Alone and Together: Resilience in a Fluid Socio-Technical-Natural System

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Disruption to routines is an increasingly common part of everyday life. With the roots of some disruptions in the interconnectedness of the world and environmental and socio-political instability, there is good reason to believe that conditions that cause widespread disruption will persist. Individuals, communities, and systems are thus challenged to engage in *resilience practices* to deal with both acute and chronic disruption. Our interest is in chronic, *everyday resilience*, and the role of both technology and non-technical adaptation practices engaged by individuals and communities, with a specific focus on practices centered in nature. Foregrounding nature's role allows close examination of environmental adversity and nature as part of adaptivity. We add to the CSCW and HCI literature on resilience by examining long-distance hikers, for whom both the sources of adversity and the mitigating resilience processes cut across the social, the technical, and the environmental. In interviews with 12 long-distance hikers we find resilience practices that draw upon technology, writ large, and nature in novel assemblages, and leverage fluid configurations of the individual and the community. We place our findings in the context of a definition for resilience that emphasizes a systems view at multiple scales of social organization. We make three primary contributions: (1) we contribute an empirical account of resilience in a contextual setting that complements prior CSCW resilience studies, (2) we add nuance to existing models for resilience to reflect the role of technology as both a resilience tool and a source of adversity, and (3) we identify the need for new designs that integrate nature into systems as a way to foster collaborative resilience. This nuanced understanding of the role of technology in individual and community resilience in and with nature provides direction for technology design that may be useful for everyday disrupted life.

CCS Concepts: • **Human-centered computing → Empirical studies in collaborative and social computing**.

Additional Key Words and Phrases: Resilience; Socio-Technical-Natural Systems; Technology in Nature; Hiker Community

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1 INTRODUCTION

Disruption to routines from both acute (short-term) and chronic (long-lived) conditions is an increasingly common part of everyday life. With the roots of some significant disruptions in

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the interconnectedness of the world and environmental and socio-political instability, there is good reason to believe that conditions that cause disruption will persist. Among the root sources of disruption are climate change, which produces more frequent extreme weather events and permanent environmental changes; socio-political divides that result in rioting, skirmishes, and wars; and disease mutation and rapid transmission as seen in the now multi-year COVID-19 pandemic. Even those who are not acutely affected by these forms of adversity see their everyday lives disrupted, e.g., in the upending of travel and other plans, the move to (and back from) online schooling, and the need to remain on alert to vacate homes in wildfire zones, as just a few examples. A new normal is emerging where the ability to respond to fluid and unpredictable conditions is a near requirement for successfully navigating the current world.

In this paper, we study long-distance hikers who sign up for a disrupted life by embarking on a walking journey, living primarily in nature, that lasts at least a month. Because they choose to subject themselves to disruption, they differ from those who must contend with uninvited circumstances. However, this desire to circumvent "conventional societal expectations" may well place long-distance hikers in a population of interest to collapse informatics, for they share many similarities with what Tomlinson et al. describe as a "purposefully marginal group" who, importantly, "are not marginalized through economic or other circumstances" [62]. Yet, unlike most purposefully marginal groups whose ideology is to prepare for and permanently embark on a disrupted future, hikers may opt out of the prolonged disruption by ending their journey, though because the complete journey is the goal, most are reluctant to do so. They draw upon technologies writ large to enable resiliency, yet they must grapple with disruptions to the technology caused by weather, lack of network connectivity, and irregular availability of electrical power. And they enact resilience both individually and in dynamic social configurations. The resulting *socio-technical-natural system* provides a microcosm of a highly disruptive world where researchers can investigate how individuals and communities use technologies to adapt to adversity; it also reveals how technologies themselves are vulnerable to disruption in nature and must be utilized with adaptations.

In his CSCW 2019 paper on everyday resilience, Semaan [57] cites Southwick and colleagues [60] as stressing that "scholars must continue to empirically operationalize resilience in situ, as the evocation of resilience can differ depending on the context." To this end, we conducted an interview study of 12 long-distance hikers to address the following research questions concerning their in situ resilience experience:

RQ1: *How can we characterize factors that contribute to resilience in a (fluid) socio-technical-natural system, at both an individual and collective level?*

RQ2: *How does the unusual setting of long-distance hiking inform technology design for resilience in the everyday lives of the rest of us? That is, in what ways do long-distance hikers and their experience provide a lens on resilience more generally?*

We make the following contributions:

- Following calls for understanding resilience in context, we contribute an empirical account of resilience for individuals and a community who are quite different from those studied in previous CSCW and HCI investigations. Our study subjects choose to replace their life's daily routines with a new set of routines that are subject to disruption and where technology is helpful but also "iffy" and nature is foregrounded.
- Based on our analysis of resilience and technology enacted by hikers, we refine existing models for resilience to reflect the situation where technology as a tool of resilience is itself subject to adverse conditions. Our adversity-adaptation feedback model may be useful for analyzing other situations where technology is precarious.

