Introduction

Hiking and camping have seen a meteoric rise during COVID-19 times with 90 percent more visitors compared to previous years (Brassil 2020), adding to already expanding use in protected areas from adventure sports, the health and wellness movement, and spillover from Hollywood movies. These activities have provided recreation to millions, while also promoting appreciation for nature and furnishing physical and mental health benefits, Yet, the higher demand also has proliferated the spread of non-sustainable paths and campsites, with unacceptable impacts in protected areas, particularly along high-traffic, long distance trails near population centers.

For example, the Appalachian Trail (AT) in the eastern United States, the locus of our work, lies within a days drive of more than one-half of the US population, and more than 3 million hikers typically experience some part of it annually (Appalachian Trail Conservancy 2017). The thousands of distance (LD) hikers who attempt to walk its entire 2,193 mile length exacerbate trail stresses since the span of time needed for these thru-hikers to traverse the entire trail and short hiking seasons concentrate most LD hikers in a moving "bubble" of exceptionally high use. In addition, the AT relies on collaboration among hikers, land managers, NGOs, and clubs operating across multiple states. Any breakdown in this cooperation can result in the trail infrastructure sustaining damage that may be difficult to reverse, such as visitors expanding existing campsites or creating new ones, human waste, soap, and eroded soils that degrade water quality, garbage that attracts dangerous wildlife, or trash that takes decades to decompose (Ballantyne & Pickering 2015, Hammitt *et al.* 2015, Marion *et al.* 2016). Such impacts also can significantly degrade the quality of recreational experiences overall (Lynn & Brown 2003).

Recreation ecologists who study visitor impacts have developed effective protocols with the potential to mitigate these impacts through sustainable trail infrastructure practices. The AT land management and volunteer community in particular has embraced the national Leave No Trace (LNT) program of conservation ethics and low impact practices such as camping on sustainable campsite and appropriate food storage to protect wildlife {Leave No Trace Center for Outdoor Ethics, 2021 #242}. Yet, consistently applying these protocols to influence visitors' behavior, and understanding the spatial aspects of this behavior in real time, remain a challenge.

Social media and associated technologies hold promise for undergirding a socio-technological system to help address these challenges. Potential LD hikers already learn about and become inspired by the stories, pictures, and other information available from social media, discovering where to go, how to choose a campsite, and how to interact with the environment without undue harm. Many LD hikers on the trail now use mobile apps (*e.g.*, Guthook, Strava) for satellite GPS navigation, accessing trail data to find water sources and campsites, allowing others to follow their progress on the trail, browsing for weather forecasts and news, and connecting with friends via Instagram, Twitter, and other platforms. For their part, resource managers have piloted the use of mobile apps to protect conservation values by collecting information on visitor distribution and numbers to better manage user impacts (Muñoz *et al.* 2019, Stamberger *et al.* 2018). Proactive, coordinated communication efforts across multiple information sources and regular two-way messaging among the trailgoing community remains elusive, however.

Our project explores the opportunities and tensions of digital technologies in sustainable trail and camping infrastructure management by: 1) building a concept of trail infrastructure that connects with cyber infrastructure increasingly integral to the LD experience; 2) identifying the spatial, socio-cognitive, and behavioral aspects of LD hikers' movements to understand how digital

technologies mediate psychological and social experiences in protected areas; and 3) developing with resource managers and LD hikers a prototype app-based trail infrastructure messaging system for experimental use and evaluation. Four sets of research questions guide our inquiry.

1) What benefits do LD hikers seek and experience on the trail? Do these benefits change over time spent on the trail and vary systematically across different types of hikers? What benefits do resource managers, NGOs, volunteer trail maintainers, and hiking clubs responsible for trail infrastructure seek to provide with their activities?
2) Do LD hikers use digital technologies prior, during, and after their AT hike? How do they characterize experiences with digital tools and technologies, including their motivations, attitudes, and challenges? What kinds of information, resources, and tools would they find useful during a hike? What is their level of awareness of LNT principles?
3) How do resource managers, NGOs, and trail volunteers use digital technologies in their everyday work? How do they characterize their experiences with digital tools and technologies, including their motivations, attitudes, opportunities, and challenges? What kinds of tools, information, and resources would they find useful in decision-making?
4) What are the points of tension and overlap between managers and agency staff, volunteers, and LD hikers in terms of their *socio-technological worlds*—values, beliefs, practices, and the broader organizational conditions?

SmarTrail Concept

Our project seeks to develop a fundamental understanding of the socio-technological world of LD hikers and resource managers to inform development of a cyber-based information system that supports sustainable trail infrastructure services. As such, we need both to construct a coherent meaning of trail infrastructure services in the socio-natural environment and to excavate the context of the socio-technological environment in which the information will be processed.

We use the principles of ecosystem services (Braat & de Groot 2012, Daily 1997, Millennium Ecosystem Assessment 2005), most particularly the concept of "cultural" services, as a starting point. This framework focuses on identifying and managing ecological structures and processes that undergird human well-being through various services that provide benefits to people. In the case of hiking, these benefits may include recreation stimulation, aesthetic pleasure, physical and mental health improvements, a heightened sense of identity, and emotional connection to natural environment, for example. Moreover, our work hinges on the idea of trail infrastructure services as deriving from dynamic interactions with the trail environment. Such infrastructure services, as with cultural ecosystem services more generally, are constructed through an active, co-produced creation of relational processes with the trail infrastructure that depends on cognitive and emotional processing of the natural and social environment, perception, and imagination (Chan *et al.* 2011, Gee & Burkhard 2010). As such, understanding the demand for these services requires an interpretive lens to reveal the personal and collective values that yield identities, enable experiences, and equip capabilities (Fish *et al.* 2016, 212).

