELs are then attached to their corresponding U.S. Census block group (UberMedia, 2021b). Pulling from such a large sample size, Near can provide visitor use estimates with high levels of confidence (Rice et al., 2022). Near's data reports that their data validity for demographic measures highly significant ($p<0.01$), with a "Pearson's correlation between the (inferred) number of UM device users per income bracket and the number of census respondents per income bracket" of 0.994, and a Pearson's correlation of 0.999 for ethnicity reports (Ubermedia, 2021b, p. 4). CEL's, representing individual visitor's home locations, are the bases for descriptive statistics about the sampled population and the PSA analysis.

Data were exported for initial, scoping analysis in March of 2022. Scoping analysis was conducted using this data to inform research design development through the identification of target interview locations. A final data export was conducted on March 3, 2023. Data queries are established using ArcGIS Pro and authoritative shapefiles provided by the US Forest Service. Polygons representing RNRAW boundaries were used to export mobile phone location data from Near (formerly UberMedia). This dataset query consisted of two primary forms of mobile phone location data. First, the dataset included records of GPS points representing visitor mobile phones up to two hours (7,200 seconds) prior to entering the boundary of the Rattlesnake National Recreation Area between February 28, 2021 to February 28, 2023, organized by an individual, anonymized device identifier. Second, paired to the same device identification code, the dataset included the Common Evening Location (CEL) of those visitors included in the sample. CELs, which are geo-masked to anonymize individual identities, are then attached to their respective census groups.

Once data were obtained from Near's VISTA platform as tabular data, location points were uploaded to ArcGIS Pro. These location data were organized as two feature layers in two separate map projects: one representing visitor CEL's for PSA analysis, and another displaying all GPS location pathing points for visitor devices two hours prior to entering RNRAW. Data were then ready for analyses to examine research questions R1a and R1b.

**Analysis: Research Question 1**

In this study, visitor GPS location pathing points and CEL points were used to obtain a more complete understanding of visitation to the RNRAW. PSA analysis was done according to the methods of Guan et al. (2020; 2021), which included using kernel density analysis to understand interpolated densities of visitors' home locations across the greater Missoula area. A PSA is defined as "the area from which a park attracts a population that uses its services" (Guan et al., 2020, p. 1). Kernel density analysis applies a smoothly curved spatial surface around each point in a dataset, producing a circular area with a certain search radius (Beeco & Brown, 2013). Kernel densities were calculated in ArcGIS Pro, with both visitor sample PSA's processed with the same geographic extent, and with a uniform output cell size of 100 screen point units and a search radius of 500 sq. meters—based on the study area extent. The densities that result from the PSA analysis, shown in Figures 6 and 7, represent quantiles (following Guan et al., 2020; 2021)—classes containing approximately an equal number of observations—of visitation which range from least

(1st quantile) to most (6th quantile). Visitor Use Density Analysis followed guidance from similar studies that have derived visitation density from mobile phone location data (Creany et al., 2021) and using point data derived from GPS units (D'Antonio et al., 2010). For this analysis, kernel density analysis is also applied to data points (as above), though in this case the individual data points represent individual user locations within the PPA study area of interest. Kernel densities were calculated and displayed using ArcGIS Pro at the same spatial extent, with a uniform output cell size of 15 screen unit points applied to each individual location point and an upper display density set to 1.0 and no weight applied to the dataset (ESRI, n.d.).

Prior to running spatial analysis, data processing filters were applied to the mobile phone location data export to complete each of the identified analyses:

1. Visitation Density to Identify Primary Access to RNRAW

First, the full NEAR data export of GPS pathing location was processed for visitor use density and PSA analyses. For all RNRAW visitors, the original pathing dataset included 349,803 individual location points (between February 28, 2021 to February 28, 2023). Each point provides metadata that includes the location, date, and time where that individual mobile device connected to a cellular network. These points were used to identify which transportation networks and access point(s) host the greatest number of local visitors approaching the RNRAW. To do so, the dataset was clipped in ArcGIS Pro to only include points within ½ mile (804 meters) (0.5 mile) of the RNRAW boundary. This distance buffer of ½ mile (804 meters) was used as a proxy for an area of local, pedestrian access to a PPA (Yong & Diez-Roux, 2013; Lee & Hong, 2013) which had also been previously utilized as a definition of PPA access by local PPA managers (Missoula Parks and Recreation, 2004; 2019). Data were then displayed (see results, Figure 4) to show the relative density of use for different local access points to the RNRAW.

2. Definition of the 'pedestrian' sample

Next, the mobile phone location pathing data were refined to isolate the pedestrian sample. The pedestrian sample consisted of those devices that represented RNRAW visitors that were actively recreating (non-motorized travel) through the Rattlesnake Valley PPA network during the travel-to phase of their recreation experience. To identify this sample, two filters were applied to the data. First, visitor device locations that represented visitors travelling at an average speed greater than 15 miles per hour were removed from the dataset. This speed was selected as a conservative estimation for the average maximum speed for an individual involved in active transit (e.g. walking, running, or biking) while travelling uphill through the study area towards the RNRAW (gaining approximately 415 vertical feet from the lower portion of the study area to the main RNRA trailhead) (Owen & Murphy, 2019; Fitzpatrick et al., 2006). To do this, motion statistics were calculated using ArcGIS Pro for each device's track segment in the study area of interest.

Second, location points were overlaid with an authoritative data layer representing publicly accessible land boundaries in the Rattlesnake Valley PPA network using ArcGIS Pro. Devices which had at least one point of their track that overlapped with public land boundaries were retained. Devices tracks that did not intersect public lands, and therefore did not travel through the Rattlesnake Valley PPA network during their travel to RNRAW, were removed. After this data processing, the resulting dataset included 15,259 geolocated points representing 525 unique devices.

3. Visitor Use Density Analysis within the Rattlesnake Valley

Next, the GPS pathing dataset was spatially clipped to remove points that fell outside of Missoula County or within RNRAW boundaries. This dataset was clipped to only include the greater Missoula area, a spatial filter that was defined in ArcGIS Pro using an authoritative data layer representing the Missoula Metropolitan area, with the spatial extent set to fit the metropolitan area in the map frame displayed in Figure 6 and Figure 7. Application of this filter resulted in a sample of 250,944 unique GPS points, representing 4,492 unique RNRAW visitors. These pathing GPS point data were then displayed as kernel density heatmaps. The same analysis was conducted for the 'pedestrian' sample, identified in step two.

4. PSA Analysis

Last, the following steps were taken to prepare the data for PSA analysis. For all RNRAW visitors between February 28, 2021 to February 28, 2023 included in this sample, the dataset included 4,492 visitor CELs. From that sample, 3,947 records had valid latitude and longitude values to establish a CEL. From that sample, the data were further refined to only display those CEL's in the greater Missoula area, which was defined in ArcGIS Pro using an authoritative data layer representing the Missoula Metropolitan area. The resulting dataset included 1,748 unique CEL's. RNRAW visitor PSA analyses were then conducted for this sample representing all local RNRAW visitors (n = 1,748) and for the 'pedestrian' sample (n = 525), representing visitors that were actively recreating through the Rattlesnake Valley PPA network as they travelled-to the RNRAW.

After analysis, these data provided a representative sample of RNRAW visitors that entered the RNRAW between February 28, 2021 to February 28, 2023, including both a sample of local RNRAW visitors and a subsample of RNRAW visitors that utilized the Rattlesnake Valley PPA network. The results of the PSA and pathing analyses, showing relative densities of visitor use and service populations were then used to qualitatively compare the routes that visitors use to travel-to RNRAW. These two paired methods provide an understanding of the composition of RNRAW visitors and their travel behavior while recreating in the study area. Finally, visitation density for the pedestrian sample, represented as kernel density hotspots of use within the Rattlesnake Valley PPA network, provided a foundation for the qualitative interviews conducted to answer this study's second pair of research questions.

**Data Collection: Research Question 2**

Having defined components of visitor characteristics and visitor behaviors for both RNRAW visitors and RNRAW visitors utilizing the Rattlesnake Valley PPA network, the second set of aims in this study seek to gather, interpret, and map the motivations and perceptions that visitors bring to the travel-to phase of their recreation experience in the visitor-streams leading to study area. GPS pathing data analysis identified which corridors and intersections (e.g., trail networks, pedestrian paths) receive the greatest density of use from pedestrian (e.g., non-motorized) users, which determined the initial interview recruitment locations in the Rattlesnake PPA network. Data collection sessions began in the lower portion of the Rattlesnake Valley PPA network at three locations identified by visitor use density analysis: the entrance to Greenough Park, near the intersection of Vine and Monroe St, and on Van Buren St near Gregory Park.

From the identified starting point, interview participants determined the route of travel, continuing until all prompts in the interview guide had been asked and the interview concluded. From that point, the interviewer would either return to a starting location or begin to recruit from the nearest trail intersection to where the previous interview concluded. The scope of this study focused exclusively on visitors engaged in active transit - those who were actively recreating through the Rattlesnake Valley PPA network. Visitors that utilized motorized transportation for their 'travel-to' phase did not pass through the Rattlesnake Valley PPA network, and therefore were not eligible to participate in this study.

"Go-along" interview methods set forth by Carpiano (2009) were adopted, conducted in situ while recreationists are actively engaged in the travel-to phase of their recreation experience (Carpaino, 2009). Interviews followed the application of this method as demonstrated in recent research related to cultural ecosystem services, namely Teff-Seker at al. (2022). Interview methods allowed interview participants to guide the route through their travel-to phase within greenspace visitor-sheds which represent a variety of users, PPA destinations, and available RES.

The interviewer led participants through a semi-structured, conversational interview while adopting a natural approach, as used in Kusenbach (2003), where the one walks with the interviewee (or adopts their preferred transportation method), following their path while the interview progresses. This approach, where the visitor defines the entire route, is reliant on the interviewee possessing a familiarity with the area and agency in their activity. This walking interview method falls on one end of a spectrum of walking interview typologies, opposite more formalized methods such as guided walking tours (Evans & Jones, 2011). During the go-along interview experience, the researcher prompted questions and discussion with the interviewee to encourage reflection on the location(s) where RES are perceived and how they influence recreation decision-making.

Potential interview participants were recruited on-site, using a convenience sampling strategy as approved by the University of Montana IRB (#154-22) (Kvale & Brinkmann, 2009). Interview participants were recruited between September, 2022 and February, 2023. Interview sampling shifts were determined by researcher availability, and included weekend (n = 18) and weekday (n = 14) interview dates.

Following the convenience sampling strategy, potential interview participants were approached at pre-determined locations and asked to participate in the study. In order to qualify for participation, potential interviewees had to: 1) agree to participate and 2) be traveling to the RNRAW. At the recruiting site, all recreationists that passed the interviewer were approached. The interviewer provided a brief introduction to the study, then asked the filtering question "Are you headed to the Rattlesnake National Recreation Area or Wilderness today?". If the potential participant was 18 years or older and responded "yes" to the filtering question, they were eligible to participate. All eligible potential participants that agreed to be participate were interviewed. The interviewer then conducted embodied "walking" interviews with interview participants, matching the recreation activity of the interviewee.

To blend qualitative interview data with spatially-explicit records, interviews were recorded using a Sony hand-held recording device with Rode lapel-microphone attachment, which was synced to a GPS track collected on a Garmin eTrex 10. To sync data collection, the researcher reset and GPS device track at the same time as they started the recording device. Prior to beginning the interview, an audio marker (e.g. "Start") was signaled by the interviewer to capture a starting timestamp for the interview (Evans & Jones, 2011). Garmin eTrex 10 units are cited by the manufacture as having a positional accuracy of within 3.65 meters 95% of the time (Garmin Ltd., 2020). The interview administrator prepared equipment so that the GPS track and the audio recording were started at the same time, marking the start time of the interview, and positioning the audio recording device on the interview participant during the go-along interview. This method for translating walking interviews into qualitative GIS has been cited as the most straightforward and effective means of producing spatial data from walking interviews, as reviewed by Evans and Jones (2011).

Interviews followed a semi-structured interview guide consisting of approximately 12 paired prompts and questions, with each question followed by probing follow-up questions (See appendix 1). The prepared interview guide was utilized by the interviewer to provide comparable results across participants and to continually guide participant responses back to spatially-explicit responses related to the provision of RES. The interview guide allowed, however, for participant responses to range in length and scope, pause, and revisit different components of the interview – allowing for unique insights and to encourage freedom of response (Kvale & Brinkmann, 2009). Questions centered on the direct, active experience and observations of interview participants as they related to RES and route decision-making.

A series of prompts, offered by the researcher over the course of the interview, prompted the interviewee to provide specific reactions and reflections related to RES. Teff-Seker et al. (2022), provide a standardized protocol that has been used to assess CES in PPA settings, which was adapted to assess RES for this thesis. Once started, the interviewee was encouraged to determine the travel route of the interview, following the route that they would have otherwise taken. The interview administrator led the interviewee through the interview guide, which included a series of guided series of prompts adapted from Teff-Seker et al (2022). Participants were encouraged to take their time in responding to interview prompts, to call out and describe their thoughts related to any specific on-trail route decision, and elaborate on points as prompted by the interview administrator.

The interview protocol designed by Teff-Seker and Orenstein (2019), has been applied to assess CES through walking interviews (Teff-Seker & Orenstein, 2019; Teff-Seker et al., 2022). The protocol is broadly based on the "six focusing steps developed by Gendlin to address the felt sense, i.e., the genuine, intuitive, embodied experience", which encourages participants "to "make a space" in the first step, and then, for each successive step, follow stages 2–6 of Gendlin's focusing process (locating the felt sense, holding, resonating, asking, receiving what comes)…" (Teff-Seker et al., 2022, p. 4). Interviewees address their felt sense, along with any other thoughts or reflections, at each step of the phase. As an auto-ethnographic method, researchers must recognize their role in co-creating knowledge with the participant

(Stevenson & Farrell, 2018). Similar studies have presented methods that guide researchers in recognizing their contributions to the findings, while creating space for the interviewees to guide the physical and emotive path of the interview (Teff-Seker et al., 2022; Kusenbach, 2003).

**Analysis: Research Question 2**

To address the second set of research questions for this thesis, semi-structured, embodied "go-along" interviews were conducted in the Rattlesnake Valley PPA network between September, 2022 and February, 2023. 32 interviews were conducted, ranging from 09:12 to 46:25 in length, with an average interview time of 21:52:04. Interviews were digitally recorded and transcribed verbatim; pseudonyms were used in place of participant names (if given) for confidentiality purposes. Interview participants were encouraged to determine the pace of the interview, continuing at their previous pace, slowing to describe a specific area, or stopping to elaborate if they wish. Interview data were collected, transcribed, coded, and later joined with spatial data collected with a GPS device during the interview

This approach aimed to capture different user types, experiences, and activities. Interviews were conducted in the late Summer (n = 4), Fall (n = 23), and Winter (n = 5). Interview participant activities included hiking/walking (n = 8), walking with dogs (n = 11), biking (n = 8), running or jogging (n = 3), Winter "fat" biking (n = 1), and cross-country skiing (n = 1). Two additional interviews were conducted but omitted from results, one due to the poor audio quality and one due to brevity/non-participation.

A qualitative data analysis program, Nvivo, was used to systematically code and organize the data collected in interviews. Interview transcripts were reviewed and edited in full and coded twice. Coding schema were developed in reference to literature that has used qualitative data and inductive coding to assess RES. For example, Rice, Taff et al. (2020) organized visitor sentiments into five categories of RES: 1) adventure and achievement, 2) natural quiet and solitude, 3) nature appreciation, 4) social/family togetherness, and 5) spirituality and inspiration. (Rice et al, 2020). Qualitative analysis depends on accurately identified concepts that later serve as "categories for which data are sought and in which data are grouped" (Lazar, 2017 p.304). These concepts, or coding categories, may be constructed in different ways: from an existing theoretical framework, the researcher's interpretation (research-denoted concepts), and original terms provided by the participants (in vivo codes) (Lazar, 2017). Once a coding approach has been determined, two primary approaches to analyzing the data exist: emergent coding and a priori coding. Emergent coding refers to the qualitative analyses conducted without any theory or model that might guide your analysis – the process simply starts with notes and statements marking interesting concepts or ideas. Those ideas are continuously refined until themes and a coherent model forms that captures the important details. A priori coding involves the use of an established theory or hypothesis to guide the selection of coding categories, often informed from previously published work related to the topic of investigation (Lazar, 2017).