- We examine resilience processes engaged by individuals and the long-distance hiking community that involve both collaborative and individual processes. We identify a need for designs that integrate nature into systems for collaborative resilience that support and respect a range of individual desires surrounding time in nature. We provide design insights for technology to help individuals, both within and outside the hiking community, to better cope with disruption.

This nuanced understanding of the role of technology in individual and community resilience in and with nature provides direction for technology design that may be useful for everyday disrupted life.

2 BACKGROUND AND CONCEPTS

In this section, we provide contextualizing terminology and information about hikers and their use of technology in nature.

2.1 Contextualizing Hikers

The hiking community has two distinct groups with overlapping but different information needs and social behaviors. *Day hikers* visit trails as a recreational outing, selecting those that are convenient. They typically complete the hike within a single day while carrying all food, water, and safety equipment they expect to need. *Long-distance hikers* spend many days, even months, on a trail, often carrying as little as possible due to weight concerns. As an extreme case of long-distance, *thru-hikers* complete an entire lengthy trail in one multi-month excursion, scheduling periodic deliveries of re-supplies at points along the trail. *Section hikers* are also long-distance hikers, who complete portions of a long trail, often spending weeks at a time on the trail. In describing our interview population we will distinguish between the various types of long-distance hikers for additional context; when we use the phrase "long-distance hikers" we mean all types.

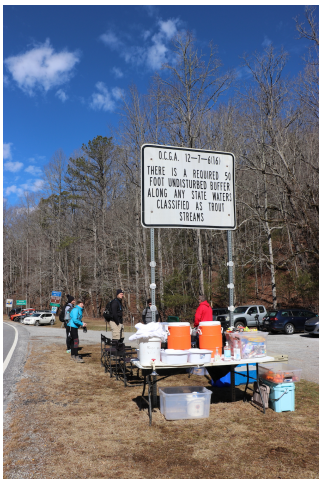


Fig. 1. Trail angel setup photographed by one of the authors on a portion of the AT. Feb, 2021.

The three most popular thru-hiking routes in the United States are the Pacific Crest Trail (PCT), running along the west coast from Mexico to Canada; the Appalachian Trail (AT), running along the east coast from Georgia to Maine; and the Continental Divide Trail (CDT), also running from Mexico to Canada, starting in New Mexico and ending in Montana. These three constitute the "triple crown" of thru-hikes.

Long-distance hiking has engendered a unique a network of individuals who provide support to hikers despite the fact that they are strangers. These individuals have elevated status as *trail angels*, and dedicate considerable time and resources to their special roles. Their contributions typically include providing meals (sometimes served hot, a rare luxury for hikers) as well as car rides in and out of towns. Figure 1 shows what a typical trail angel setup entails.

2.2 Socio-techincal-natural Systems

Our study examines long-distance hikers' experiences in *socio-technical-natural systems*. Importantly, these systems involve complex interactions between social structures, technology, and nature. In this paper, we specifically probe how these interactions challenge or promote the resilience of

long-distance hikers. Moreover, we call attention to the ways that different aspects of the system might interact (harmoniously or contentiously) in a way that impacts hikers. Whether or not technology should be used in the context of nature is often a topic of controversy among hikers, as we learned from our interviews, as well as from HCI literature (for example, [25]). Our goal is not to argue for one side or the other, but given the fact that technology *is* being used, our intention is to describe *how* it is used in this setting. Moreover, our work is able to glean unique insights into how technology is used by people who *choose* to enter a context that is prone to disruption, and thus requires them to exercise a certain level of resilience.

In a book about technology in the outdoors, McCrickard et al. provide a framework that defines four elements of "HCI outdoors" [48], namely: the outdoors, humans, computers, and interaction. We draw inspiration from this framework as the scope of their categories help us exemplify the complex interactions we hope to characterize. To explicate our understanding of socio-technical-natural systems, we define the social systems, technology, and nature that comprise these in the context of long-distance hiking:

Social: Due to the nature of our interviews, perhaps the richest component in our paper revolves around the "social" element of socio-technical-natural systems. The HCI outdoors framework defines the "human" element as including either an individual or a group, whose qualities may affect their environment and use of technology [48]. Borrowing from this concept, the "humans" in our study revolve around the community of hikers and adjacent groups.