In addition to this departure from the thrust of much ecosystem services work, we enlarge the supply side of ecosystem services in our study. The biophysical supply side of ecosystem services occupies the top level of the well known cascade model of ecosystem services (*e.g.*, Potschin & Haines-Young 2016), but with some exceptions (Castro *et al.* 2014, Geijzendorffer *et al.* 2015, Larondelle & Lauf 2016, Wei *et al.* 2017), the explicit linking of the supply and demand sides has not featured in the literature. The supply side of trail services needs active

management, however, not only due to its reliance on constructed elements of trail infrastructure, but also because the benefits that LD hikers experience from this infrastructure derive in part from how well resource managers manage the supply of infrastructure services that embody rival goods (*e.g.*, more visitors on a trail may decrease tranquility, degrade aesthetics, pollute water sources, *etc.*). As with environmental protection more generally, resource managers have a variety of tools to influence the rival aspects of trail services (Bemelmans-Videc *et al.* 1998, Taylor *et al.* 2012), such as direct regulation (*e.g.*, the closure of trails in areas recently burned), economic interventions (*e.g.*, camping and shelter fees in congested areas of the trail), and voluntary mechanisms (*e.g.*, the new voluntary AT thru-hiker registration site to promote better planning of hiking schedules to mitigate congestion), but we focus here on information-based instruments such as providing information on LNT principles.

Many conventional information systems focused on narrow technological aspects within organizational boundaries have faced resistance and failed to achieve expected outcomes. Behavioral scientists have argued that this partly reflects a failure to incorporate social, cultural, and psychological forces, alongside technological ones, in system design (Bostrom & Heinen 1977, Briggs *et al.* 2010). Our socio-technological information system aims for a fit among technological subsystems (*e.g.*, devices, tools, techniques), social subsystems (*e.g.*, knowledge, attitudes, and values of users), and environmental subsystems (*e.g.*, organizations relations and the rules and regulations governing these relations) to improve managerial decision-making.

In crafting this socio-technological information system, we draw on work on information flows from the common pool resources literature (Hess & Ostrom 2003) expanded on by Hogendorn and Frischmann (2020) to conceptualize information promoting trail infrastructure services as the culmination of ideas, artifacts, and facilities. *Artifacts* in Hess & Ostrom (2003) relate to a discrete, observable representation of an idea, such as a LNT message that a resource manager might push to LD hikers to reduce camping impacts. *Facilities* store artifacts and make them available, the mobile-app platform that connects resource managers and hikers. *Ideas* represent the broader principles or creative construction of what is valuable, which may be LNT principles from the resource managers and inspiration, recreation, or tranquility from the hiker side.

This information flow involving ideas, facilities, and artifacts already has received attention in the trail world, although not labeled as such. A small literature has emerged specifically on the *digital technology practices* of hikers and backpackers and the effects of media and communication devices on peoples' experiences with and connection to nature in wilderness settings, for example (Arendt & Matthes 2016, Levi & Kocher 1999, Mayer *et al.* 2008, Pergams & Zaradic 2008, Marion *et al.* 2018, Dustin *et al.* 2017). Hikers attempting LD hikes or the entire AT (thru-hikers) have varying motivations and intentions for their journeys (Borrie & Roggenbuck 2001, Silas *et al.* 2016), and their technology practices and orientations vary as well (Egger *et al.* 2020). Some intend a largely "digital free" experience, but others expect to remain connected to their social networks. Similarly, their relationships with the social and environmental world in the wilderness context varies. While social media use during a hike was previously frowned-upon as betraying the ethos of "awayness" and voluntary disconnecting encouraged in both the popular and technical literature (Bryson 1999, Helms *et al.* 2019, Harmon 2015, Aranda & Baig 2018), the sentiment has shifted as smartphones have gained ubiquity and as younger hikers attempt thru-hikes. In addition to their utility for retrieving information,

digital technologies allow LD hikers to express themselves as they find meaning through experiences on the trail.

A parallel body of research on *hiking cultures* providing insight into the diversity of hiking motivations and practices as well as areas of conflict between different hiking identities (Fondren 2016, Lum *et al.* 2020). As noted earlier, some resource managers already have begun to embrace social media and mobile apps (Buscher 2014, Büscher & Igoe 2013, Jepson & Ladle 2015). Our previous work with students has considered how trail cultures manifest on Twitter (Bartolome 2018), and how thru-hikers can find a sense of community on the trail by maintaining connection to the AT Reddit online community (Kotut *et al.* 2020). But this work focuses almost exclusively on hikers; surprisingly little research has appeared on the digital technology orientations, attitudes, and practices of trail maintainers and resource managers and how they see the role of these socio-technological trends influencing and/or improving practice.