In thematic analysis, once data are collected, the researcher generates short descriptions ("codes") for parts of the text relevant to the research question or field. The researcher then finds recurring themes or thematic patterns among the codes and explains their manifestations and connections with each other in relation to the research topic (Aronson, 1994; Braun and Clarke, 2006). The current study used a mixed approach to coding interview data. To answer the first component of this study's second research question, an a priori coding approach was used to place a narrower focus on the provisioning of RES. To answer the second component of this study's second research question, which attempted to identify how RES informs visitor decision-making, I adopted a grounded approach to qualitative coding. This approach incorporated the a priori definitions of RES, but also allowed for emergent codes and themes to develop while interpreting the interview data. The ground-up or inductive analytical method was used to discover the various types of RES-related insights that the interviews provided which did not align with the theoretical background applied to a priori codes, allowing for the development of themes and codes without defining all theme categories beforehand (Teff-Seker et al., 2022).

Each interview was analyzed separately, then codes from the group of 32 interviews were analyzed collectively. A new "theme" was determined if at least 10% of the site sample respondents addressed it, to avoid purely individual or anecdotal themes (Teff-Seker et al, 2022). The first pass of coding focused on applying a priori codes and highlighting potential emergent codes, the second pass reviewing code assignments for uniformity and to apply emergent codes to the data (idiographic analysis) (Patterson & Williams, 2002). For those individual codes that were emergent and identified via idiographic analysis, overarching themes across cases were then identified, coded into broader themes, and assigned into categories which spanned across individuals (nomothetic analysis) (Patterson & Williams, 2002). These elements represent themes that were persistent across interviews, and elevated to the thematic level of the themes for Recreational Ecosystem Services, which were theoretically derived though a priori analysis. See table 4 for a list of the major interview content themes that were coded. Once fully coded, interview data were then used to produce a geographic representation of visitor perceptions of RES and visitor decision-areas informed by RES.

Interview results, then, were translated into a 'spatial transcript' of visitor perceptions and decision-making factors related to RES across space. Spatial qualitative analysis is the identification of spatial patterns associated with qualitative data, often utilizing one of two primary approaches: manifest data collection or latent spatial data collection (Steinberg & Steinberg, 2015). In manifest spatial data collection, the researcher actively plans to incorporate some geographic information into the case-by-case data collection process. For instance, you might have a survey that asks a series of questions about a particular topic and also establishes a geographic locator for the person or household that completes the survey. Latent spatial data collection is used when some form of geographic location may be attached or connected to the data but you have to find, tease out, or append that information to the data. (Steinberg & Steinberg, 2015). This thesis, collecting interview data in tandem with a GPS track, represents an application of manifest spatial data collection (Evan & Jones, 2011; Lazar, 2017). This practice introduces an active, embodied collection of spatial data that complements the interview method while building off similar studies that have organized thematic RES codes that capture visitor perceptions are attached to individual locations or managerial settings (as in Rice, Taff, et al., 2020). By mapping qualitative interview results in conjunction with the PSA, this analysis can assess RES provisioned during the travel-to phase. A better understanding of visitor decision-making, particularly those that may be directly related to management issues, provides an important insight into management implications across greenspace networks.

**Table 1. RES Themes used to code interview data.**

| **RES Themes**<br>Sample (*n*=32 interviews) | **Theme Category** |
|---|---|
| **RES-Informed Route or Location Decision** | **RES [a priori],<br>Visitor Decision-making [a priori],<br>& Emergent** |
| **Spirituality, Reflection, or Inspiration** | **RES [a priori]** |
| **Nature Appreciation** | **RES [a priori]** |
| **Routine** | **Emergent** |
| **Social or Family** | **RES [a priori]** |
| **Adventure & Achievement** | **RES [a priori]** |
| **PPA Networks** | **Visitor Decision-making [a priori]** |
| **Rattlesnake Valley-Specific Values** | **Emergent** |
| **Solitude and Quiet** | **RES [a priori]** |
| **Feedback to Managers** | **Emergent** |
| **Recreation Conflict** | **Emergent** |

GPS unit-derived position data were collected at 15 second intervals. GPS tracks were saved as point features for analysis in ArcGIS, where each interview track is represented as a series of points spaced by 15 seconds of travel time. Following the guidance of D'Antonio et al (2010), 15 second intervals provide an adequate resolution of visitor behavior, while still producing a dataset that is manageable in size for data processing and analysis. In this sample of interviews, 5 of the 32 interview tracks had some, though minimal, level of GPS satellite connectivity interference during the interview and had timestamps that differed from the predetermined 15-second intervals within the GPX track. Factors influencing GPS signals can include topography, vegetation cover, and weather conditions (D'Antonio et al., 2010). For these tracks, data were cleaned to provide a matching temporal field to their respective interview transcript's coded statements.

Data were then exported from Nvivo, converted to time-stamped codes, and organized as tabular data. Coded statements were joined to a GPS timestamp (spaced at 15-second intervals) that fell most closely to the time of the statement in ArcGIS Pro, with statements treated as individual points. For statements that spanned multiple point units of time (e.g. 30+ seconds), the temporal mid-point of the coded statement was used to join the coded statement with its temporal location within the elapsed time of the GPS track. To answer the second research question, the distribution of coded values across the greenspace network were qualitatively assessed as individual tracks and in sum. This approach followed the basic outline presented in Evans & Jones (2011) as "the most technically innovative level of analysis involved mapping the conversation in a GIS through the creation of spatial transcripts" (p. 852).

Statements that were coded to RES-informed decision-making codes display the density of coded statements across the interview sample population. Coded statement points were mapped as a kernel density 'heatmap', where each cell in the rasterized visualization is assigned a value that represents its relative density in the mapped dataset. RES-informed decision points were mapped using a kernel density method, with densities drawn with a radius of 30 screen point units, an upper density threshold set to 1.00, and no weight applied to the dataset. Spatially-explicit RES statements are shown as a heatmap, using the same kernel density method, with a radius of 15 screen unit points, an upper density threshold set to .80, and no weight applied to the dataset. (ESRI, n.d).

The application of methods used to answer the second research question in this thesis fall into the category data collection methods used in 'public participation geographic information systems' (PPGIS) and data analysis in the family of 'qualitative GIS'. Following examples of qualitative GIS methods to assess visitor perceptions and values (Rice, Taff, et al., 2020; Lowery & Morse, 2013), this analysis allows for visitor decision-making based on RES to be translated directly to a spatial representation of their recreation experience.

# CHAPTER IV: RESULTS

## Mobile Phone Location Data Analysis

***Research Question 1a:*** *How can anonymous, aggregated mobile phone location data be used to conduct a park service area analysis for visitor use monitoring across a network of greenspaces?*

To answer research questions R1a and R1b, analysis produced a PSA and visitor use density analysis for RNRAW visitors, establishing the distribution of local visitors to the RNRAW. To further demonstrate an application of these methods and to inform qualitative analysis for research questions R2a and R2b, the same pair of analyses were applied to a subset of the RNRAW visitor sample population representing visitors that were actively recreating as they travelled to the boundary of RNRAW through the Rattlesnake Valley. This subset of the sample, referred from here on as the pedestrian sample, represents the hikers/walkers, dog-walkers, cyclists, cross-country skiers, skateboarders, runners, and equestrians that utilized the Rattlesnake Valley PPA network as they 'travelled-to' the RNRAW during their recreation experience. This pair of results helps to clarify a focus on the visitor population of interest in this study, the pedestrian subset of the sample (non-motorized travel), and provides a point of comparison against the sample all RNRAW visitors (e.g. approaching RNRAW by motorized or non-motorized travel).

In this study, visitor GPS location pathing points and CEL points were used to obtain a more complete understanding of visitation to the RNRAW. To do this, mobile phone location data were used in the following ways:

1. To identify which local access point(s) host the greatest number of users (thus defining the study area of focus for this thesis, the RNRAW). (Figure 4);
2. To understand what travel networks were utilized by RNRAW visitors (Figure 8);
3. To define the Park Service Area for all RNRAW visitors (Figure 6);
4. To assess the distribution of all RNRAW visitor's home locations across the Missoula area (Table 2);

5. To reduce the sample population to the pedestrian visitor dataset (e.g. only those visitors that utilized the Rattlesnake Valley PPA network via non-motorized travel on their way to RNRAW), and to understand the density of use among that sample population across the study area (Figure 9);
6. To define the Park Service Area for those users (Figure 7); and
7. To assess the distribution of that sample population's home locations across the Missoula area (Table 3).

For all RNRAW visitors, the original pathing dataset included 349,803 individual location points (between February 28, 2021 to February 28, 2023). Each point provides metadata that includes the location, date, and time where that individual mobile device connected to a cellular network. These points were first used to identify which transportation networks and local access point(s) host the greatest number of visitors accessing RNRAW (Figure 4). This exercise demonstrated that the greatest density and the majority of visitation to RNRAW occurs in the Rattlesnake Valley. Figure 4 shows the relative density of visitor location points entering RNRAW, highlighting the predominant density of local access and use of the RNRAW that occurs through the Rattlesnake Valley.

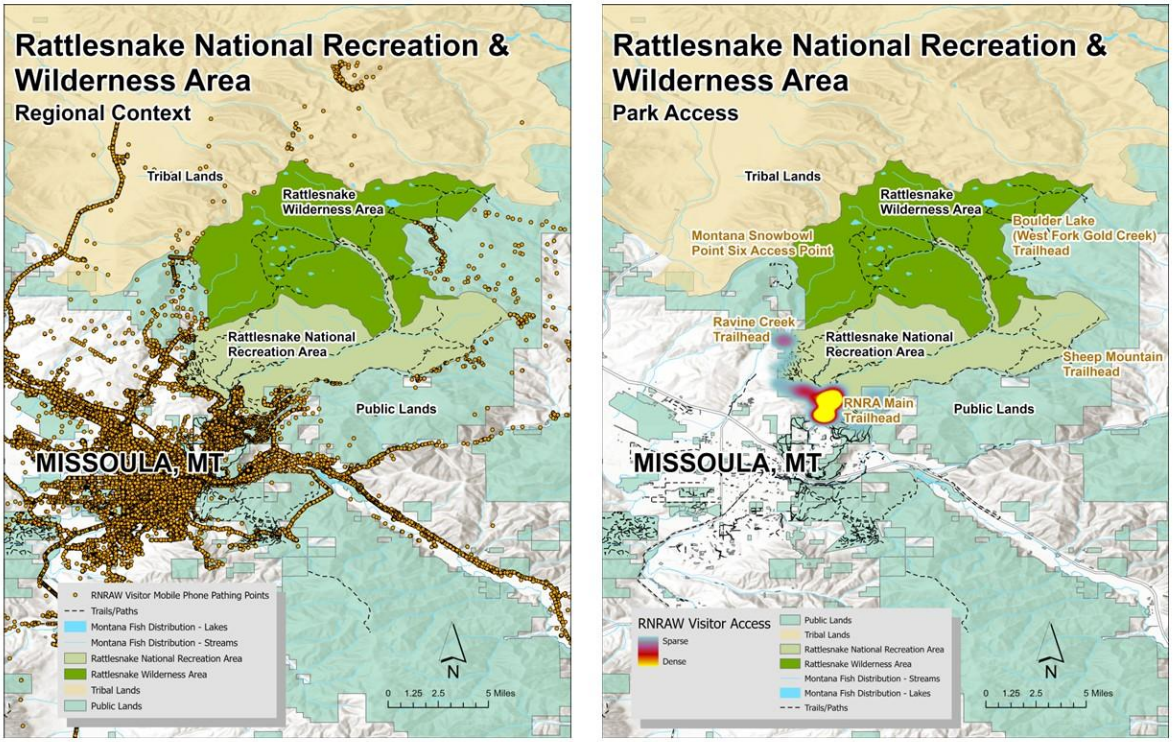



**Figure 4. Regional visitation patterns were assessed for all visitors to determine the density of visitation to established RNRAW local access points.**

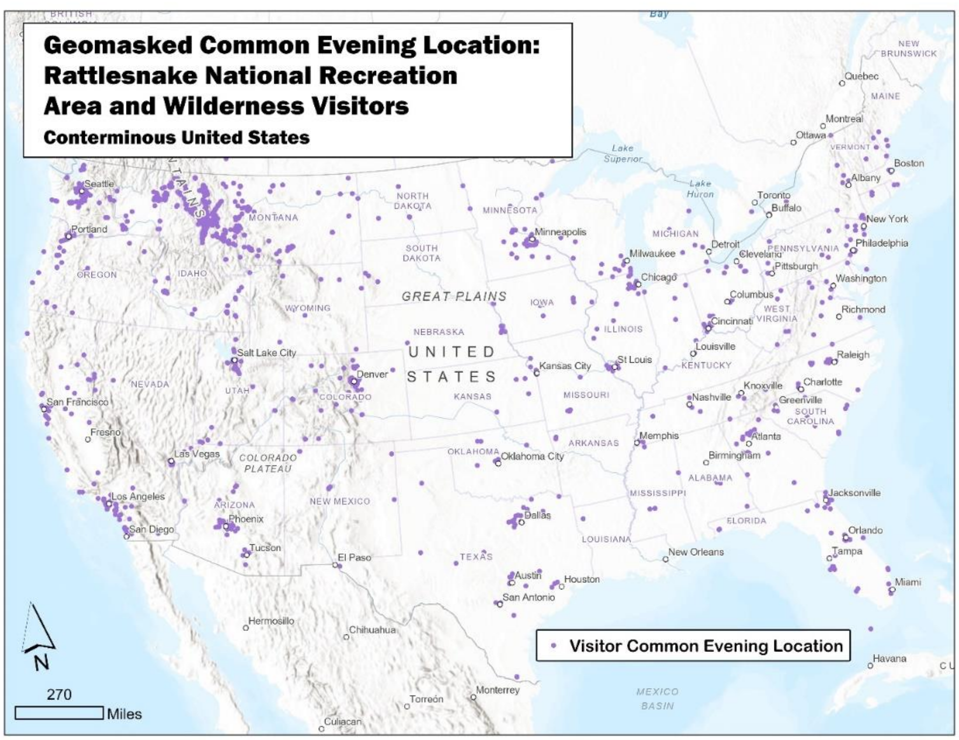


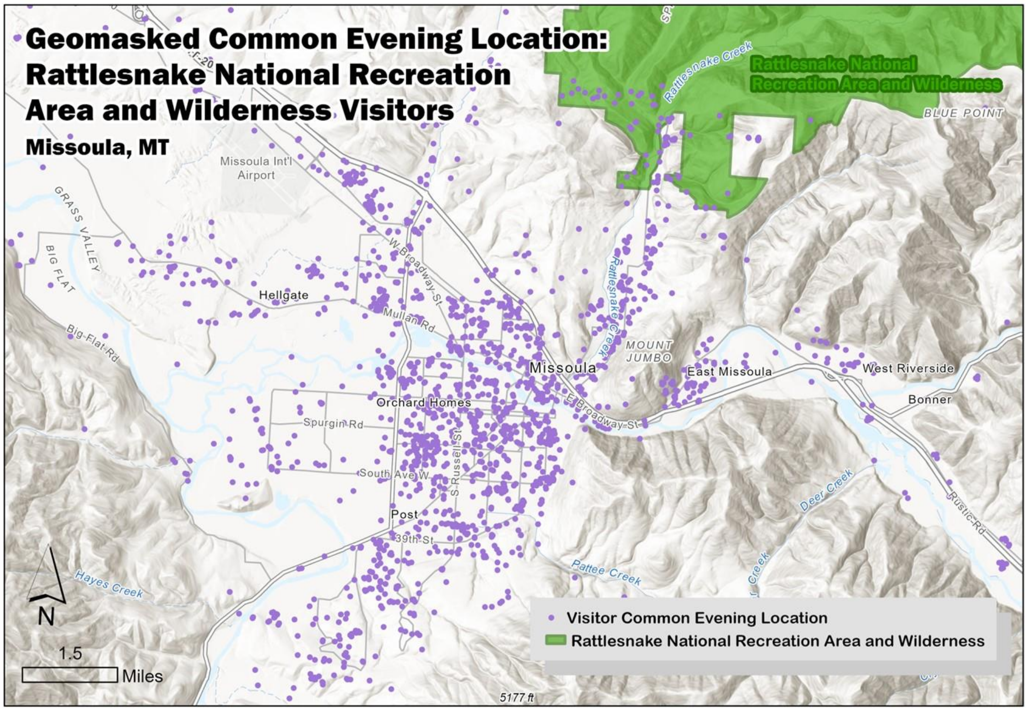

**Figure 5. RNRAW Visitor Common Evening Locations (CEL), visitors between February 28, 2021 to February 28, 2023 (n = 3,947).**

For all RNRAW visitors between February 28, 2021 to February 28, 2023 included in this sample, the dataset included 4,492 visitor CELs. From that sample, 3,947 records had valid latitude and longitude values to establish a CEL, shown in Figure 5. 26.8% of RNRAW visitors had CELs outside of the state of Montana, and visitation included visitors from across the United States. Home location points from that sample of visitors were summarized to quantify the proportion of visitors that live in the state of Montana (n=2,891), within Missoula County (n=2,294), within Missoula's city limits (n=1,517), and local geopolitical boundaries. Results summarized in table 2. Those visitor CELs that were within the greater Missoula area (n = 1,748) were used to conduct a PSA analysis, shown in Figure 6.