Regardless of any individual hiker's intent to hike solo or in a group, long-distance hiking is embedded in a social context. The existence of trails in nature is largely the result of collaborative work and information sharing. Trails exist because people collectively chose to follow a particular path; as one person wore down a path through nature, the trail itself signalled to others that someone had gone before them. Beyond their immediate physical presence, trails are known because people collectively share information about their whereabouts, either publicly (e.g., maps, trail signs, and blog posts) or privately (e.g., word of mouth).

Beyond the trails themselves, there are policies that govern where trails are allowed, when they are accessible, and how people should behave on the trail. Park rangers and trail coalitions, such as the Pacific Crest Trail Association [7], safeguard and maintain the integrity of trails; they also care for the general safety and well-being of hikers on the trail and collaborate with emergency responders, such as search and rescue crews. Finally, there is the immediate social context that involves in-person interactions between hikers that encounter each other on the trail.

Technology: Most of our references to "technology" will allude to modern, digital tools. However, in the context of the socio-technical-natural systems in hiking, we use a broad definition of technology to include both digital as well as analog or physical tools, such as paper maps or compasses. The more advanced the tool, the (potentially) richer the information it provides, and the higher the accuracy of that information, but also the more vulnerable the technology is to failure when faced with the harsh and dynamic conditions on the trail. Importantly, the "technical" component of socio-technical-natural systems goes beyond McCrickard et al.'s concept of "computers" for HCI outdoors, as these are limited to "electronic systems" [48].

Nature: Our definition of "nature" begins with McCrickard et al.'s definition of the outdoors [48]:

> *"an environment which is not indoors and lacks the controls and amenities of the indoors, for which factors like weather and lighting are of particular concern"*

McCrickard et al. further describe the outdoors as a range of climates, e.g., tropical or dry, as well as a on a spectrum of human development, e.g., from rural to urban. For our purposes, nature includes the setting which hikers navigate, such as the trail itself and the elements. Specifically within socio-technical-natural systems, nature influences how hikers may or may not interact

with technology. Critically, human activity can alter nature either temporarily or permanently, positively or negatively, and thus can affect both hikers' experience of the trail and their use of technology during the trek.

3 RELATED WORK

Our hiker microcosm connects to concepts of resilience, disruption, and nature, combined with technology's role across these. We thus draw on four threads of CSCW and HCI research in our work. The first concerns technology and resilience in varied settings of adversity; resilience processes and tools are central in this thread. The second concerns collapse informatics and nomadic contexts, where we find a connection between the long-distance hiking community's everyday practices and people who purposefully reject traditional social practices in preparation for and in response to potential disruptions. The third thread focuses on the design for graceful degradation of technology, as this features prominently in our Discussion. Finally, we review the literature on technology in nature and hiking; here the outdoors is dominant.

3.1 Technology and Resilience

Mark, Al-Ani, and Semaan conducted early work in HCI using the specific term "resilience" [44, 46]. In 2008, these authors compare and contrast experiences of those in Israel, where technology was widely available, and Iraq, where technology was quite limited prior to the war, but expanded rapidly once war began [44]. They find many instances of technology as a critically useful resource to replace prior in-person routines, such as group paper writing; to enable new communication routines, such as blogging as a form of empowerment; and to act in concert with physical resources, such as cars to create new assemblages of physical and technological to accomplish work goals. In the case of Iraq, the instability of the technical infrastructure led to creative ways to deal with that disruption by changing the means of communication from one media to another, by seeking out an Internet cafe when home access was disrupted, or by developing self-organized systems of electrical power [44, 46]. Notably, these examples of overcoming technology disruption involve using somewhat similar technology, from a different source, or in a different place, or of a different type.

More recently, HCI researchers have begun examining resilience in everyday settings as a contrast to crisis settings created by environmental disasters or the extreme challenge experienced by war-torn communities. Vyas and Dillahunt focus on individuals with low socio-economic status and use resilience as a strengths-based lens to examine their ongoing practices as they navigate their everyday lives [71]. The use of technology to support resilience emerges from the study, but non-digital strategies – such as visiting a community care center to obtain information – also see substantial use. Vyas and Dillahunt characterize the facets of resilience into so-called *inner phenomenon*, or individual strategies, and those termed *outer phenomenon*, or community strategies. Among key community strategies are reciprocity, sharing, and maintaining strong social ties. Semaan gathers findings from three very different communities experiencing prolonged disruptions, with a focus on how technology is used, created, and re-appropriated [57]. Echoing Vyas and Dillahunt, Semaan also recognizes resilience as an ongoing process, with self-organizing infrastructures as part of the method to overcome breakdowns in existing infrastructures. A key framing from both works is the combination of routines with infrastructuring as a way to build resilience when disruption and adversity are chronic conditions.