Rather than simply connecting or disconnecting people to natural settings, contemporary *mobile web*, *web 2.0*, and *geoweb* applications and platforms are fundamentally re-creating human subjects and trail infrastructure they ‘‘prosume” (Graham *et al.* 2013, 465, Zook & Graham 2007, 468). The one-to-many communicative aspect of these technologies can allow LD hikers to be a part of a community even when not formally associated with a place-based club or group. Individuals communicate bi-directionally with the apps, providing information about themselves and their activities through trackers and sensors and inputting self-reported information, which is aggregated over time and presented back to the individual reflexively. Communication also occurs among peers, via sharing of data about performances and experiences using social media functions such as liking and commenting, thus creating networks of LD hikers and enabling new communities of both known and unknown followers coalescing around the practice of long-distance hiking (Barratt 2017, Groth 2014, Lomborg & Frandsen 2016, Smith & Treem 2017).

This trifecta of digital technologies creates an information landscape overlaying the human-produced terrain of trail infrastructure that may shift over a long distance hiking experience. No research to date, to our knowledge, has integrated these sources of hiker generated digital content (information flows) and strands of research on hiker culture and digital technology practices to inform sustainable trail infrastructure services and guide resource managerial decisions.

Methodological Approach

We use a participatory mixed method research design to steer the development of SmarTrail—a cyber-based information system to guide sustainable trail infrastructure management. Our five-part approach draws from our previous work with multiple inter-linked methods such as social media analysis, systematic grounded theory, cross-sectional surveys, and a series of collaborative and participatory design sessions leading to prototype development and its deployment.

1. social media analysis of Reddit, Twitter, Instagram

We start examining our research questions with analysis of self-reported hiker preparation, experience, and reflection on three social media platforms: Reddit, Twitter, and Instagram. We selected these platforms for the diversity they represent of different styles of engagement by stakeholders playing different trail infrastructure roles, and the platforms’ prior and intended uses. Reddit is a social information aggregation platform that gathers users in communities, or subreddits, on different topics, including many related to hiking and the Appalachian Trail. Users gain prestige from gaining “upvotes,” with a culture of experts that answer questions from

a constant stream of eager though less-informed parties. Twitter and Instagram are both lower-effort platforms that support quick posts of text snippets and images, respectively. Hikers widely use them on the trail to share successes, frustrations, and general information, yielding a temporally organized repository of knowledge. Mining social media has grown in popularity and use in recent years, and our team has experience in mining data from each of these platforms (Bartolome 2018, Kotut *et al.* 2020, Kotut & McCrickard 2021, Niu *et al.* 2020).

To begin to answer our research questions, we will use multiple data aggregators such as Pushshift (pushshift.io) and BigQuery (cloud.google.com/bigquery), which ensure a broad coverage of all posts and fields from each of the platforms. Timestamps, hashtags, and geotags will allow us to cluster and arrange the information to reveal a high-level understanding of the times, people, places, and topics common in each platform. Examining correlations among the themes and topics from the posts will reveal common themes (*e.g.*, people who report on wildlife may seem more careful about safely storing their food), and techniques such as k-means clustering and axial coding will reveal groupings. The former particularly helps to craft unbiased groupings of data on terms and fields identified as most important for each dataset. Axial coding will show prominence of terms chosen by our proposal team and stakeholder group.

2. interviews of current and past LD hikers, volunteers, ATC and agency staff

We will use a *systematic grounded theory methodology* to inform our interviews of hiking stakeholders. The framework will be guided by preliminary constructs from the social media analysis, but grounded in data (Corbin & Strauss 2008). Like many inductive studies, we will not select our interviewees at random (Nowell & Albrecht 2019, 353), but rather proactively to capture different contextual factors relevant to our research questions concerning technology orientations and practices; that is, we will seek different genders (Akman *et al.* 2005), experiences and background (Ng *et al.* 2010), and geographic regions (Georgia through Maine). We will aim for a sample of 30 trail maintainers, resource managers, and agency staff.

The cooperative AT governance model noted earlier involves the US National Park Service, US Forest Service, other federal and state agencies, the non-profit Appalachian Trail Conservancy (ATC), and 31 volunteer-based trail clubs, so our interviews necessarily span an array of organizations. The ATC leads the management, making it our initial focus for interviews. By virtue of our past collaborations with the ATC as well as with federal and state agencies having AT interests, we already have an *entrée* into these entities. We also will draw interviewees from two other umbrella organizations—the American Hiking Society and Appalachian Long Distance Hikers Association—that have expressed interest in our research. In addition, our sample will include volunteers and trail maintainers from the AT trail clubs, as well as contacts identified in our social media analysis. Finally, we will recruit 30 past AT hikers for 30-45 minute zoom interviews by advertising on relevant Reddit and Facebook hiking communities such as hikit (r/hiking), r/AppalachianTrail, and AT Thru-Hikers and section hiker Facebook groups. Moreover, we will triangulate our interview data with agency reports such as the ATC's Conservation and Trail Management Policies, including land and resource management and visitor management, and the social media analysis of knowledge gaps in trail management.

3. survey of LD hikers

Our survey will pose a set of questions to capture fives types of information from LD hikers: 1) socio-economic and demographic info (*e.g.*, income, education, age, *etc.*); 2) types of trail infra-

structure services valued and behavior to realize this value (*e.g.*, dispersed camping to increase tranquility); 3) digital technology use on the trail, the information sought or shared with this use, and the influence of this on hikers' connections with nature; and 4) knowledge of LNT principles; and 5) attitudes about sharing LNT-related information among trail stakeholders.