**Table 2. Spatial Distribution of Rattlesnake National Recreation and Wilderness Area (RNRAW) Visitor's Home Locations as a Percentage of Total Visitation.**

| **RNRAW Visitors** | Sample (*n*=3,947) |
|---|---|
| City of Missoula (n = 1517) | 38.4% |
| Ward 1 as a percentage of City of Missoula visitors (n=390) | 25.8% |
| Ward 2 as a percentage of City of Missoula visitors (n=268) | 17.7% |
| Ward 3 as a percentage of City of Missoula visitors (n=235) | 15.5% |
| Ward 4 as a percentage of City of Missoula visitors (n= 206) | 13.6% |
| Ward 5 as a percentage of City of Missoula visitors (n=173) | 11.4% |
| Ward 6 as a percentage of City of Missoula visitors (n=242) | 16.0% |
| Florence (n=164) | 4.2% |
| Lolo (n=98) | 2.5% |
| East Missoula (n = 64) | 1.6% |
| Target Range (n=57) | 1.4% |
| Bonner-Milltown & West Riverside (n=50) | 1.3% |
| Frenchtown (n=35) | 0.9% |
| Orchard Homes (n=29) | 0.7% |
| Missoula County (n = 2,294) | 58.1% |
| State of Montana (n = 2,891) | 73.2% |

*** 1,514 points were included in the sample used to calculate the distribution of visitors by ward.**



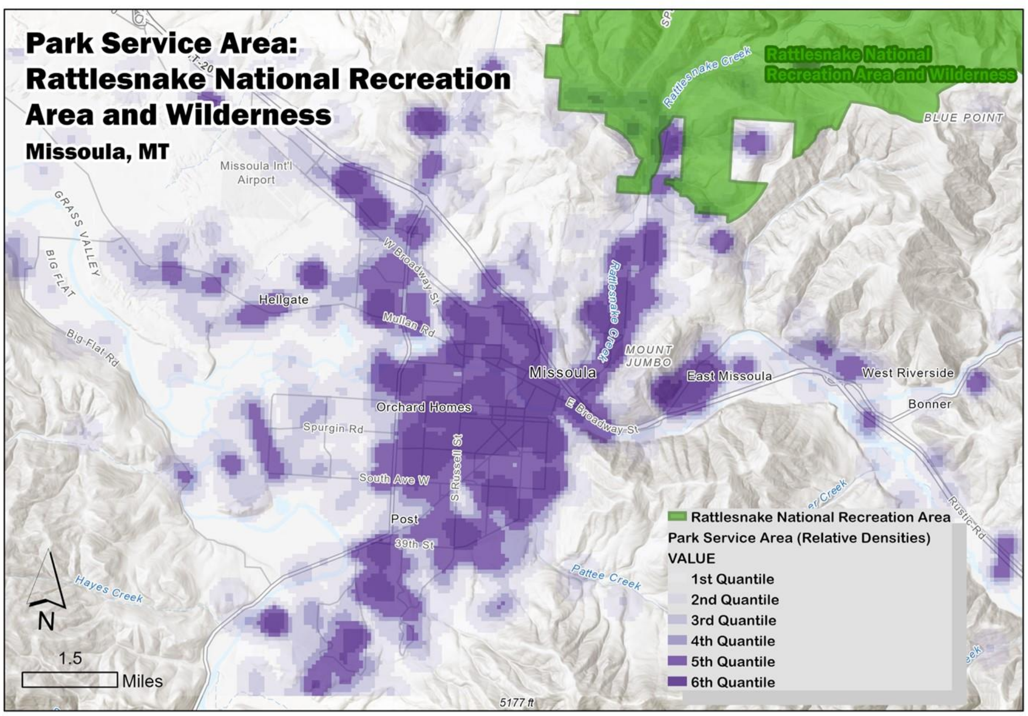



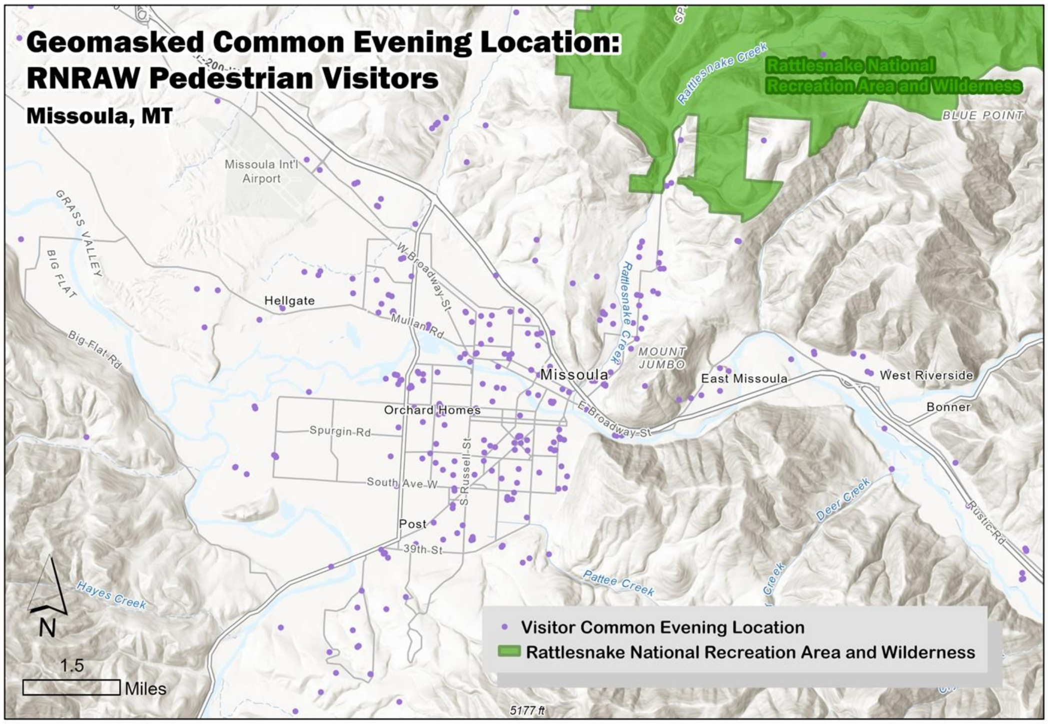

**Figure 6. Common Evening Location and Park Service Area for all RNRAW visitors (vehicle and pedestrian-based) in the greater Missoula Area.**

Data analysis then isolated the 'pedestrian' sample, which consists of those devices that represented RNRAW visitors that were actively recreating (non-motorized travel) through the Rattlesnake Valley PPA network during their travel-to phase. The pedestrian sample included 15,259 geolocated points representing 525 unique devices. The distribution of this visitor sample is summarized in Table 3. Using the CELs of the pedestrian sample (n = 525), a PSA was defined for this sample. This PSA, shown in Figure 7, represents the kernel densities of home locations for the pedestrian sample - visitors that utilized the trails and greenspace of the Rattlesnake Valley PPA network in the travel-to phase of their recreation experience.

**Table 3. Spatial Distribution of Common Evening Locations for Rattlesnake National Recreation and Wilderness Area (RNRAW) Visitor's that were determined to have accessed RNRAW via the Rattlesnake Valley PPA Network**

| **RNRAW Pedestrian Visitors Utilizing Rattlesnake Valley PPA Network** | Sample (*n*=525) |
|---|---|
| City of Missoula (n = 237) | 45.1% |
| Ward 1 as a percentage of City of Missoula* visitors (n=71) | 30.6% |
| Ward 2 as a percentage of City of Missoula visitors (n=39) | 16.8% |
| Ward 3 as a percentage of City of Missoula visitors (n=35) | 15.1% |
| Ward 4 as a percentage of City of Missoula visitors (n= 31) | 13.4% |
| Ward 5 as a percentage of City of Missoula visitors (n=39) | 16.8% |
| Ward 6 as a percentage of City of Missoula visitors (n=17) | 7.3% |
| Florence (n=17) | 3.2% |
| Lolo (n=18) | 3.4% |
| East Missoula (n = 9) | 1.7% |
| Target Range (n=12) | 2.3% |
| Bonner-Milltown & West Riverside (n = 12) | 2.3% |
| Frenchtown (n=1) | 0.1% |
| Orchard Homes (n=5) | 0.9% |
| Missoula County (n = 343) | 65.3% |
| State of Montana (n = 403) | 76.8% |

***232 points were included in the sample for the distribution of Missoula visitors by ward.**



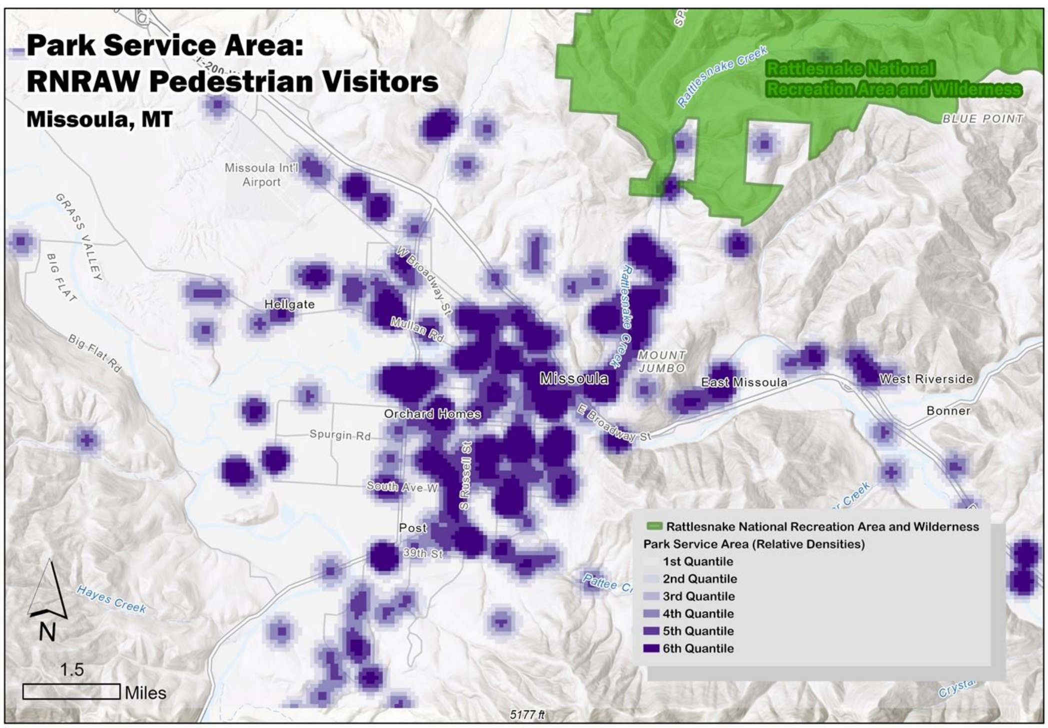




**Figure 7. Common Evening Location and Park Service Area for pedestrian visitors to RNRAW from the Missoula metropolitan area (those visitors that utilized the Rattlesnake PPA network through non-motorized travel).**

***Research Question 1b:*** *What routes to or between PPAs (and their relative density of use) are identified through spatial analysis?*

PSA analyses provide an understanding of who visitors are (e.g. demographic information) and where they are coming from (e.g. home location). After establishing the PSA of all RNRAW visitors and the PSA for RNRAW pedestrian visitors, GPS pathing data provides further insight into the distribution of those visitors in a specific temporal phase of their recreation experience, the travel-to phase. Figures 8 and 9 represent the travel-to phase for visitors approaching RNRAW through the rattlesnake valley. Figure 8 shows mobile phone location data points for all visitors in this sample travelling to RNRAW, and the relative density of those points as they travel to RNRAW through the Rattlesnake Valley. Here we see the greatest concentration of visitors travelling along road networks as they approach access points immediately adjacent to RNRAW boundaries. Corridors that include a greater density of visitors traveling to RNRAW include nearby highway exits and W. Greenough, Lolo St, and Van Buren Streets funneling into Rattlesnake Drive and the Main Rattlesnake Trailhead.

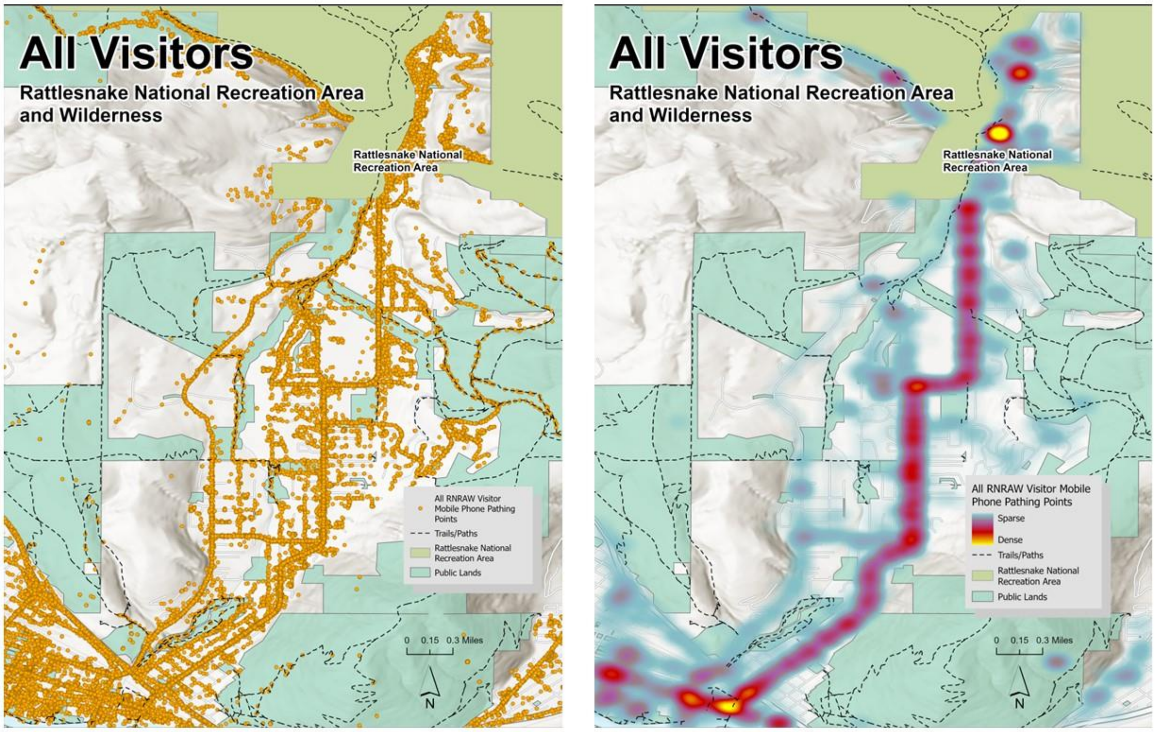



**Figure 8. Mobile phone location data sample of all visitors to RNRAW travelling through the Rattlesnake Valley between February 28, 2021 to February 28, 2023.**

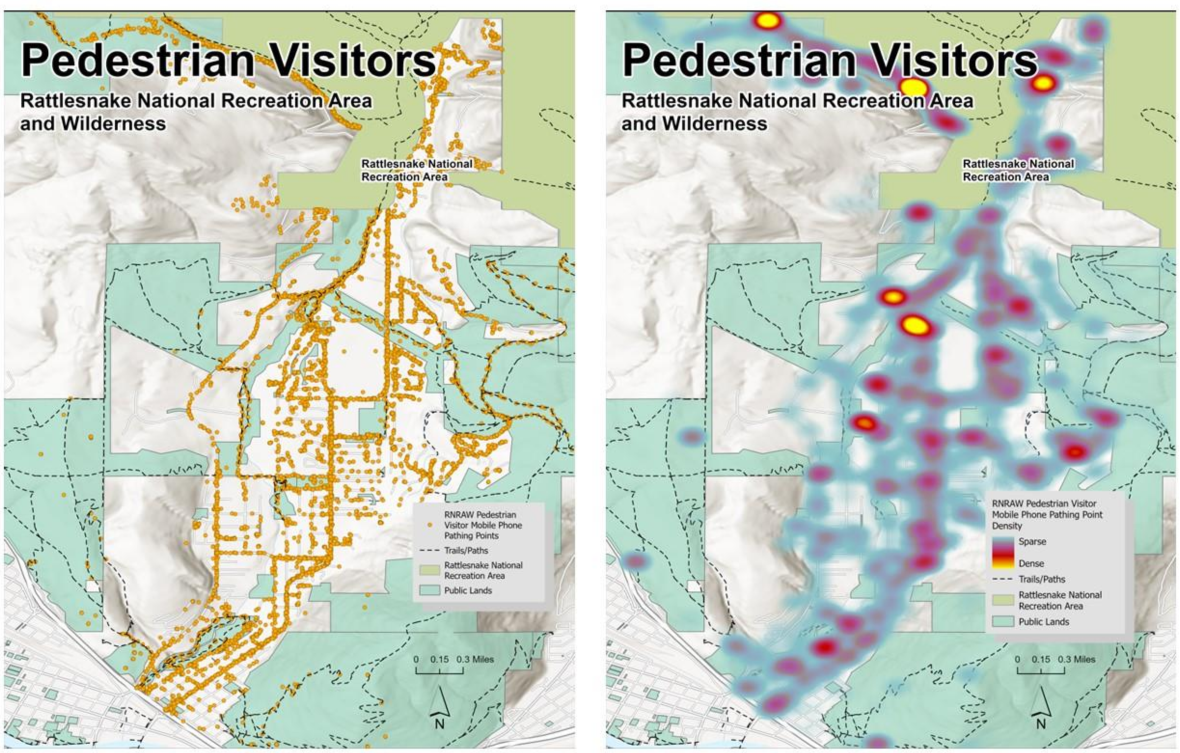



**Figure 9. 'Pedestrian' visitors utilizing the Rattlesnake Valley PPA Network to access RNRAW.**

Figure 9 displays the GPS pathing points and visitation density for the pedestrian sample. These RNRAW visitors were selected for travel speed and PPA network presence to represent visitors that were engaged in active transit on their way to RNRAW. In this case, we see a more dispersed distribution of use. Use concentrates along side streets, major trail corridors, and the numerous trailheads or local access points for the series of PPAs in the Rattlesnake Valley leading to RNRAW. A comparison of these two representations of visitation density (Figure 8 and Figure 9) highlights the potential differences in the resource, social, and managerial settings experienced by these two samples of RNRAW visitors during the travel-to phase of their recreation experience. Importantly, these samples do not represent all visitors to the RNRAW. Rather, the samples are a representative, random sample of visitors which are derived from a panel of mobile phone devices (as a proxy for visitors) compiled by Near, the mobile phone location data vendor (Ubermedia, 2021a). Limitations associated with the use of mobile phone location data will be described in greater detail in the limitations section of this thesis.

**Recreational Ecosystem Services and Visitor Decision Making**

***Research Question 2:*** *How do visitor perceptions of RES vary across space within the travel-to phase of the recreation experience?*

A robust understanding of visitor behavior on the ground, while valuable, cannot provide an accurate knowledge of the underlying values behind that behavior (Rokeach, 1973). Without theory to guide an understanding of the underlying motivations and values behind behaviors, there may be no real or actionable knowledge generated by research, particularly concerning applications of big data (Li et al., 2018). To interpret the underlying motivations for the travel behavior identified through PSA and pathing analysis, this study aimed to create space for the language and perceptions of visitors on the ground, actively involved in a distinct phase of their recreation experience. The reflections and perceptions of visitors are then used as participatory GIS datapoints related to RES perception, decision-making based on RES outcomes, and their recreation experiences in greenspace networks. Finally, the qualitative interview data were related to spatially-defined hotspot data to provide a more holistic understanding of the visitor experience—combining descriptive and evaluative data (Manning, 2011).

In this this study, the results of the visitor use pathing analysis provided the foundation for a more comprehensive understanding of the recreation experience among RNRAW visitors utilizing the Rattlesnake Valley PPA network. Visitor use monitoring analysis identified hotspots of use within the PPA network for the particular population of interest (the pedestrian sample), defining locations for interview participant recruitment. Interview data were then used to examine how these visitors perceived RES during the travel-to phase of their experience, and how RES informed the decision-making process that determined their recreation experience.

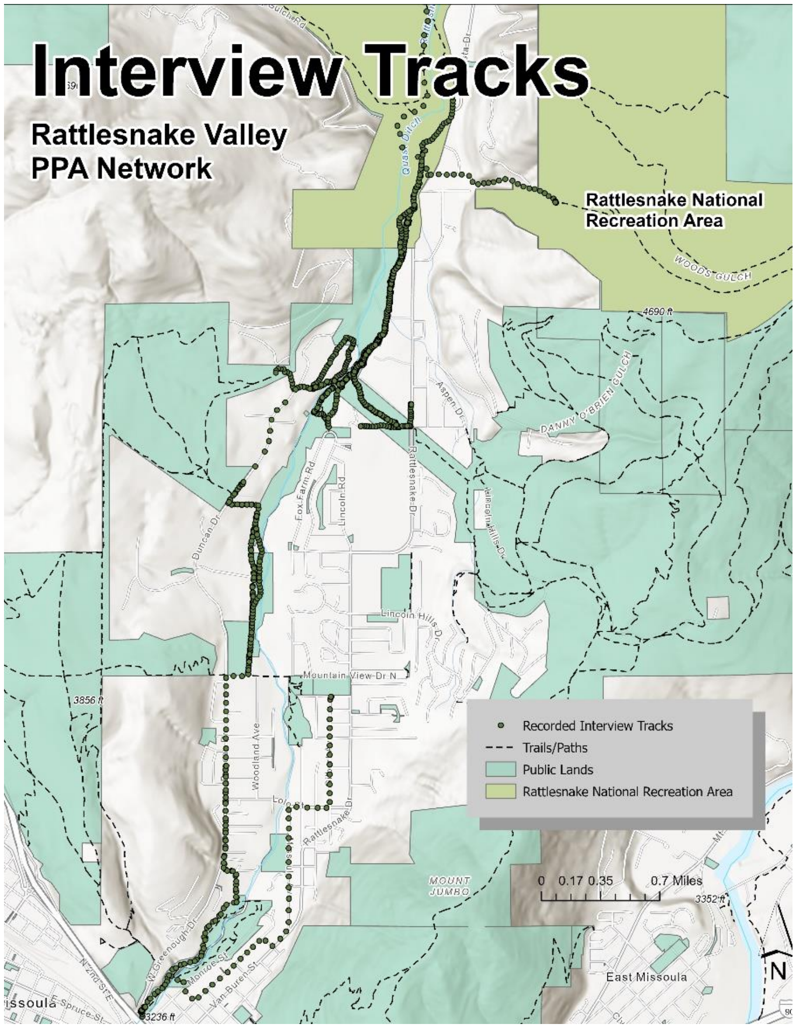



**Figure 10. Interview GPS Tracks**

32 interview tracks, shown in Figure 10, provided interview coverage across much of the study area. Interview recruitment started in the lower portions of the Rattlesnake Valley PPA network, then travelled along individually-defined visitor-streams, following the routes of participants as they travelled to RNRAW. Data collection began at the three locations, as determined by the results of an initial visitor use density analysis: the entrance to Greenough Park, near the intersection of Vine and Monroe St, and on Van Buren St near Gregory Park. Interview participant activities included hiking/walking (n = 8), walking with dogs (n = 11), biking (n = 8), running or jogging (n = 3), Winter "fat" biking (n = 1), and cross-country skiing (n = 1).

All a priori themes were represented in the interview data, coded as 1) spatially-explicit RES statements, 2) specific route or location choices informed by a priori RES themes, or as 3) statements related to the theme of PPA networks or connections. In addition to a priori themes and codes, the emergent themes of “routine”, “Rattlesnake Valley greenspace-specific values”, “feedback to managers”, and “recreation conflict” were identified through inductive analysis and added to the coding schema. Coding schema, along with categories of theme development and representative quotes, are included in Table 5. Spatially-explicit RES statements were restricted to a priori codes, including statements related to themes of spirituality, reflection, or inspiration (n = 156 statements), nature appreciation (n = 126), social or family (n = 63), adventure & achievement (n = 58), and solitude or quiet (n = 39). In sum, 611 statements were coded to the a priori RES themes (including 169 statements coded to a priori RES-informed route or location decisions), 57 statements were coded to the a priori theme of PPA networks or connections, and 211 statements were coded to emergent themes.

**Table 4. Qualitative interview data codes, including both pre-determined a priori codes and emergent codes.**

| Interview Data: Codes & Representative Quotes | | | |
|---|---|---|---|
| | | | **Sample (*n*=32 interviews)** |
| **Coding Categories** | **Themes** | **Example Child Codes** | **Representative Quotes** |
| **RES [a priori]** | **Spirituality, Reflection, or Inspiration** n= 156 | Personal Reflection during recreation n=28<br>Role of this place in the interviewee's life n=27<br>Appreciation generally n=19<br>Mental reset or break n=16<br>Spirituality, reflection, or inspiration route choice n=16<br>Importance of conservation n=13<br>Peaceful n=6 | "We moved here in 1984, just around the corner. So I used to ride my bike up here all the time before. Well, I guess before that developed at all… Yeah, I just wander around all over the place. I come here because I feel like this is my area…. Yeah, I'm a lot older. Yeah, a lot slower. But this is why I live here. It's because of outdoor recreation, just being outside and not being too crowded."<br><br>"Today, I as it happens, I just taught public lands. So I was kind of just debriefing in my own mind about how the class went and how the students responded and things that I will probably try to change up next time to do it a little better, more effectively. You know... and that's often the case. If I'm in the morning, I'm looking ahead, thinking about what am I going to do today and who am I trying to reach? What do I want to accomplish? How do I want it to go? And if it's more, at the end of the day, I'm thinking about how did it go? What might I want to do better? So that's part of it is very reflective in terms of preparing for or debriefing. And that's true almost whatever activity I'm engaged in, except for maybe horseback riding, because then I'm just thinking about the horse and being very present in that experience with that animal." |
| | | | |
| **RES [a priori]** | **Nature Appreciation** n= 126 | Nature Appreciation route choice n=44<br>Selection based on conditions N = 12<br>Beauty n=11<br>Signs of nature n=10<br>Changes in nature n=9 | "So when I'm out here, especially on my own, I'm mostly reflecting on nature."<br><br>"I'd say for me, it's the natural beauty, the sounds, the birds, the river. We just crossed over river. The sound of my feet on the trail and not a paved road. Yeah, just the sky and the trees. It's just we're just out in nature, you know, that'sind of my best experiences. Like, I'm in nature, and that is rejuvenating for me. You know, I had a big workday today, lots of people. Now I get to do this and kind of like exhale and just kind of be…"<br><br>"I might be different. I usually am pretty nature focused. I mean, I think some people think about problems, but I am so lost in how beautiful it is that it doesn't really think |

| | | | |
|---|---|---|---|
| | | Sounds of nature<br>n=9<br>Views<br>N = 9<br>Selection based on habitat<br>N = 6 | about anything else. Yeah, well, I think I'm lucky because I know being with other people, I noticed their they don't seem to notice what's around them. They seem to be more internal. Yeah. And for me, this is so overwhelmingly beautiful. It's like I become one with it. And so its a really good experience, no doubt…" |
| | | | |
| **Emergent** | **Routine**<br>n= 79 | Routine or familiar route choice<br>n=55<br>Convenience route choice<br>n=10<br>Easy or accessible<br>n = 6 | "So I started up. I parked at the power lines. So I come up here depending on time. Yeah, today is probably a shorter one. I'll walk up here across the street, you know, by the main trailhead, the tarmac, go on the other side and I'll go up to the horse gate and then I'll turn around. But I'll take all the different paths that are available in that distance. Yeah. Like I kind of make as much of a circle as I can without, like, doubling back on the same trail. "<br><br>"Okay. I am definitely going for a walk. I started on Kanabad, which is where I live and I choose different routes today. I'll probably just go to the end of this trail and then I go up to that next street, Duncan Dr. And go down Duncan to Lolo and then come back home along the creek. Yeah, it's about a four mile walk. " |
| | | | |
| **RES**<br>**[a priori]** | **Social or Family**<br>n= 63 | Social or Family route choice<br>n=19<br>Signs of humans or infrastructure<br>n=14<br>Community<br>n=10<br>Dog-specific interactions or community<br>n=6<br>Neighbors or friends<br>n= 4<br>Family<br>n=4 | **"**Well, I will say it's not nature… But watching this house come together. This one is new. And it's, you know, kind of modern and different. But I've enjoyed watching it kind of come together. And, yeah, they've done a really beautiful job on the landscaping. So I'm always interested in seeing when there's stuff like that."<br><br>**"**I like seeing areas that used to be, you know, farms or people's homes when the rest of the community wasn't here. Yeah. So it just makes me feel like I'm out of town. I like seeing some kind of historic infrastructure. Old farmhouses or something, like, a view without a lot of development on it. How it used to be…"<br><br>**"**I would say up here, like I know from the history that there used to be a lot of up here in through the Rattlesnake, like homesteading people lived in. Sometimes I'll see something that maybe looks like a ruin or, you know, old foundation. Yeah. So that'll pop up into my mind now and then. Yeah. Especially up in the Rattlesnake. There's one up here that I'm always curious about, too." |
| | | | |
| | | Exercise or workout | |

| | | | |
|---|---|---|---|
| **RES**<br>**[a priori]** | **Adventure & Achievement**<br>n= 58 | n=21<br>Adventure & Achievement route choice<br>n=18<br>Trying something new<br>n=6<br>Try something new route choice<br>n=9<br>Fun<br>n=4 | **“**That's really something, your brain catches all these senses, and then squishes something out of it and call it fun.”<br><br>**“**Well, you know, I guess I enjoy a challenge of trying to do a climb. Yeah, but I've been riding all in all since the weather cleared up back in March or. And. But not, as you know, we had some iffy weather. And so I haven't gotten as many miles in as I would normally have. Okay. Right. Turn here. Hit the top of the hill….”<br><br>“It was a good experience, but…you know, I think it's mainly exercise. Really.” |
| | | | |
| **Visitor Decision-making**<br>**[a priori]** | **PPA Networks**<br>n= 57 | PPA Connections route choice<br>n=31<br>Avoid non-PPA impacts (avoid driving, avoid pesticide, bike paths or safety)<br>n=12<br>Infrastructure transitions<br>n=5 | “Yeah. So, in this area, we're seeing a little bit like recreation, infrastructure [points to power station], public lands, but then also right next to kind of agricultural private lands. I mean, I really just think it's a part of the landscape in Montana. There's, you know, and thankfully there's people that do on some of these private lands that have easements that allow people to access their public lands. No, I would just say that it's just kind of part of the ecosystem that we have here in Montana that, you know, has been manufactured over the past, oh, 120 years or I can't remember when we became a state, the 1880s, 1890s, something like that. And its that's I hunt and fish all the time. This is just part of what I have to navigate to get outside.”<br><br>**“**Coming this way is the least traffic route we come through Greenough Park. Yeah. Come up on Jackson the sidewalk into Missoula Ave, up Wiley along the creek along here. So for the most part we've avoided any main road. Yeah. So that's the most important reason we choose this route.” |
| | | | |
| **Emergent** | **Rattlesnake Valley Greenspace-Specific Values**<br>n= 51 | Site memory<br>n=16<br>This place vs. Others<br>n=16<br>Other people – negative<br>n=10<br>Other people – positive<br>n=6 | “I really feel like you can tell that there's more use. Especially on the main trailhead, and it just makes me nervous. Yeah, there's nothing you can do about it. But I think just making sure that this the landscape preserved and more people don't mean... like ruining it.... you know?”<br><br>“I just really... I love what it is here.”<br><br>“I mean, you can look at a forest and it's beautiful and you know, somebody from the East Coast in New York City doesn't quite understand. Like the golden light |

| | | | |
|---|---|---|---|
| | | | we're seeing right now and how just awesome it is to be just outside. And so, the more people that know about it, whether that's hunting, fishing, hiking, camping, mountain biking, as long as it's done respectfully in the lands, treated respectfully, have at it…I think that's the main thing I would want to do is make sure that it's respected.” |
| | | | |
| **RES** <br> **[a priori]** | **Solitude and Quiet** <br> n= 39 | Solitude route choice <br> n=19 | “Oh. Peace. Peacefulness…. And it's often not crowded, which is really which adds to that peacefulness. I think you could sometimes go quite a way without seeing anybody, especially on a weekday. I happen to be retired now so I can recreate during the week. Yeah. Which is really nice. “ <br><br> “It’s huge for me. It's like... the number one thing I'm looking for, whether I'm hunting or fishing or hiking or camping or whatever. It's not that I don't like people. I want everybody to experience this, but it's just like getting away from everybody and everything and just… It's kind of the point of getting out here.” |
| | | | |
| **Emergent** | **Feedback to Managers** <br> n=24 | Other users <br> n=9 <br> Land Management <br> n=5 | “Weeds. Yeah, it's been it's really depressing. Especially where we hike a lot right up here at the what we call the yellow rocks, which is the sunlight trail, basically. “ <br><br> “This is getting way more use than it used to. Yeah, like more than double. Yeah. He used to be able to come up here and it would be one quarter to a third full. This last summer since the pandemic, it's been not just the parking lot, but all the way in. Yeah, that's unusual. That's a new thing, but it means more people are getting outdoors.” |
| | | | |
| **Emergent** | **Recreation Conflict** <br> n= 12 | | “…Because some of them [bikers] are pretty fast. Especially down along the creek. Yeah, that's can be pretty scary. Yeah. Because you don't hear them with the water rushing. And there's a lot of children on those trails from the school. “ <br><br> “…Yeah, it does [inform where I recreate]. Especially on the other side. Where, you know, I'll take trails over there that don't allow bike riders just because of that. You know, the ones where the bikers don't go as often. And I'm a biker too. I'm not saying that it's bad. I just want a little warning.” |
| | | | |