This fifth part of the survey will utilize choice experiments—also known as factorial survey, vignette studies, and conjoint analysis (Atzmüller & Steiner 2010, Louviere 1996, Louviere *et al.* 2000, Rossi & Nock 1982)—to identify preferred choices out of a limited set of alternative LNT information scenarios. Previous studies including some of our own have employed choice experiments to examine hiker preferences on a variety of attributes (*e.g.*, Cahill *et al.* 2008, Lawson & Manning 2003, Kohlhardt *et al.* 2018, Guo *et al.* 2015), but none to the best of our knowledge have addressed digital information sharing. Our social media analysis and interviews will reveal the most trenchant attributes to consider, but we anticipate that these will include some combination of the information itself (type of information shared) and the process of sharing it (*e.g.*, frequency of messaging, privacy concerns).

We will recruit our survey sample of AT hikers at three northbound trail interception points, two at trail festivals held to promote local economic development (in NC at mile 275 in mid-April, and Duncannon Appalachian Trail Festival in PA at mile 1,150 in mid-June) and the third at a trailside public campground (in VT at mile 1,700 in early August). This three-site interception aims to collect one-time responses from 350 LD hikers in total over a 3-month period, capturing whether practices and perspectives on information retrieval/sharing and trail infrastructure services change along the trail (hiker attrition precludes a panel approach).

4. develop prototype app-based trail navigation and information collection

Full development and extensive testing of SmarTrail lies well beyond the scope of this proposal, but we seek to prototype and test aspects of SmarTrail to ground truth and improve our understanding. At its core, we envision SmarTrail as a hub to collect and disseminate information that focuses on supporting the interconnected communities and sub-communities of trailgoers, not just LD hikers but also volunteers, agency staff, scientists, and others.

This type of system serves as an information repository, drawing both from highly trusted sources providing regulated information (*e.g.*, locations, mileage, closures) as well as from users and volunteers furnishing observations and opinions (*e.g.*, difficulty in finding water). While the SmarTrail vision will evolve through the above activities, we anticipate a prototype centered on collecting and disseminating knowledge related to three LNT principles and the Sustainable Campsite initiative. Our desire to focus these early prototyping efforts on these areas stems from the centrality of LNT principles to most protected area managers, the desire to reduce new campsite creation (proliferation) and expansion by campers, and the need anonymous geotagged data on the number and spatial distribution of LD hikers and campers to inform managers seeking to balance supply and demand for finite hiking resources.

We will employ a participatory design (PD) approach to the development of the SmarTrail cyber-based information system. PD roots in stakeholder involvement, giving members from all stakeholder groups a voice in the design process. Our PD approach will engage stakeholders in regular roundtable meetings, with each meeting centered on an artifact or prototype. Our social media analysis, survey, and interviews will help us identify representative stakeholders with the interest, motivation, and enthusiasm to take part in these regular sessions. At the earliest stages

of the design process, the meetings will focus around some aspect of existing trail culture (such as personas of common trail users, task maps of current and envisioned ways to share knowledge) to ensure buy-in and broad usability of the envisioned knowledge repository and apps. Meetings at the later stages of the design process will focus on SmarTrail prototypes, initially early sketches and wireframes and then later functional apps, with coverage of the web apps used for planning and reflection and mobile apps for sharing knowledge on the trail.

5. deploy, test, and analyze use of prototype trail system

The final activity of the project will focus on an expert review of our SmarTrail prototype. As just described, the PD process helps ensure the design takes into account many different perspectives about what the knowledge collection and distribution system needs. However, the process also needs an external vantage from people not engaged in the development process.

Our expert review will ask a representative collection of stakeholders across the various user domains to review our design and reflect on its potential utility in different situations. The stakeholders will differ from those on the design team to gain fresh outlooks on the prototype design, though drawn from the same pool of stakeholders (*e.g.*, LD hikers, trail maintenance volunteers). We anticipate choosing 7-9 people across the various stakeholder groups to take part in a 1-2 hour video prototype walkthrough, questionnaire, and reflection.

This walkthrough will present a series of common tasks, along with questions to elicit feedback from the review group. The questions will reflect the themes from our prior interview and survey tasks and seek to identify the degree to which our knowledge repository and collection of apps will help increase knowledge and awareness and/or help to establish tighter community bonds. The feedback will influence the recommendations for crafting mobile and web applications, as well as the underlying structure of a knowledge capture and management system.

Broader Impacts

Hiking contributes over $3.5 billion every year to the country's GDP (BEA 2020), in addition to unmeasured personal health and intrinsic benefits to hikers. Yet, sustaining the infrastructure to support trail services poses challenges in the face of increasing use pressures and deteriorating conservation outcomes. The recent bipartisan passage and signing into law of federal legislation to fund trail and other outdoor infrastructure improvements on federal land, the Great American Outdoors Act in 2020 (134 Stat. 682), highlights the importance of these services to a cross section of the country. Our SmarTrail approach to blend digital information flows with spatial, social, psychological, and cultural dimensions represents a potentially transformative way to leverage this support to improve trail infrastructure performance and deliver high quality hiker experiences as well as meet conservation objectives. Further, our socio-technological information framework aims to illuminate the barriers and opportunities to using digital technologies to improve performance across other infrastructures as well.

Appropriateness to EAGER, Infrastructure Focus, NSF Programs, and Investigators

SmarTrail marries the fields of social psychology, public policy, human-computer interaction, and recreation ecology to develop a transdisciplinary-informed understanding of the socio-technological world of hikers and resource managers. We focus on *trail infrastructure*, which as with the larger category of *transportation infrastructure* to which it belongs, typically represents a derived demand, a path toward services that LD hikers value directly (*e.g.*, aesthetics, recreational pleasure, tranquility). We believe that our transformative contributions lie both in

our conceptualization of supply and demand side of trail services and in the novel information landscape of digital technology, social practices, and cognition that we fashion to join these sides. While we examine only on one type of infrastructure and only on one trail, our behaviorally informed approach is directly relevant to other trails and other infrastructures.

Within SBE, our work fits within the core concerns of the *Decision, Risk and Management Sciences* program, namely decision making, perception, the use of decision aiding tools, public policy, and communication. The *Human Networks and Data Science* program also is relevant, since we work at the nexus of a digital information environment and human behavior. Across NSF our work relates to and we bring expertise in CISE (*Human Centered Computing* and *Smart and Connected Communities*), through the computer scientist on our team and BIO (*Dynamics of Integrated Socio-Environmental Systems*), through our recreational ecologist.

Our project PI, Kris Wernstedt, works on decision-making under uncertainty and risk. He brings expertise in survey design and statistical analysis, as well as over 300 miles of hiking experience on the Appalachian Trail. His role will be to lead the design, implementation, and recruitment of subjects in the panel study and associated data analysis. Shalini Misra brings expertise in social and environmental psychology, with a focus on cognitive and interpersonal aspects of mobile technologies. She will lead the design and implementation of the interviews of LD hikers and associated data analysis. Scott McCrickard conducts research in the field of Human Computer Interaction, concentrating on notification systems on mobile devices and leading Virginia Tech's Technology on the Trail initiative. Scott will lead the social media analysis and app development tasks as well as co-lead the app deployment process. Finally, Jeff Marion specializes in recreational ecology, centering on research and monitoring to evaluate environmental impacts resulting from trail and camping use in protected natural areas. He has backpacked all of the AT and will lead the agency interviews and co-lead the app deployment.

Results from Prior NSF Support

NSF Award 1133263: *DRRC/Collaborative Research: Emergency Management in Rural America: Decision-Makers Use of Climate Science in Flood Planning and Management* (9/1/2011-12/31/2016, $198,000). Intellectual Merit: Project deepened understanding of the impact of forecast uncertainty about threatening climate events on expert decision-making, documenting how established decision heuristics influence choices by public sector managers to protect their communities. Broader Impacts: Our work demonstrated and communicated the promise of seasonal climate forecasts to the emergency management community through seminars and presentations at professional conferences. Project publications include (Roberts & Wernstedt 2016, 2018, 2019, Roberts *et al.* 2019, Wernstedt *et al.* 2019, Roberts *et al.* 2020)

NSF Award 2028242: *RAPID: Distancing and Digital Information in the Face of COVID-19* (05/1/2020 - 04/31/2021, $98,285). Intellectual Merit: Project elaborates construal level theory by empirically distinguishing between the spatial and psychosocial dimensions of the construct of psychological distancing and calibrating the psychological impacts of immersion in online environments during a period of very limited in-person interactions. Broader Impacts: Study offers to increase understanding of the judgments, perceptions, and behaviors that result from different digital information interactions and social distancing restrictions to help develop better strategies to respond to future large-scale crises. Project was recently awarded and no publications have yet been produced under this grant.

References

Akman, Ibrahim, *et al.* 2005. "E-Government: A Global View and an Empirical Evaluation of Some Attributes of Citizens." *Government Information Quarterly* 22 (2):239-257. doi: https://doi.org/10.1016/j.giq.2004.12.001.

Appalachian Trail Conservancy. 2017. *Appalachian Trail Conservancy Annual Report*. Harpers Ferry, WV: Appalachian Trail Conservancy.

Aranda, Julie H., and Safia Baig. 2018. "Toward "Jomo": The Joy of Missing out and the Freedom of Disconnecting." 2018.

Arendt, Florian, and Jörg Matthes. 2016. "Nature Documentaries, Connectedness to Nature, and Pro-Environmental Behavior." *Environmental Communication* 10 (4):453-472. doi: 10.1080/17524032.2014.993415.

Atzmüller, Christiane, and Peter M. Steiner. 2010. "Experimental Vignette Studies in Survey Research." *Methodology: European Journal of Research Methods for the Behavioral and Social Sciences* 6 (3):128-138.

Ballantyne, Mark, and Catherine Marina Pickering. 2015. "Recreational Trails as a Source of Negative Impacts on the Persistence of Keystone Species and Facilitation." *Journal of Environmental Management* 159:48-57. doi: https://doi.org/10.1016/j.jenvman.2015.05.026.

Barratt, Paul. 2017. "Healthy Competition: A Qualitative Study Investigating Persuasive Technologies and the Gamification of Cycling." *Health & Place* 46:328-336. doi: https://doi.org/10.1016/j.healthplace.2016.09.009.

Bartolome, Abigail. 2018. "Describing Trail Cultures through Studying Trail Stakeholders and Analyzing Their Tweets."Master's Thesis, Virginia Tech.

BEA. 2020. *Outdoor Recreation Satellite Account, U.S. And States, 2019*. Suitland, MD: Bureau of Economic Analysis, US Department of Commerce.