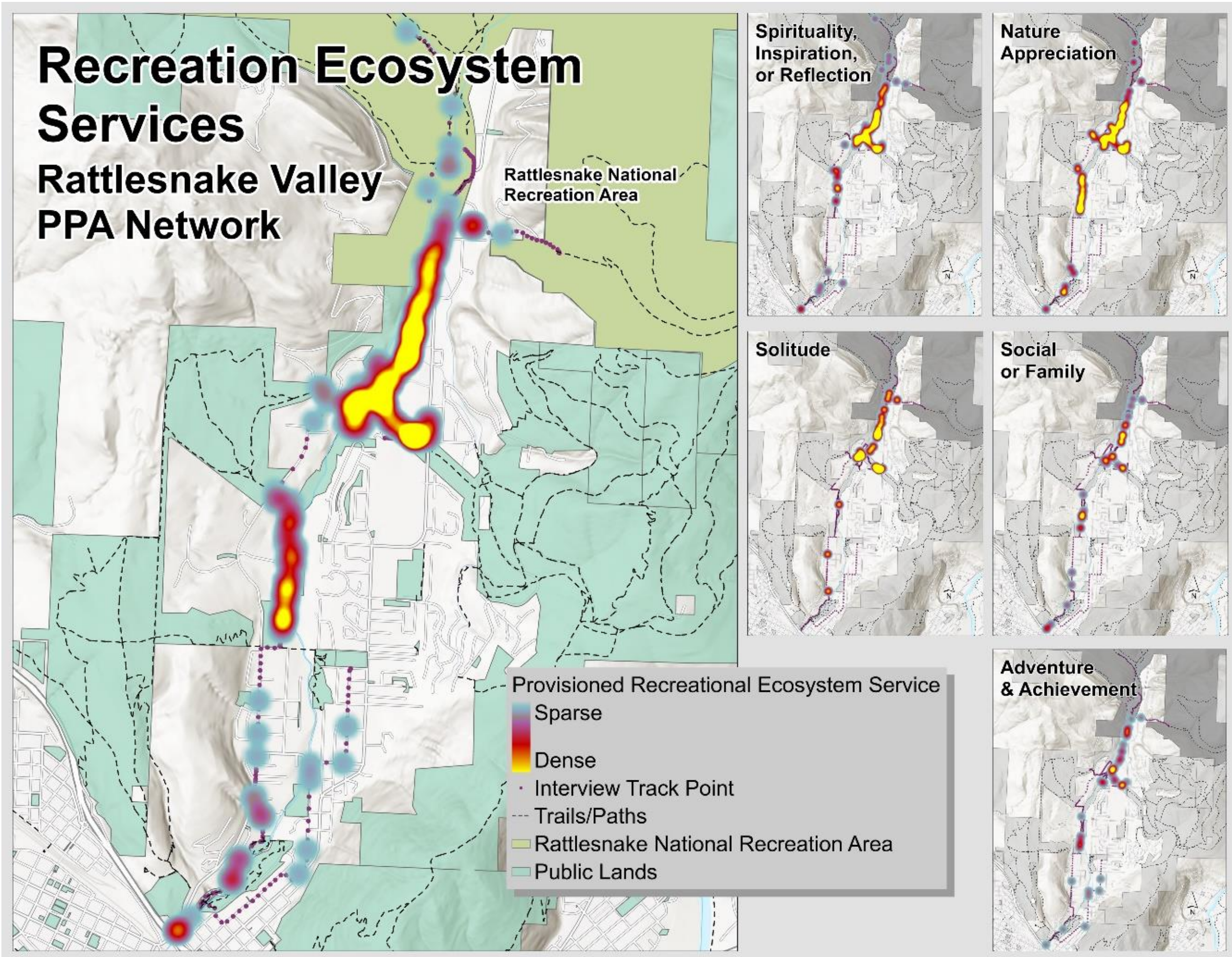



**Figure 11. Map series of interview respondent's identified locations of RES provisioning**

Following a priori and inductive coding analysis of the recorded interview data, coded statements and their respective timestamp in the interview were joined to a matching timestamp in individual GPS tracks. Once attached, the distribution and position of thematic codes can be examined spatially. Trends in the distribution of codes were examined for individual interview tracks, and for the merged sum of all interviews and coded statements. Figure 11 shows the density distribution of spatially-explicit interview statements related to RES, coded and merged across all interviews. Interview participants provided descriptions of RES as they experienced them in the moment during the semi-structured walking interview. I led participants through a series of prompts, included in the interview guide in Appendix 1, that are meant to encourage reflective thinking, put a name to sensory experiences as they occur, and "think at the edge" (Teff-Seker et al., 2022 p.55). Interview participants were prompted to expand upon statements related to the feeling or meaning underlying their recreation experience, and statements were continually clarified by the interviewer over the course of the interview. In Figure 11, the map at left represents any spatially-specific statement about values, feelings, behaviors, or emotions that related to the a priori or inductively coded RES themes. The maps at right show the distribution of statement specific to an individual RES theme.

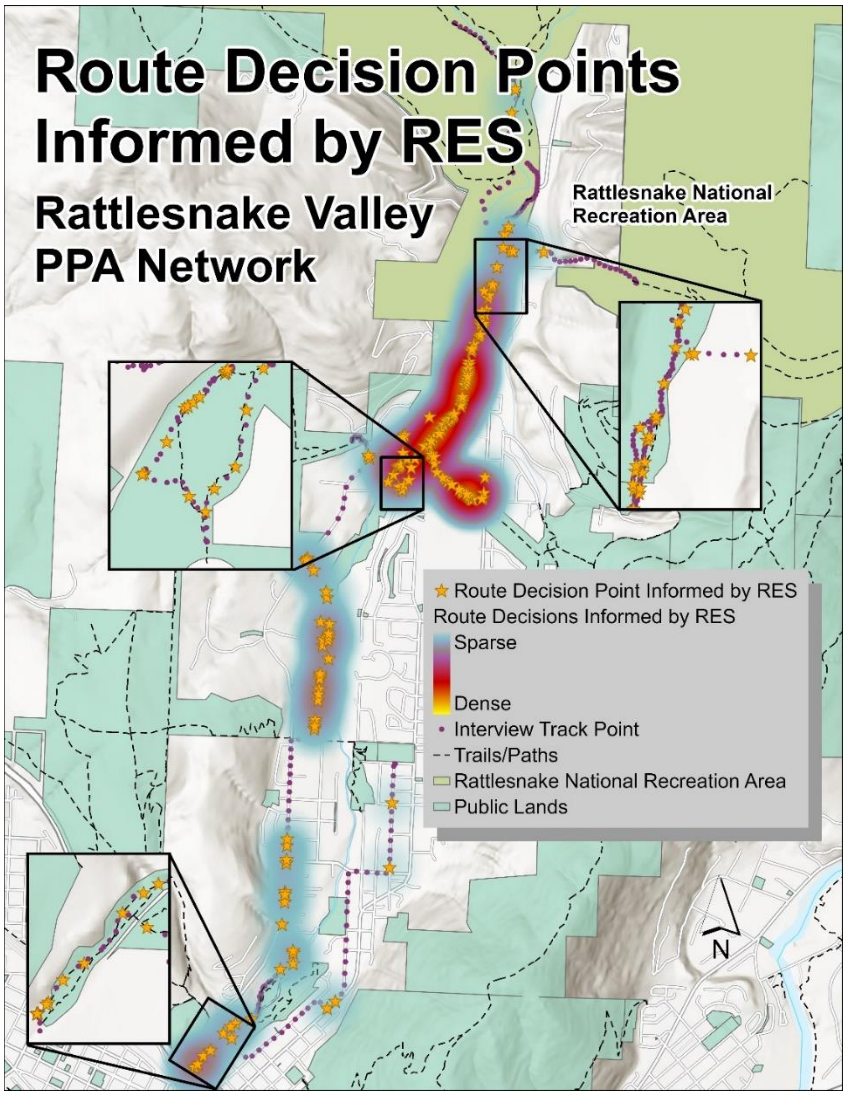



**Figure 12. Interview track points and RES-informed decision points.**

***Research Question 2a:*** *What role(s) do recreation ecosystem services play in visitor decision-making in the visitor-streams leading to PPAs (during what is traditionally thought of as the travel-to phase of outdoor recreation)?*

Questions and clarifying prompts throughout the interview guide encouraged participants to call out, identify, and describe the decisions that were guiding the route choices that were guiding their recreation experience. Figure 12 shows coded points for all RES-informed route or location decision statements, represented as individual points (shown as stars) across all interview tracks. Each point indicated in Figure 12 with a star represents a statement that was coded to the theme "RES-informed route or location decision". To better visualize the distribution of these coded statements, Figure 13 shows the density distribution of coded statements across all interviews. All RES-informed route or location decisions are shown in the heat map exhibit at left, with individual code distributions shown in the map exhibits at right. With a better understanding of how visitors perceive RES across the Rattlesnake Valley PPA network, we can then examine how those perceptions inform the choices that visitors make while recreating.

RES-informed route or location-specific statements were either coded to a priori-defined RES themes or emergent themes, as shown in Figure 13. A priori RES-informed route or location themes including statements related to nature appreciation (n = 43), PPA connections (n = 30), solitude or quiet (n = 19), adventure & achievement (n = 18), social or family (n = 18), and spirituality, reflection, or inspiration (n = 16 statements). Emergent themes included statements related to routine or familiar route choices (n = 45) and descriptions of multiple RES values (n = 8). In sum, 144 statements were coded to the a priori RES-informed decision themes, 53 statements were coded to emergent route-decision themes. Figure 13 shows the density distribution of spatially-explicit interview statements related to RES-informed route or location decisions, coded and merged across all interviews.

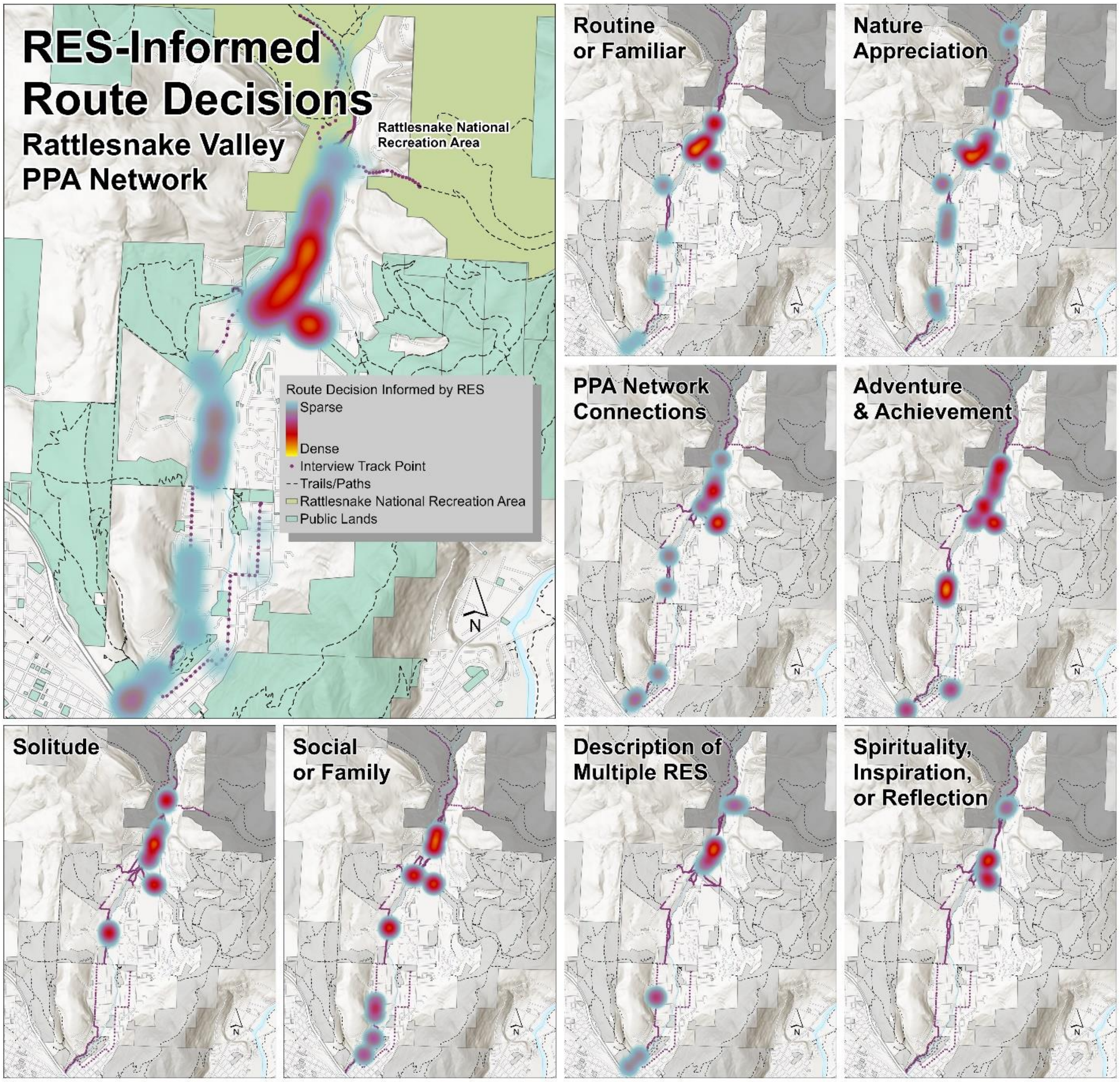



**Figure 13. Map series showing density of RES-informed decision-making locations**

**Table 5. Table of RES-informed decision-making points codes and representative quotes.**

| **RES-Informed Route or Location Decision Codes & Representative Quotes**<br>n= 197 | | |
|---|---|---|
| | | **Sample (*n*=32 interviews)** |
| **Child Codes** | **Example Sub-Child Codes** | **Representative Quotes** |
| Routine or Familiar<br>n= 45 | Convenience<br>Quickest or easiest way | "… this trail is where I brought her [dog] for her first walk. It's her special place. And mine, too."<br><br>"I am going for a run. I try to do it a couple of times a week, start at my house… and try to do a loop. So I do this maybe twice a week at this time of year, maybe more." |
| Nature Appreciation<br>n= 43 | Selection based on conditions<br>Selection based on habitat<br>Views | "It's the nature. Yeah, just the nature. Like the nature and being out in the in the little bit of the wild and then being able to go this way and get a little bit of sun. So if we go left, we get some sunshine. Yeah. So we'll try to do that and get, you know, depends on the weather. If we feel like, oh, we get extra sun, we'll go to the places that have a little more sunshine in the day…"<br><br>"I like it in this part [because I am] seeing the mountains without houses. Yeah, up here, I like the open space. And again, I feel fortunate that we in Missoula have so much open space to walk in and look at. And I love the rural aspect of this area." |
| PPA Connections<br>n= 30 | Avoid non-PPA impacts (avoid driving, avoid pesticide, bike paths or safety)<br>Infrastructure transitions | "Yeah, I try to avoid busy roads as much as possible, so having that trail that goes out along the railroad tracks is really nice. And then obviously coming this way instead of up duncan drive makes it nice also."<br><br>"… one of the rides I really like to do… I ride from my house and I go down, like, railroad avenue or whatever it's called. That border two tracks out towards 93. And then, you know, you go up like Grant Pass. And then you go up like ravine trail and drop in. Sometimes I'll ride the loop out there and come down this way. But there's something to be said for like [when] you leave from [home]... I mean it's a small city, but it's still a city once you're in there... and then you go through this really very, very industrial freight yard. As industrial as it comes. And then grant pass [Grant Creek Rd and up to Ravine TH] … [over there] it's like big kind of over-the-top homes, like and rolling neighborhoods. And then you like, you know, you get on this Forest Service trail and in another hour you're pretty out there, you know, that's kind of a nice set of transitions… And I'm only three and a half mile from the trailhead and [if I bike, then it's] one less car filling it up..." |
| Adventure achievement route decision<br>n= 18 | Try something new | "I came this way today… because I was looking for a challenge" |