Bemelmans-Videc, Marie-Louise, *et al.*, eds. 1998. *Carrots, Sticks & Sermons : Policy Instruments and Their Evaluation*. New Brunswick, NJ: Transaction Publishers.

Borrie, William T., and Joseph W. Roggenbuck. 2001. "The Dynamic, Emergent, and Multi-Phasic Nature of on-Site Wilderness Experiences." *Journal of Leisure Research* 33 (2):202-228. doi: 10.1080/00222216.2001.11949938.

Bostrom, Robert P., and J. Stephen Heinen. 1977. "Mis Problems and Failures: A Socio-Technical Perspective. Part I: The Causes." *MIS Quarterly* 1 (3):17-32. doi: 10.2307/248710.

Braat, Leon C., and Rudolf de Groot. 2012. "The Ecosystem Services Agenda:Bridging the Worlds of Natural Science and Economics, Conservation and Development, and Public and Private Policy." *Ecosystem Services* 1 (1):4-15. doi: https://doi.org/10.1016/j.ecoser.2012.07.011.

Brassil, Gillian R. 2020. "As Hiking Surges During the Pandemic, So Do Injuries." *New York Times*, November 28, 2020.

Briggs, Robert O., *et al.* 2010. "Special Section: Social Aspects of Sociotechnical Systems." *Journal of Management Information Systems* 27 (1):13-16. doi: 10.2753/MIS0742-1222270101.

Bryson, Bill. 1999. *A Walk in the Woods: Rediscovering America on the Appalachian Trail*. 1st. ed. New York, NY: Random House.

Buscher, B. 2014. "Nature 2.0: Exploring and Theorizing the Links between New Media and Nature Conservation." *New Media & Society* 18. doi: 10.1177/1461444814545841.

Büscher, Bram, and Jim Igoe. 2013. "'Prosuming' Conservation? Web 2.0, Nature and the Intensification of Value-Producing Labour in Late Capitalism." *Journal of Consumer Culture* 13 (3):283-305. doi: 10.1177/1469540513482691.

Cahill, Kerri L., *et al.* 2008. "Exploring Visitor Acceptability for Hardening Trails to Sustain Visitation and Minimise Impacts." *Journal of Sustainable Tourism* 16 (2):232-245. doi: 10.2167/jost804.0.

Castro, Antonio J., *et al.* 2014. "Ecosystem Service Trade-Offs from Supply to Social Demand: A Landscape-Scale Spatial Analysis." *Landscape and Urban Planning* 132:102-110. doi: https://doi.org/10.1016/j.landurbplan.2014.08.009.

Chan, Kai, *et al.* 2011. "Cultural Services and Non-Use Values." In *Natural Capital: Theory and Practice of Mapping Ecosystem Services*, edited by Peter Kareiva, Heather Tallis, Taylor H. Ricketts, Gretchen C. Daily and Stephen Polasky, 206-228. Oxford, UK: Oxford University Press.

Corbin, Juliet M., and Anselm L. Strauss. 2008. "Basics of Qualitative Research (3rd Ed.): Techniques and Procedures for Developing Grounded Theory." In. Thousand Oaks, California. https://methods.sagepub.com/book/basics-of-qualitative-research (accessed 2021/02/01).

Costopoulou, Constantina, *et al.* 2016. "Studying Mobile Apps for Agriculture." *IOSR Journal of Mobile Computing & Application (IOSR-JMCA)* 3:44-49. doi: 10.9790/0050-03064449.

Daily, Gretchen C., ed. 1997. *Nature's Services: Societal Dependence on Natural Ecosystems*. Washington DC: Island Press.

Dustin, Daniel, *et al.* 2017. "Landscape to Techscape: Metamorphosis Along the Pacific Crest Trail." *International Journal of Wilderness* 23 (1):25-30.

Egger, Inta, *et al.* 2020. "Digital Free Tourism – an Exploratory Study of Tourist Motivations." *Tourism Management* 79:104098. doi: https://doi.org/10.1016/j.tourman.2020.104098.

Eichler Inwood, Sarah E., and Virginia H. Dale. 2019. "State of Apps Targeting Management for Sustainability of Agricultural Landscapes. A Review." *Agronomy for Sustainable Development : Official journal of the Institut National de la Recherche Agronomique (INRA)* 39 (1):1-15. doi: 10.1007/s13593-018-0549-8.

Fish, Robert, *et al.* 2016. "Conceptualising Cultural Ecosystem Services: A Novel Framework for Research and Critical Engagement." *Ecosystem Services* 21:208-217. doi: https://doi.org/10.1016/j.ecoser.2016.09.002.

Fondren, Kristi M. 2016. *Walking on the Wild Side: Long-Distance Hiking on the Appalachian Trail*. New Brunswick, NJ, USA: Rutgers University Press.

Gee, Kira, and Benjamin Burkhard. 2010. "Cultural Ecosystem Services in the Context of Offshore Wind Farming: A Case Study from the West Coast of Schleswig-Holstein." *Ecological Complexity* 7 (3):349-358. doi: https://doi.org/10.1016/j.ecocom.2010.02.008.

Geijzendorffer, Ilse R., *et al.* 2015. "Improving the Identification of Mismatches in Ecosystem Services Assessments." *Ecological Indicators* 52:320-331. doi: https://doi.org/10.1016/j.ecolind.2014.12.016.