| | | |
|---|---|---|
| | | "So we actually, take a turn here… and I get to go down… That's why I love downhill, too, because you can't be in your head. And, you just let it rip…Yeah, and it's not. Well, I don't think it's bipolar-ism. It's just inhale, exhale. Yeah. Learn how to turn on. Turn off. Right side versus left side. Perspectives of things." |
| Solitude or Quiet<br>n= 19 | | "On this trail specifically, being like tucked away comes to mind…"<br><br>"Peacefulness… It's often not crowded over here, which really adds to that peacefulness" |
| Social or Family<br>n= 18 | Infrastructure or human signs | "In this section, I always find fun because it's very possible for me to bump into my friends before I go off my ride and I like to see people. It's kind of like the social part of my exercise route. So it's just good to be out here. It's my connection…"<br><br>**"**That and where like my dog can go easily. Yeah. Which is nice. I feel like there's a lot of other people that are also like...out with their dogs and it feels like a welcoming environment to sort of like have him and him to be able to like meet other animals. So that's kind of another benefit to being on this section of trail." |
| Spirituality or Inspiration or Reflection<br>n= 16 | Mental break or reset | **"**Well, I work to do a lot of thinking about my work. And this part of the trail is kind of a poignant thing to me. I was riding my mountain bike up here and had a crash. Just up ahead here. Broke, shattered my femur pretty badly. I made a mess of myself. I think my fall and all of that led to the trail being re-engineered to the gentle slope that it is now, really prior to the previous slope, which was about to 2x as much… I always look at the spot where I crashed and how that kind of fundamentally changed my life."<br><br>**"**…There's different like stretches of this [part of the walk], like this little narrow area that we just went through. I really like because it feels like sort of closed and enclosed and it just feels like you're a little bit closer to nature. So, I like those pieces of the trail. Yeah. And then any time we go by, water is really nice because he loves to get in there [dog]. So, it's just like an easy little, like sort of mental and physical break." |
| Description of Multiple RES<br>n= 8 | | "It's in one sense routine. I've lived in this area for four years and this is one of two routes I take. I have to go down by the stream on the rattlesnake side, but when it's open, I'll go up and get some elevation change to get my heart rate up on the jumbo side. And so in that sense, it's routine, but in another sense, it never is. There's always something a little bit different, like another critter that joins us on our long, impromptu or here are the different season's hot, cold rain snow. So it's really never routine. And open space is really the reason I moved to Montana. Yes. And I make use of it in some way every single day." |

| | |
|---|---|
| | "It's the Nature. Yeah. The river. The beauty. Just the quiet. Yeah, and the community, too. It's like the people that are out here, just, you know, most people are friendly and say, hey, and its just kind of easy. Yeah. Just kind of a good feeling. Yeah, just the the natural beauty is it. We love it." |
| | |

# CHAPTER V: DISCUSSION

The research questions explored and the methodological approaches utilized in this thesis aimed to emphasis the spatial and temporal connections (i.e., 'visitor-streams') in a recreation experience that could bridge adjacent fields of research to outdoor recreation research (primarily occurring within the PPA 'basin'). As visitors traverse natural resource, social, and infrastructure settings during their travel-to phase of the recreation experience, the interactions that occur on the sidewalks, roads, and adjacent PPAs inform their experience within their PPA destination. A quantitative understanding of RNRAW's PSA and the results of visitor use monitoring using mobile phone GPS pathing data set a foundation for a qualitative exploration in a recreation setting that is under-researched in outdoor recreation literature, the travel-to phase. The study area for this thesis, ranging from road corridors to silent single-track, aims to further define a connective thread between outdoor recreation research, recreational ecosystem service (RES) research, and related research in adjacent fields such as urban planning and public health. Finally, through the exploration of methods and theoretical perspectives, this thesis aims to provide results and methods that contribute a perspective that is useful for management applications.

By conducting analysis that integrates trends identified through the application of big, quantitative datasets with trends identified through qualitative, thematic analysis of interview data, this study represents a mixed methods approach to mapping RES (Teff-Seker et al., 2022; Pavlovskaya, 2009; Schuurman, 2009). The dialogue between the spatial, technological processes and qualitative methods led Cope and Elwood (2009) to conceptualize GIS as eminently mixed-method practice, method, technique and epistemology. Pavlovskaya (2006; 2009) argues that GIS research does not fit neatly into either quantitative or qualitative categories. Both quantitative and qualitative approaches can provide scientific rigor, emphasize complexity or simplicity; and both are socially embedded and constructed (Pavlovskaya, 2009). Thus, GIS is a tool that does not come with an inherent epistemology. Therefore, it fits especially well with mixed-methods approaches, creating connections between positivism with reflexivity, post-positivism, and pragmatism paradigms (Brown et al., 2017; Martin & Schuurman, 2020).

**Mobile Phone Location Data Results**

The first consideration for this discussion, then, is regarding the application of mobile phone location data to the Rattlesnake PPA network. The use of GPS tracking is an essential tool for visitor use monitoring research on human movement and spatial patterns of use in PPAs, and the use of mobile phone location data's GPS pathing records represents a novel, big-data source of GPS locations that could inform a number of questions related to the spatial patterns of PPA visitors (D'Antonio et al, 2010; Monz et al., 2019; Guan et al., 2020, Rice et al., 2022; Whitney et al., 2023). This study utilized an approach that used an established application of this data (PSA and visitor use density analyses) in a novel setting (PPA networks), to inform a qualitative interview methodology.

An important consideration of the Near dataset and future research utilizing mobile phone location data is an exploration of the utility of visitor location data provided from mobile phones across geographic (biophysical) settings. Mobile phone location data provides the distinct advantage of tracking visitor movement across their entire recreation experience (as opposed to just within a PPA) (Monz et al., 2019). However, the exact mechanics of mobile phone location data quality across geophysical settings is an area in need of further research. The processes of analysis that produce samples of location data vary between mobile phone location data vendors, and there has been limited research to date assessing the utility of this data in areas with limited availability of mobile network coverage (Whitney et al., 2023).

4G LTE coverage distribution for device-users connected to cellular networks through AT&T Mobility, T-Mobile, US Cellular, and Verizon are tracked and reported by the Federal Communications Commission for both voice and data. Data coverage is displayed in the map below if it is provided by a carrier with at least "5/1 Mbps, 90% cell edge probability, 50% cell loading factor at a maximum resolution of 100 meters" (FCC, 2021). In this study area, as shown in Figure 14 showing cellular service in the Rattlesnake Valley, LTE data coverage was determined to be adequate for this application of device-level mobile phone location. Though not shown in Figure 14, LTE data coverage across the region illustrates significant gaps *within* the boundaries of RNRAW (FCC, 2021). Given this level of coverage in backcountry areas of RNRAW, I question the ability to obtain an effective sample size with acceptable accuracy within the bounds of the park itself, however such analysis is beyond the scope of this project.

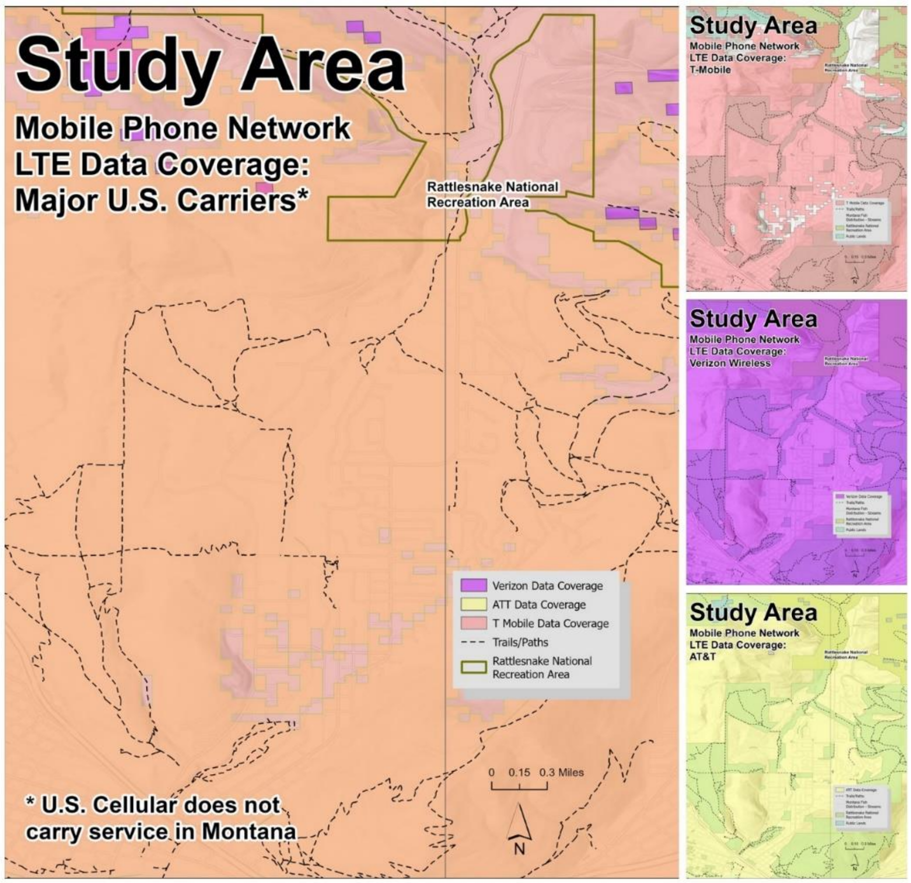



**Figure** 14. **LTE Data service coverage within study area. Individual carrier coverage at right, combined coverage at left. Coverage data obtained from Federal Communications Commission Mobile LTE Coverage web map, coverage data last updated May 15, 2021.**

Utilizing mobile phone location data for visitor use monitoring in PPAs, particularly as a novel method in need of further descriptive research for these particular settings, requires a consideration of its strengths and limitations for both research questions and the study area’s characteristics. In designing a research question that is informed by this data, researchers should consider how the study area's values, recreation infrastructure, and cellular coverage can either mediate or exacerbate the strengths and limitations of this data (Monz et al., 2019; Rice et al., 2022; Liang et al., 2018). In the case of RNRAW, this data is being applied to a novel context in PPA research - near the edge of a gradient of cellular coverage and with a focus on a "network of PPAs" in which visitors travel across a variety of public lands and recreation infrastructure settings on their way to RNRAW.

Finally, in PPA settings like the RNRAW where there is already a baseline or recent visitor use monitoring data collected through traditional methods, mobile phone location data to be applied as a complementary and comparative source of quantitative data to traditional measures of visitor use. This may not apply to all PPAs, but is an important consideration as the body of research in PPA management that utilizes mobile phone location data continues to grow. This strategy, utilizing mobile phone location data in PPA settings with an established visitor use monitoring dataset obtained through "traditional" methods, has been employed other researchers looking to test the capabilities of this big data source (Liang et al., 2022). For PPA's with porous boundaries, this exercise in 'rapid' visitor use monitoring to identify where visitors are coming from and what local access points to the park are experiencing the highest density of use provides an extremely valuable comparative baseline of data and a visitor management perspective that may other be prohibitively costly for many land management agencies to obtain otherwise.

**Recreational Ecosystem Services and Visitor Decision Making**

Interview participants were able to express their perspective on RES while they are actively being provisioned (Carpiano, 2009; Kusenbach, 2003). By adopting these methods, this study aimed to capture insights that were closer to the true nature and meaning of the recreation experience to the visitor. This approach to the underlying meaning of the recreation experience “provides insights into the actual nature of the experience visitors receive (i.e., rather than simply indicating visitors experienced challenge it described the meaning of challenge, the role it played in the experience, and the specific features of the setting that made the experience challenging)” (Patterson, 1998, p. 450). In interpreting the spatially-coded interview data across the Rattlesnake Valley PPA Network, researchers utilized a basic theoretical grounding in describing outdoor recreation as having three primary components: resource, social, and managerial settings (Anderson & Brown, 1984; Manning, 2011).

Combining these three settings can provide the foundation for analyzing a specific recreation experience, no matter the interpretive framework that is applied to the examination (e.g., satisfaction-based vs. meanings-based). For most RES values, interview participants seemed to shift between perspectives that detailed the specific outcomes of their experience (e.g., exercise, a mental break) and a meaning-based interpretations of recreation experiences, where recreation experiences is examined as "as an emergent phenomenon motivated by a not very well-defined, precise, or specified goal of acquiring stories that ultimately enrich their lives" (Patterson, 1998, p. 450). This was demonstrated through a priori and emergent codes throughout the interview data.

An emergent finding specific to this study area was the tendency for interview participants to equate descriptions and values related to the social settings of their recreation experience at RNRAW to the Rattlesnake Valley PPA network at large. There was a recognition among participants that there were differences in managerial settings (e.g., referencing PPA's managed by the City of Missoula vs. the U.S. Forest Service, or changes in allowed use) and specific resource conditions were often described when detailing perceptions of RES or RES-informed decisions (e.g., walking towards particular views, or choosing social trails that led the visitor closer to Rattlesnake Creek). However, social components of RES-related statements, or statements about the character of social components of the area in general, often lumped the RNRAW, individual PPAs and trail corridors, and route segments that passed through other portions of the valley (e.g. sidewalks or streets) into general values about "The Rattlesnake". For those that shared aspects of this theme, visitors would often use "The Rattlesnake" as a broad construct to refer the role that recreating in this place played in other parts of their lives (e.g., their reasons for living where they do, as a point of comparison against other places, or as a counterpoint to other parts of their lives). In other words, for some visitors, the RNRAW may be thought of as a component of "The Rattlesnake", instead of a stand-alone PPA basin:

*"Yeah, I think this whole area is pretty continuous for us [referring to trails in the area]. It's like, our daughter did a two-hour ride today and so she was up here already [RNRAW boundary] and there and*

*everywhere. So, yeah, it's all just kind of the Rattlesnake to us. That's cool. Since we live up here and we don't have to park. Yeah, I'm very lucky."*

Other participants described their perceptions of the Rattlesnake Valley PPA network as an extension to the RNRAW, describing how various environmental conditions or RES-values might inform their decisions about which portion of the network to visit on any given day:

*"….you know, a number of my friends that come up here to recreate, really just recreate in the National Forest because they go to that big trailhead. But the people that I ride horses with and most of the people that live in this neighborhood… they are in the know… When it's sunny, I'm on that side. And when it's really hot, I'm on this side because I want to be down by the creek... It all ties together… And it's such an amazing amenity. So it's all the Rattlesnake. I use it always like its one big network…"*

In the case of this PPA network, boundaries between public lands that are managed by different agencies are likely "fuzzier" to visitors than they are to PPA managers (Morse, 2020). For some interview participants, there was little or no distinction between the values and the relationship they had with RNRAW and with the Rattlesnake Valley in general. Theoretical concepts that rest on ideas of visitor relationships to a PPA (such as place attachment or place identity) may present some level of pro-environmental spillover from the PPA 'basin' to the surrounding areas included in the 'visitor-steam.

Spatially, interview data supports a conclusion that a greater density of RES are provisioned in PPA greenspaces than in the transportation corridors that connect them. We can see from the results of the kernel density analysis of RES and RES-decision themes that nature appreciation and solitude appear to be particularly clustered within greenspace, indicating settings where visitors perceived higher values in the natural resource setting. Adventure and achievement and social or family values, however, are distributed more evenly across natural resource or managerial settings. Among RES-informed route or location choice statements, there seemed to be a clustering effect for the 'solitude' and 'spirituality, inspiration, or reflection" within the PPA greenspaces in the upper portion of the study area, along Rattlesnake Creek and closer to RNRA.

Overall, interview data lent strong support to the idea that visitor perceptions of RES and recreation outcomes are closely tied to resource, social, and managerial settings. Importantly, however, visitor perceptions and decisions were not determined by setting alone, nor are interpretations of different settings uniform across different users. While settings are an important component of visitor experiences, individual perceptions and provisioned RES are the sum of a wide range of inputs. Visitors expressed varying levels of awareness or sensitivity to changes in resource, social, or managerial settings as they led the interview through the course of their recreation experience.

Interview data, at the individual level, was often consistent with theoretical frameworks for RES. For example, visitors make route choices to maximize solitude or nature appreciation RES values, as one would predict based on the three-factor framework of landscape potential, recreational infrastructure, and visitor use (demand) offered by Kulczyk et al (2018). This characterization of decision-making seemed to work especially well for visitors with a specific outcome in mind for the recreation experience:

*"We take this cut-through because there are a lot of bikes on this [other] trail and she [dog] is not very bike-wise. So I usually go up higher where there's less bikes."*

*"I wanted to come here… and all [my ride] of today… for that big climb up from Marshall to here. And then around Sawmill. It's just kind of… the least traveled zone. Yeah, the rest of the ride is kind of pretty commonly travels by Missoula mountain bikers. So I kind of like the spots that get me a little off the beaten path and are kind of hard"*

Similarly, visitor decision-making or perceptions of RES-provisioning seemed to reflect changes in the resource, social, or managerial settings of their experience. In these cases, visitors would report RES values when they are in proximity to areas with "matching" settings or value-cues around them:

*"… when we get up to this spot, I think of my friends I have who live up here. So I'll be thinking of them and maybe see if their car is there. And I guess any trail that I walk by reminds me of other times that I walked through that area, and who I walked with…"*

Furthermore, visitors seem to segment their recreation experience across RES values that are informed by resource, social, and managerial settings. Visitors described the changes in settings or meanings that differentiated portions of their recreation experience:

*"Well once I'm here I can kind of check out... On the friend's part* [previously described section with high social RES value] *I'm always like radar-aware in case I'm seeing friends, or anything like that. And now I*

*think about that less, and in parts the trail becomes wider, and then I'm thinking more about wildlife. If I might see them along or off the corridor. I guess it then becomes channeled into... a more solitary, or not really solitary, but more solitude. And like single-track thinking vs. path-thinking. So, I kind of look forward to each spot. Like I know up ahead, in these woods, there's some blind turns so you have to have respect for other trail users. Right. And other parts where I don't have to think about that as much. So yeah every part has a little... every segment has got little... system that I look forward to."*

*"It starts to get good by ... this section. You're getting into the woods... when I notice that I'm starting to notice my breathing and noticing the sound of the water. And that's what I key into is like, ahhh, the water. Yeah. Now I'm okay. Everything's good. Yeah, my stress is gone... I like this route because there is water. Yeah, and the water definitely acts as a de-stressor for me. So I ride [this way] instead of maybe some others because they don't all have water."*

When comparing across the full sample of interview data and their spatial representations (Figure 11 and Figure 13), however, the transition between RES values across recreation settings is less obvious. Two visitors that are asked to describe their interpretation of the same area may arrive at different conclusions and experiences. When walking along the Rattlesnake Greenway and asked to describe the area immediately around them, two participants demonstrate how their reflections on the same space result in opposing interpretations.

Interview Participant A:

***Interview Participant: "****I mean, to me. This is Montana. I was born and raised in Missoula. So this is like the Montana I'm used to seeing is like agriculture, wild places [next to each other along the trail]. I truly think that these places can and quite frankly, the nature and state of the world, they have to exist. We still see whitetail deer running along. It's still beautiful."*

Interview Participant B:

***Interview Participant:*** *"And the funny thing is, is because I grew up here and…The amount of people that come up here now that don't say hi, that are extremely rude. Yeah, that is just astonishing to me. Like, look, you can't come up here and be cranky. Or be creeps, but they do, so it's really changing. Yeah. Like, have you noticed that?"*

***Interviewer:*** *"Like, in terms of trail etiquette?"*

***Interview Participant:*** *"Where'd you grow up? Not here."*

***Interviewer:*** *"Right, in Illinois."*

***Interview Participant:*** *"So you don't. You're too young to know. Like what Montana really used to be. You have to go to eastern Montana now. Yeah. ... Great Falls and over in. It's more. But Montana used to be. Yeah. This is not what Montana was. It's not even what Missoula was 15 years ago."*

RES-informed decisions are not mutually exclusive, and often multiple RES are combined to weight or mediate recreation decisions, whether the decision relates to activity type or destination selection, moment to moment route, dynamic route choices, or reflections on the recreation experience itself. Perspectives shared through interviews in this study suggest that RES-values exist within a cognitive hierarchy, and visitor decision-making reflects the multitude of values, believes, and motivations that inform that hierarchy. As such, interview responses often presented a mixture of RES-values that informed any particular route decision:

*"This is kind of beginning of the training program that I'm trying out in this year. Well, I'm not as fit as I'd like to be, so it's really just kind of a longer, enjoyable, easy ride…I'm watching my heartrate and trying to ride at about 130 beats per minutes for two hours. Yeah. And so that's the whole intention of the actual ride itself… so I'm trying to lose some weight and I'm trying to get back into it overall. Besides the physical part of it, you know, there's a real strong emotional aspect to it as well for me. Yeah. Riding and running kind of helps to recalibrate my brain and enjoy things more."*

Finally, interview data strongly supported a conclusion that RNRAW visitors travelling through the Rattlesnake Valley PPA network use perceptions of RES to inform their choice of location and route through the course of their recreation experience. Other research that has attempted to outline distinctions between individuals' expressions of values of their experiences and the language of value of ES through focus groups found that their "most salient finding is that participants had difficulty describing their experiences in terms of a benefit to their wellbeing or as a value" (Stålhammar & Pedersen, 2017, p. 6). Everyday language does not always match the language of underlying values, personal motivations, and RES. Embodied walking interviews seem to be a particularly effective tool in helping to uncover, encourage, and record the often fleeting and hard to capture perceptions of ecosystem services being provisioned to an individual.

Interview data was supportive of Morse's (2020) interpretation of the recreation experience as a "social-ecological complex adaptive system". Participants navigated the shifting window of resource, social, and managerial settings across scales: from moment to moment (as in describing RES-informed decisions at each trail juncture), for their distinct recreation experience (as in their motivation for choosing that place at that time on that day), and in relating to recreation experiences or activities overall (as in describing perceptions of biking or walking in general). While RES has grown in prominence, application in research, and recognition among researchers, it does not have a widely-adopted management framework attached to it. Though the concept has continued to gain support and recognition, and Rice, Newman et al. (2020) introduced an RES Interpretive Framework to guide PPA management decisions using RES values. An important component of developing RES as an interpretive framework that is appealing and actionable for PPA managers is the development of methods, language, and interpretation techniques that are easily implementable, reproducible, and help communicate management directions.

**Management Implications**

Impacts related to increased recreation resource demand and use present significant challenges to PPA managers in the Western U.S., including biodiversity loss, changes in wildlife behavior patterns, depreciative behavior, and recreation conflicts (Timmons, 2019; Winter et al., 2019). PPA managers are further challenged by limited resources available to devote to either ecological or visitor use management (such as budget constraints, staff shortages, and lack of technical expertise) (McCool & Kline, 2020; Pitas et al., 2022). As visitor use increases, use pressure may threaten the values for which PPAs were originally conserved, particularly for PPAs that are managed for a diverse set of recreation opportunities (such as the LAC zones in RNRAW) or are managed for a particular set of experiences. The findings of this study may help PPA managers to contextualize their role in a broader network of PPAs and recreation experiences. Whether a PPA is a quick pass-through as a part of a visitor-stream or a PPA 'basin', thinking about the 'travel-to' phase and the visitors that enter a PPA through porous boundaries may help to target infrastructure management, communications, interpretation, and visitor use management. For PPA managers or advocates looking to identify supporters or potential candidates for park stewardship, the concept of PPA-value spillover may identify shared values or audiences among the people, parks, or institutions connected to PPA basins through visitor-steams.

This research may contribute to researchers and managers in two main ways. First, this study advances a novel application of methods to a unique context in PPA research. As mobile phone location data is still a relatively new application of data to visitor use studies, this thesis helps to further develop research methods that apply mobile phone location data to visitor use monitoring in the PPA context. This work builds on recent PSA analyses that have utilized mobile phone location data (e.g., Guan et al., 2021; Li, Chen, et al., 2021), and expands the application to include an examination of connective networks between PPAs. This study also advances methods that could be used in future research to utilize mobile phone location data to obtain demographic information, which has seen limited but promising uses (e.g., Monz et al., 2021) and provides a case study of this data source's usefulness as a visitor monitoring tool.

Concerning the second method applied in this thesis, a strength of the embodied, walking interview method utilized in this study is that it presents findings in the lived perceptions and language of PPA visitors. PPA managers might adopt this method, or a similar practice, in scoping efforts looking to understand visitor perspectives on management actions. Ibitayo & Virden (1996) demonstrated the difference between manager and visitor perceptions of depreciative behaviors in PPAs, with PPA managers perceiving significantly higher levels of depreciative behaviors that the visitors perceived. Results were also suggestive of a relationship between the frequency of a park's use and the park user's perceptions about the extent of depreciative behaviors (Ibitayo & Virden, 1996). This relationship may have an outsized effect on how parks are managed, where managers and those with longer relationships to a place may perceive and act upon beliefs and values that do not align with other visitors. Interview evidence seemed to support this relationship, as the perceptions of RES and RES-informed decisions differed between those who stated that they had a deeper relationship with RNRAW and the Rattlesnake PPA Network (e.g. neighbors, routine users) as compared to those who had spent less time in the study area. The practice of embodied walking interviews, whether incorporated into research or taken as an anecdotal practice by PPA managers, may help 'ground' manager perceptions in the perceptions of visitors and mediate the effect of this relationship on PPA management decisions.

Second, this thesis provides an insight into visitor use of PPAs across management boundaries. Capturing a broader picture of recreation experiences across the landscape provides a number of useful insights into applied management problems. This research could inform local transit and recreation planning by identifying density of use across different pedestrian corridors – and thus areas for funding allocation, the development of new trails and amenities, and the prioritization of parking development or sustainable transit opportunities. As recreation use intensifies in urban-proximate PPAs, planners and managers could use these methods to efficiently allocate scarce or constrained resources (e.g., parking availability, trail maintenance funding, seasonal closures) and to address historic inequities in park funding allocation (Wolch et al., 2005).

An understanding of visitor perceptions of RES, and thus motivations behind visitor spatial behavior and route decisions, could inform management decisions for natural resource and infrastructure settings. For example, an understanding of visitor perceptions and behavior across networks of greenspace that are simultaneously managed for connection of human, plant, and animal populations could help managers effectively communicate use restrictions that were created to protect RES-values such as quiet and solitude or nature appreciation. Further, by examining transit corridor density, managers can have a better understanding of where, when, and how visitors are coming to visit PPAs. Incongruent policies between land owners could result in conflicts between users (e.g. a network of use that has different pet-leash policies, or differences in user group access), interactions between users and the environment (e.g. non-sanctioned trail use). As planners aim to efficiently utilize limited capital investment funds and encourage sustainable transit options, PSA can identify use-density that is specific to particular amenities, activities, or experience types. Through a better understanding of the recreation experiences that occur closer to home (e.g. in urban-proximate visitor-streams), researchers can pursue management policies that center under-represented visitor needs and preferences while simultaneously addressing management concerns at PPA settings that have reported crowding, limitations on use, etc.

Managers can then prioritize those areas that experience the highest demand, and plan for development that aligns with user-demonstrated preferences. This thesis aims to contribute to PPA management decisions that prioritize PPA connectivity and facilitate development in urban-proximate PPAs that supports RES provisioning to visitors without incurring negative results associated with increased visitor use (such as user conflicts, parking constraints and road congestion, ecological impacts). Focusing on a network of urban-proximate greenspaces, a 'visitor-shed', represents a shift in the conceptual framework typically applied to outdoor recreation research and RES research. By representing different managerial settings within PPA 'basins' and across 'visitor-streams' in a wildland-urban interface, this research offers methodological and theoretical contribution to the fields of RES and outdoor recreation research.

Recreation planning that recognizes opportunities to integrate managerial settings that maximize RES-values across a greenspace PPA network may be able to improve the visitor experience while providing a spectrum of recreation opportunities in the greenspace networks that are closest to the homes of local visitors. Through a better understanding of visitor's experiences, PPA managers could encourage a diversity of use and a rich recreation experience before the visitor enters the PPA boundary. This outcome could help to mitigate visitor impacts to biodiversity and wildlife (e.g. creating diverse recreation opportunities closer to areas of dense development), recreation conflicts (e.g. crowding due to bottlenecks in access, conflicting allowed uses across different PPAs in the same network), and practical limitations that managers may not be able to address due to limited capacity (e.g. parking limitations, service of infrastructure that is difficult to access) (Goldstein et al., 1983; Benedict & Mcmahon, 2006).

PPA visitors bring a variety of motivations to the entire spectrum of the PPA network. One person's haven for solitude, escape, and nature appreciation is another's setting for daily exercise, social connection, or commuting. Systems for segmenting users, like the Recreation Opportunity Spectrum, apply a coarse spatial scale to a fine-scale perception of experience. Particularly for urban-proximate PPAs and greenspaces that facilitate connections to larger PPA landscapes, visitor use planning should recognize the "micro-climates" of experience that occur across a PPA or PPA network (Goldstein et al., 1983; Missoula Parks and Recreation, 2019).

## Methodological and Theoretical Contributions

This thesis makes two primary contribution to methods and theory for the mapping and understanding of the recreation experience in outdoor recreation research. First, despite its position among the foundations of outdoor recreation research, there has been very little academic attention on the concept of the phases of the recreation experience (Clawson & Knetsch, 1966). Further research into the distinct phases of the recreation experience may reveal further nuances of the recreation experience. As an under-studied component of the recreation experience, the travel-to phase and greenspace networks may create space in outdoor recreation research for the perspectives and behaviors of under-studied visitor populations (Clawson & Knetsch, 1966; Moore & Driver, 2005; Starnes et al., 2011). Where there is already a significant body of research with a primary emphasis on particular types of recreation experiences (for example, out-of-state visitors to large, charismatic federally managed PPAs), a focus on the travel-to phase and greenspace networks may provide a shift in outdoor recreation research focus to everyday recreation experiences that occur closer to home and in urban-proximate PPAs and greenspace.

Second, this thesis provides an exploration of both methods and theory that may help other researchers to advance a systems-based approach to examinations of the recreation experience. This approach examined the Rattlesnake Valley PPA Network as a 'visitor-stream', connecting RNRAW visitors to and from a PPA 'basin' that fits within a larger landscape of protected areas (i.e., the visitor-shed). This conceptualization of the visitor experience may help other researchers or managers reflect on any individual PPA's role in the larger context of recreation experiences in protected areas. Furthermore, researchers have noted the utility in designing management and conceptual frameworks that align with concepts in natural sciences, as most PPA managers approach management issues with a natural resources background rather than one in recreation planning (Rice et al., 2020). Finally, this conceptualization of the recreation experience may also help to place greater focus and value on urban-proximate PPA's and greenspace networks.

In a comprehensive study on trails and physical activities, Starnes et al. (2011) identified several gaps in the literature related to studies of trail use. Gaps identified include a "lack of data on trail-use among racial and ethnic minorities" (p. 1172), a lack of a conceptual framework for understanding trail use and physical activity behaviors, and that studies that include "children and youth, older adults, and racial and ethnic minorities are a research priority" (Starnes et al., 2011, p. 1161). Urban-proximate PPA visitation consists of a higher proportion of ethnic and racial diversity than other Urban-Distant PPA settings (Ewert, 1998), and federal agencies have noted that "[demographic] changes are significant because non-white populations in the United Sates are more concentrated in large metropolitan areas that the overall population… [increasing] urbanization and ethnic diversification will challenge… agencies that manage for outdoor recreation." (Floyd & Thompson, 2008). Furthermore, public parks and trails provide benefits for those who often have limited transportation options, like children and the elderly (Schultz et al., 2016). An understanding of recreation experiences that are facilitated by greenspace networks and connective trails close to home are an important component of centering understudied user groups and placing a focus on the services that are provisioned to all PPA visitors. In the application of theory to visitor behavior, Gómez & Malega (2007) called for more studies that explore the relationship between perceived benefits of recreation and park use. A focus on the travel-to phase and a framing of recreation experiences within a 'visitor-shed' could help outdoor recreation research examine salient themes or processes that are particularly relevant in urban-proximate PPAs, helping to connect outdoor recreation research to related fields of study that have immediate impacts on public health, equity, and urban planning (Schultz et al., 2016; Samdahl & Kelly, 1999).