Graham, M., *et al.* 2013. "Augmented Reality in Urban Places: Contested Content and the Duplicity of Code." *Transactions of the Institute of British Geographers* 38 (3):464-479. doi: 10.1111/j.1475-5661.2012.00539.x.

Groth, Stefan. 2014. "Quantified Cyclists and Stratified Motives: Explorations into Age-Group Road Cycling as Cultural Performance." *Ethnologia Europaea* 44:38-56. doi: 10.16995/ee.1120.

Guo, Tian, *et al.* 2015. “Determinants of Responsible Hiking Behavior: Results from a Stated Choice Experiment.” *Environmental Management* 56 (3):765-776. doi: 10.1007/s00267-015-0513-1.
Hammitt, William E., *et al.* 2015. *Wildland Recreation: Ecology and Management*. 3rd ed. Chichester, UK: Wiley-Blackwell.
Harmon, Mary E. 2015. “Computing as Context: Experiences of Dis/Connection Beyond the Moment of Non/Use.”PhD Thesis, UC Irvine.
Helms, Karey, *et al.* 2019. “Away and (Dis)Connection: Reconsidering the Use of Digital Technologies in Light of Long-Term Outdoor Activities.” *Proc. ACM Hum.-Comput. Interact.* 3 (GROUP). doi: 10.1145/3361111.
Hess, Charlotte, and Elinor Ostrom. 2003. “Ideas, Artifacts, and Facilities: Information as a Common-Pool Resource.” *Law and Contemporary Problems* 66 (1/2):111-145.
Hogendorn, Christiaan, and Brett Frischmann. 2020. “Infrastructure and General Purpose Technologies: A Technology Flow Framework.” *European Journal of Law and Economics* 50 (3):469-488. doi: 10.1007/s10657-020-09642-w.
Jepson, Paul, and Richard Ladle. 2015. “Nature Apps: Waiting for the Revolution.” *Ambio* 44. doi: 10.1007/s13280-015-0712-2.
Kohlhardt, Regan, *et al.* 2018. “Is This Trail Too Crowded? A Choice Experiment to Evaluate Tradeoffs and Preferences of Park Visitors in Garibaldi Park, British Columbia.” *Journal of Environmental Planning and Management* 61 (1):1-24. doi: 10.1080/09640568.2017.1284047.
Kotut, Lindah, *et al.* 2020. “Preparing for the Unexpected: Community Framework for Social Media Use and Social Support by Trail Thru-Hikers.” CHI '20: Proceedings of the 2020 CHI Conference on Human Factors in Computing System.
Kotut, Lindah, and D. Scott McCrickard. 2021. *The Long Way Home: News Values in Stories Told by Appalachian Trail Thru-Hikers on Instagram.*: (Under review at the ACM Conference on Computer Supported Collaborative Work: CSCW 2021).
Larondelle, Neele, and Steffen Lauf. 2016. “Balancing Demand and Supply of Multiple Urban Ecosystem Services on Different Spatial Scales.” *Ecosystem Services* 22:18-31. doi: https://doi.org/10.1016/j.ecoser.2016.09.008.
Lawson, Steven R., and Robert E. Manning. 2003. “Integrating Multiple Wilderness Values into a Decision-Making Model for Denali National Park and Preserve.” *Journal for Nature Conservation* 11 (4):355-362. doi: https://doi.org/10.1078/1617-1381-00068.
Leave No Trace Center for Outdoor Ethics. 2021. “Leave No Trace.” Leave No Trace Center for Outdoor Ethics, accessed Feb. 3, 2021. https://lnt.org/.
Levi, Daniel, and Sara Kocher. 1999. “Virtual Nature: The Future Effects of Information Technology on Our Relationship to Nature.” *Environment and Behavior* 31 (2):203-226. doi: 10.1177/00139169921972065.
Lomborg, Stine, and Kirsten Frandsen. 2016. “Self-Tracking as Communication.” *Information, Communication & Society* 19 (7):1015-1027. doi: 10.1080/1369118X.2015.1067710.
Louviere, Jordan. 1996. “Relating Stated Preference Measures and Models to Choices in Real Markets: Calibration of the Cv Responses.” In *The Contingent Valuation of Environmental Resources: Methodological Issues and Research Needs*, edited by David J. Bjornstad and James R. Kahn, 167-188. Cheltenham, UK: Edward Elgar.
Louviere, Jordan J., *et al.* 2000. *Stated Choice Methods: Analysis and Application*. Cambridge: Cambridge University Press.