**Opportunities for future research**

This study presents a number of opportunities for future research. As this research adopted a mixed-methods approach, particular attention was made to avoid the inappropriate application of methods or data from one paradigm (e.g. positivist paradigm, quantitative data) to the another (e.g., interpretivist paradigm, qualitative data). Ultimately, quantitative analyses (R1) were used in service of a qualitative understanding (R2) of the experiences of a specific population of recreationists in a specific PPA context. As additional research outlines the strengths and limitations of mobile phone location data application in outdoor recreation research, future study could explore the quantitative relationships between PPA networks, visitor perceptions, and RES. Further research could leverage the volume, variety, and velocity of mobile phone location data to explore theory-driven, predictive research results in PPA settings.

To support further research, the RNRAW benefits from a rich history of outdoor recreation research (Kelley, 1979; McCool, 1985; Watson et al., 1990; 1995; 1996; 1997; Williams & Roggenbuck, 1992), which augments the value of this thesis's approach to using alternative, novel forms of data collection. Data collected in previous research that occurred in the RNRAW, could provide a point of comparison to the results of this study. For example, visitor use monitoring data collected by Rice et al. (unpublished) could be utilized to conduct validity analysis for the results derived from mobile phone location data in this study. A similar comparison of visitor counts at points of interest, demographic information, and temporal patterns derived from mobile phone location data and traditional methods of visitor use monitoring was recently completed by Liang et al. (2022). The datasets from research conducted in RNRAW could contribute to a broader test of validity that incorporates visitor use estimates from multiple locations across the U.S.

For research interests with a different focus, further analysis could examine where visitors are travelling within the PPA basin (using mobile phone pathing data) (as in Creany et al., 2021, Heikinheimo et al., 2020), demographic composition of visitors (using mobile phone data's Common Evening Location point; as in Monz et al., 2021), differences in visitor use or RES-provisioning across each phase of the recreation experience, or a quantitative examination of RES provisioned across managerial settings. A number of descriptive research opportunities are presented by this study's use of mobile phone location data. To date, there has not been a peer-reviewed effort to quantify the ability of mobile phone location data vendors or the accuracy of datasets across gradients of cellular coverage (e.g., figure 14). Incidentally, the dataset used in this study did include a number of pathing points located in areas that are shown to not have service in the FCC LTE Data coverage layers (e.g., northern portions of RNRAW trail systems and the Wilderness Area), but researchers do not have a framework to assess the utility of this data in areas where LTE data coverage is limited or absent. Future research could provide guidance for the use of these datasets in more remote PPA settings.

As demonstrated in this study, a powerful capability of big data is its ability to provide rapid insights across large, statistically representative sample populations (Guan et al., 2021; Jaung, & Carrasco, 2020; Liang et al., 2022). In this study, users were segmented to examine visitors who were recreating in their travel-to phase as they approached RNRAW boundary. However, any of the factors above (such as demographic information, travel paths within the PPA, or other locations visited by visitors outside of their PPA visit) could be further divided to examine sub-populations of the sampled population by a factor of interest. For example, this research could examine the demographic composition of visitors to the Rattlesnake Wilderness Area vs. the Rattlesnake National Recreation Area. The use of mobile phone location data presents a wide array of research opportunities, though future researchers should be sure to consider the strengths and limitations of this data source in selecting research questions that are well suited to its application.

**Limitations**

A number of limitations have been identified in the literature that will apply to this thesis, including limitations inherent to the study location, conceptual frameworks applied, and methods chosen. While Missoula, MT provides a useful setting for examining a range of PPAs across managerial settings that experience high levels of use, the visitor population presents limitations to generalizability across the broader population of PPA users in the USA and beyond. In 2020, 89.2% of Missoula County residents identified as white alone (not Hispanic or Latino) (as compared to 60.7% in the USA), 0.6% of the population identified as Black/African American (as compared to 12.4% in the USA), and 3.3% identified as Hispanic or Latino (as compared to 18.7% in the USA) (U.S. Census Bureau, 2020). It should be noted, however, that the purpose of this study was not to provide generalizable findings, but was instead to explore a novel application of big data and qualitative interviews to a study area that was well suited to the application, highlighting a potential method for informed PPA management decision-making and an under-studied phase of the recreation experience.

## Mobile Phone Location Data Limitations

While mobile phone location data provides a number of advantages for visitor use monitoring, there are key limitations that should be considered in this study. While the research design of this thesis was made with this consideration, researchers considering the application of mobile phone location data should be aware of the impact of mobile network service (or lack thereof) in their study area. Demographic data for both sample populations included in this study were analyzed, but not included in final analysis. The mobile data vendor selected for this thesis, Near, analyzes census data at the census block group level to derive demographic information about device users in the USA (Rice et al., 2022). While data are tested for bias between census block groups, differences within individual blocks are not visible. Therefore, reported demographic information is based on the census block group in which one resides, rather than the actual demographic background of the individual. Given this limitation, bias is easier to detect and remove in areas that have "highly typified neighborhoods, such as one with many ethnic or economic enclaves" and more difficult to detect in an area that has a "well-integrated population with few ethnic or economic enclaves" (UberMedia, 2021b, p. 4).

Sample selection presents a limitation of this data source that should be considered against alternatives (e.g. data collection in the field). Location data are collected from individual devices, meaning that the PSA and pathing analyses in this study can only include PPA visitors that had a mobile device with location services activated while travelling to or within the study area. Other users, those who do not have a mobile device or do not have an application with location services activated, are not captured (Rice et al., 2022). While mobile phone location data provides a better measure of representativeness than other big data sources used in similar applications (e.g., social media data), there is no way to ensure a truly random sample of RNRAW visitors. Furthermore, the ethics of the application of mobile phone location data to visitor use monitoring in PPAs is an area that is largely unexplored in academic literature. The application of mobile phone location data in this thesis relied on tests of validity conducted by other studies, especially Creany et al. (2021). While research suggests a high level of face validity in applying mobile phone location data to visitor use estimates, the location-specific nature of this data presents questions about the generalizability of this dataset. Due to these concerns, this study opted to only consider proportional trend analyses using this data, rather than establishing specific counts. Future research could leverage the rich history of visitor use monitoring research on RNRAW to compare the dataset used in this study to traditional visitation estimates.

### Qualitative Data Limitations

This thesis engaged the concept of RES through interviews and in analysis. In both instances, adopting this frame and language for categorizing the benefits that people receive from nature may constrain the identification and examination of benefits that do not neatly fit into this framework. Participatory mapping research presents a number of limitations, especially regarding spatial accuracy, completeness of spatial data, and time & resource costs (Brown et al., 2015; Teff-Seker et al., 2022). This thesis aimed to address the first limitation by conducting the participatory mapping exercise through 'go-along' interviews, limiting confusion or misrepresentation of data that can be introduced by conducting the exercise after the recreation experience. This method selection represents a trade-off between depth and quantity of available data.

The convenience sampling schedule utilized in this study, along with practical constraints on recruitment, may have introduced bias and additional limitations to study results. Interview data points concentrated along the PPA network corridors along Rattlesnake Creek. While this seems to generally match the results of visitor use densities shown in figure 9, two opposing and mediating limitations may have biased the interview participant sample. First, the pathing analysis for visitors utilizing the Rattlesnake PPA network was inclusive of any visitor that travelled less than 15 mph on average and passed through PPAs at any point in their travel-to phase. Thus, the sample is inclusive of visitors that drove to Rattlesnake

Valley PPA trailheads or local access points, and then engaged in active transit while travel-to RNRAW boundaries. These are important visitors to include in analysis, but may have biased the kernel density analysis for the sample population of interest towards road networks in lower sections of the study area. Second, practical limitations limited the ability for researchers to recruit interview participants along roadways in the lower portions of the study area. Practical difficulties and safety concerns in intercepting and recruiting participants along Van Buren Drive led to a potential under-representation of use in that portion of the study area.

Individual route decisions, being an inherently personal choice, are not generalizable across all visitors in all locations. However, the quotes, themes, and decisions represented in this sample population can provide valuable insight into the kinds of perceptions and language used by RNRAW visitors and into the recreation experience in the Rattlesnake Valley PPA network. It should be noted that the each of the three recreation settings influence the availability of route decisions available. For example, a greater density of solitude-informed route decisions shown in this analysis could indicate an area that is attractive to visitors seeking solitude, or it could mean that it's an area with a lot of available intersections and the interviewee is then attaching a value or rationalization to their decision.

Throughout the interview, coding, and analysis process, the interviewers' prior knowledge and experience plays an active role in understanding and organizing emergent themes from each interview (Gadamer, 1989). Therefore, the reality of the researcher's individual positionality is an important and unavoidable influence on the interview data and its analysis. This researcher's position as a white, male, representative from an institutional of higher education and local land management agencies played a role in the content of the interview data and its interpretation.

# CHAPTER VI: CONCLUSION

This study aimed to expand an understanding of how mobile phone location data could be used for visitor use monitoring in parks and protected areas, how visitor use monitoring can focus on a distinct phase of the recreation experience, and how visitors perceive RES as they travel-to a PPA through a network of greenspace. This study provides both a proof of concept for a new application of methods to a unique outdoor recreation research context and key findings about RES and visitor decision-making within the context of the recreation experience.

This application of mobile phone location data further highlights opportunities for big, secondary datasets to provide an approachable, cost-effective means for examining visitor use trends across a wide variety of PPA settings. Further, this study may serve as an example for how big, secondary data may be used to gain an initial, general understanding of behavior in a given landscape. This understanding can then be supplemented with rich, specific qualitative data collected on the ground. By collecting and integrating data across two extremes, from anonymized, device location data to the words and feelings of individual visitors, PPA managers and outdoor recreation researchers may gain a more complete understanding of how recreation experiences relate to and interact with the physical, social, and managerial settings in a PPA.

Research using the demonstrated behavior of visitors (through mobile phone location data) and direct translation of their preferences and perceptions (qualitative GIS, walking interviews) helps to bring researchers and managers closer to the true character of visitors' experiences. Through walking interviews, participants described a diverse, and sometimes polarized, range of perspectives, motivations, and outcomes related to the very same resource, social, and managerial settings. This re-enforces the idea that managers should resist the temptation to manage areas for the average visitor, recreationist or "the average camper who doesn't exist" (Shafer, 1969). PPA managers should utilize frameworks that incorporate the different ways in which visitors interpret RES across space, time, activity, and relationship to place. Furthermore, this study underscores the importance of that point for PPAs that are urban-proximate, nest within a larger network of PPAs, or have porous boundaries. This study, focusing on RES provisioning before visitors have entered RNRAW, demonstrates that factors that influence visitor use management extent beyond the spatial and temporal boundaries of a single PPA.

The results of this study represent a systems approach to understanding, and managing for, recreation experiences. A PPA boundary is a construct that provides necessary sideboards for land management, but does not directly align with the true nature of interactions that occur between the living things that move through a PPA. On the ground, ecological, social, and managerial settings are often "fuzzy". This is by no means a novel finding. Research on natural systems have recognized the limitation inherent in managing natural resources as "islands" (Forman & Godron, 1986; Forman 1995). Outdoor recreation research has struggled to define the nature of visitor experiences, how to measure those experiences (e.g. in terms of visitor satisfaction, benefits, or outcomes), and how to implement an appropriate management framework to interpret and plan for those experiences (Borrie & Brizell, 2001; Rice, Taff et al. 2020).

This thesis contributes a set of mixed methods that provide a relatively rapid and comprehensive set of data and analysis on this complex issue that is inherent to visitor use monitoring and outdoor recreation research. These findings help to fill a defined gap in outdoor recreation research and RES research, and highlights how this gap could provide a fruitful connection to other fields of study that relate to outdoor recreation, by focusing on an urban-proximate network of greenspace and visitor experiences as they traversed different management settings on their way to a PPA basin. The application of these methods may help individual PPA managers or researchers identify use patterns, locations of high RES-value, and visitor perspectives that are unique to their PPA network.

By focusing on this distinct phase of the recreation experience, this thesis aims to provide a bridge to a broader landscape of social science research. Researchers have noted a disconnect between outdoor recreation research and other disciplines with related social processes but different physical settings (Manning, 2011). A review by Samdahl & Kelly (1999) found that papers in the two leading recreation and leisure journals cited little of the relevant literature published in broader social science journals, and that the reverse was also true. Their study concluded that recreation and leisure research is "intellectually isolated from important and relevant bodies of literature" (Samdahl & Kelly, 1999, p. 180). Researchers have suggested that a potential solution to this disconnect is to "consider recreation and leisure issues in a broader cultural context" (Manning, 2011, p. 9). One avenue towards broadening the focus of PPA research to include a broader cultural context may be found in placing greater emphasis on the distinct phases, settings, and visitor perceptions of the recreation experience that happen outside the boundaries of an individual PPA. By expanding the temporal and spatial scope of visitor use monitoring research, we may find more overlap with questions, issues, and ideas that are more broadly relevant across all social sciences.

However, as outlined in the limitations section, there are important factors to consider before managers or researchers apply this study's set of methods or findings to future PPA management or research. As the application of these methods are new in outdoor recreation research, this study was inherently exploratory. By exploring the opportunities and limitations presented by mobile phone location data and embodied, go-along interviews, this study hopes to highlight opportunities for further research in the application of big data to visitor use monitoring, in participatory GIS, and in the application of mixed methods to research. As outlined in the future research directions section of the discussion, future research should place an emphasis on exploring the specific conditions of mobile phone location data validity across biophysical settings, including differences between individual vendor data products, and further exploration of the application of an RES framework to the travel-to phase of the recreation experience across a wider range of PPA settings and visitors (especially demographics).

For many PPA managers, recreation is half of their dual mandate that defines PPA management. Just as the conservation and restoration of ecological systems must incorporate an understanding of the influences and impacts of factors far outside the borders of their PPA (Forman & Godron, 1986; Forman 1995), PPA managers must adopt a similar lens in managing recreation resources and visitor experiences. Recreation experiences are the sum of multiple stages, of which only one phase may occur within the bounds of an individual PPA. Therefore, recreation planners may miss opportunities for more comprehensive PPA management if only consider the recreation experience within the bounds of their PPA. This is particularly true for PPAs in the wildland-urban interface, nested within population centers with porous physical and social borders. Utilizing a framework that considers the full visitor-shed of recreationists, from starting point to PPA basin and back, can help guide the application of resources and infrastructure development, communications, conservation policy, and interventions to guide visitor behavior.

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## APPENDIX 1: INTERVIEW GUIDE

**Participatory Mapping of Recreational Ecosystem Services in Missoula, MT**
**Qualitative Semi-Structured Interview Guide 2022**

Date: ____/___/____ ID Number: _____________ Time: ___:____ Weather: _______

Refusal's: ______________________________________________________________________

Interviewer: __________________ Potential Language Barrier: ___Yes ___No

**Interview Guide**

1. Introduction to the study & park visitation information

*[Start by thanking the participant, and providing a short introduction to the study and the purpose behind the qualitative interviews].*

2. RES activity prompt

*[Over the course of the interview, participants will respond to a series of prompts. Prompts are meant to encourage reflective thinking regarding their current & past experiences recreating in this area. As the interview progresses, individual waypoints will be marked on a paper map of the area to indicate sections highlighted by the questions / interviewee responses]*

Questions to situate interview:

I.

a. To get us started today, could you please describe what you are doing today (activity type).
b. How did you get here, where are you coming from, and where are you going?
c. Why did you choose this route?

II. Prompts to assess Recreation Ecosystem Services in guided walk-along interviews. Embodied walking interview protocol adapted from Teff-Seker et al., 2022.

a. Walk in silence for a minute, noticing your breathing and how it feels when your feet touch the ground.
b. Describe the physical experience of walking here.
c. What comes up when you look at the landscape in front of you?
d. Zoom in on something that you notice while walking through this area. Describe it. Why does it catch your eye?
e. Find a comfortable place to sit or stand. Close your eyes. Describe what you receive from your other senses.

f. Walking again, give a name to your experience of walking here. Why this name for this particular area?
g. Did anything else come up during this walk?

After each prompt, the interviewer asks non-leading follow-up questions that stem from the content provided and invite the interviewee to delve deeper and “think at the edge”. The interviewer asks questions such as…
**-Why** do you think this is what comes up for you? (e.g. if a speaker says that looking at the tree makes them happy, the listener-moderator can ask why it makes them feel happy);
**-How** (in what way) do you mean? (e.g. if a speaker says that the bird song sounds strange, the moderator can ask them in what way is it “strange” to them);
**-What else** (comes up for you right now)? (when the moderator feels that one thread of thought has ended, s/he invites the speaker to address another aspect of their experience).

III. Thinking about your entire recreation experience today, are there any feelings or locations that motivated the route that you took to get to the RNRA? Are there any other experiences or locations that you’d like to share?

3. Interview Wrap-up

*[Before we end, is there anything else that you or your group would like to share with us? Or any other comments you would like to add regarding what we chatted about today?]*

*[Thank you very much for your time!]*