Lum, C. S., *et al.* 2020. "The Long-Distance Hiking Social World Along the Pacific Crest Trail." *Journal of Leisure Research* 51 (2):165-182. doi: 10.1080/00222216.2019.1640095.
Lynn, Natasha A., and Robert D. Brown. 2003. "Effects of Recreational Use Impacts on Hiking Experiences in Natural Areas." *Landscape and Urban Planning* 64 (1):77-87. doi: https://doi.org/10.1016/S0169-2046(02)00202-5.
Marion, Jeffrey, *et al.* 2018. "Applying Recreation Ecology Science to Sustainably Manage Camping Impacts: A Classification of Camping Management Strategies." *International Journal of Wilderness* 24 (2):84-100.
Marion, Jeffrey L., *et al.* 2016. "A Review and Synthesis of Recreation Ecology Research Findings on Visitor Impacts to Wilderness and Protected Natural Areas." *Journal of Forestry* 114 (3):352-362. doi: 10.5849/jof.15-498.
Mayer, F. Stephan, *et al.* 2008. "Why Is Nature Beneficial?: The Role of Connectedness to Nature." *Environment and Behavior* 41 (5):607-643. doi: 10.1177/0013916508319745.
Millennium Ecosystem Assessment. 2005. *Ecosystems and Human Well-Being: Synthesis*. Washington DC: Island Press.
Muñoz, Lorena, *et al.* 2019. "Advantages and Limitations of Using Mobile Apps for Protected Area Monitoring and Management." *Society & Natural Resources* 32 (4):473-488. doi: 10.1080/08941920.2018.1544680.
Ng, Eddy, *et al.* 2010. "New Generation, Great Expectations: A Field Study of the Millennial Generation." *Journal of Business and Psychology* 25:281-292. doi: 10.1007/s10869-010-9159-4.
Niu, Shuo, *et al.* 2020. "Investigating Paradigms of Group Territory in Multiple Display Environments." *Proc. ACM Hum.-Comput. Interact.* 4 (GROUP):Article 13. doi: 10.1145/3375193.
Nowell, Branda, and Kate Albrecht. 2019. "A Reviewer's Guide to Qualitative Rigor." *Journal of Public Administration Research and Theory* 29 (2):348-363. doi: 10.1093/jopart/muy052.
Pergams, Oliver R. W., and Patricia A. Zaradic. 2008. "Reply to Jacobs and Manfredo: More Support for a Pervasive Decline in Nature-Based Recreation." *Proceedings of the National Academy of Sciences* 105 (27):E41. doi: 10.1073/pnas.0803331105.
Potschin, Marion, and Roy Haines-Young. 2016. "Defining and Measuring Ecosystem Services." In *Routledge Handbook of Ecosystem Services*, 25-44. Routledge : New York, NY : Routledge, 2016.
Raya, Josep Maria, *et al.* 2018. "Economic and Social Yield of Investing in Hiking Tourism: The Case of Berguedà, Spain." *Journal of Travel & Tourism Marketing* 35 (2):148-161. doi: 10.1080/10548408.2017.1350252.
Roberts, Patrick S., *et al.* 2020. "How Public Managers Make Tradeoffs Regarding Lives: Evidence from a Flood Planning Survey Experiment." *Administration & Society*:0095399720944811. doi: 10.1177/0095399720944811.
Roberts, Patrick S., and Kris Wernstedt. 2016. "Using Climate Forecasts across a State's Emergency Management Network." *Natural Hazards Review* 17 (3):5016002. doi: 10.1061/(ASCE)NH.1527-6996.0000222.
Roberts, Patrick S., and Kris Wernstedt. 2018. "Herbert Simon's Forgotten Legacy for Improving Decision Processes." *International Public Management Journal*:1-26. doi: 10.1080/10967494.2018.1502223.

Roberts, Patrick S., and Kris Wernstedt. 2019. “Decision Biases and Heuristics among Emergency Managers: Just Like the Public They Manage For?” *The American Review of Public Administration* 49 (3):292-308. doi: 10.1177/0275074018799490.

Roberts, Patrick S., *et al.* 2019. “The Emergency Manager as Risk Manager.” In *Disaster Research and the Second Environmental Crisis: Assessing the Challenges Ahead*, edited by James Kendra, Scott G. Knowles and Tricia Wachtendorf, 261-275. Cham: Springer International Publishing.

Rossi, Peter H., and Steven L. Nock, eds. 1982. *Measuring Social Judgments: The Factorial Survey Approach*. Beverly Hills, CA: Sage.

Silas, Everiin, *et al.* 2016. “The Smartphone's Role in the Contemporary Backpacking Experience.” *Networking Knowledge* 9:40-55. doi: 10.31165/nk.2016.96.491.

Smith, William Roth, and Jeffrey Treem. 2017. “Striving to Be King of Mobile Mountains: Communication and Organizing through Digital Fitness Technology.” *Communication Studies* 68 (2):135-151. doi: 10.1080/10510974.2016.1269818.

Stamberger, Lorraine, *et al.* 2018. “A Gps Tracking Study of Recreationists in an Alaskan Protected Area.” *Applied Geography* 93:92-102. doi: https://doi.org/10.1016/j.apgeog.2018.02.011.

Taylor, Christopher, *et al.* 2012. “Selecting Policy Instruments for Better Environmental Regulation: A Critique and Future Research Agenda.” *Environmental Policy and Governance* 22 (4):268-292. doi: https://doi.org/10.1002/eet.1584.

Wei, Hejie, *et al.* 2017. “Integrating Supply and Social Demand in Ecosystem Services Assessment: A Review.” *Ecosystem Services* 25:15-27. doi: https://doi.org/10.1016/j.ecoser.2017.03.017.

Wernstedt, Kris, *et al.* 2019. “How Emergency Managers (Mis?)Interpret Forecasts.” *Disasters* 43 (1):88-109. doi: 10.1111/disa.12293.

Zook, Matthew, and Mark Graham. 2007. “The Creative Reconstruction of the Internet: Google and the Privatization of Cyberspace and Digiplace.” *Geoforum* 38:1322-1343. doi: 10.1016/j.geoforum.2007.05.004.