3.2 Collapse Informatics and Nomadicity

Disruption to routines from both acute (short-term) and chronic (long-lived) conditions is an increasingly common part of everyday life. A severe example of disruption pertains to work on

collapse informatics, where the goal is to plan and envision sociotechnical systems, in the context of an "abundant present", which support "a future of scarcity" [62]. Although the advent of such a collapse may still be uncertain, there is good reason to believe that conditions that cause disruption to everyday life will persist. In responding to Tomlinson et al.'s call to examine practices that "purposefully seek to unseat everyday practice" [62], we find long-distance hikers' purposeful and voluntary disruption to everyday routines insightful. Considering our proposed socio-technical-natural system may be a useful approach to characterize hiker social norms in the context of collapse informatics.

Hikers are "nomads"; their dominant experience is being on the move and carrying everything they need. Nearly 30 years ago, networking pioneer Kleinrock argued that the state of being disconnected, due to an individual's physical mobility, should be considered *usual*, as opposed to an undesirable edge-case [35]. In his 1996 paper on *nomadicity*, Kleinrock explains that the technical challenges to nomadicity are multifaceted and, we observe, similar to those found in the long-distance hiking context, where more common challenges such as latency and reliability are heightened by physical concerns, such as weight and battery life, or the possibility of "damage, loss and theft" [35].

CSCW and HCI scholars have been interested in the nomadic work and leisure experience, as well as fluid movement between work and leisure afforded by mobile technologies. In CSCW, researchers have examined how use of mobile technologies can facilitate, for instance, remote collaboration [15, 42]. CSCW researchers have also taken into consideration these types of challenges, along with many others that "Tech-Nomads" [16] face. Scholars raise interesting questions about how technological infrastructures can best support nomadic collaboration [15] and nomadic knowledge sharing practices [55], as well as aid in the search for resources [45].

While nomadicity investigates the nuances of mobile work/leisure, work from HCI4D interrogates how users must plan their access to information with deliberation. Users with limited access to information and communication (ICT) infrastructure often needed to plan how they would mobilize towards and away from places with Internet access based on their anticipated information needs [20, 49, 70, 73]. In a similar way, *pocket preppers*–users who prepare information to be available on their devices offline in the case of a major outage of ICT infrastructure–also anticipate times when information may not be available in an online mode [3]. In each of these cases, users rely on offline storage mechanisms as a way to ensure that information is available even when the Internet is not. In our study, hikers reported that they engaged in similar planning around ICT access and information needs.

3.3 Designing for Graceful Degradation of Technology

Graceful degradation arose from design specifications introduced by Herlihy and Wing, wherein systems adapt reactively to changes in the environment using protocols that methodically relax preferred constraints so that the resulting system behavior is as close as possible to the preferred behavior [27]. Our findings and takeaways are most related to work that employs graceful degradation in the design of mobile computing systems that operate in resource challenged environments [26, 33, 76]. These systems assume that operations take place over space and time in rugged environments, so it is necessary for designers to plan for environmental changes that occur across these dimensions. Typically, these environmental changes include battery power levels and network availability. Relaxation of preferred constraints focuses on preserving data collection functionality while de-prioritizing data processing and communication. Importantly, these adaptations are managed "behind the scenes" with minimal or no attention to the adaptation brought to the user interface.

With respect to characterizing user experiences of graceful degradation of technology, there is a related body of work that explores the relationship between battery life and human interactions with mobile devices [13, 17, 39, 63, 74, 75]. Battery life is often rated as a top priority for mobile device users [17, 74]. In recent related work by Ding et al., the authors introduce an Energy-based Smartphone User Behavior Model (E-Sub), which explores the relationship between energy consumption and user behavior [17]. Critically, the work quantifies how smartphone users adapt their usage behavior based on available device power. Also relevant is work by Truong et al., which investigates user perceptions of interfaces that report on the relationship between smartphone battery consumption and application usage [63]. One particularly salient finding in this work was that several users expressed a desire to have interfaces that not only reported on "resources remaining," but also extrapolated resource availability based on recent usage patterns. In section 6, we discuss how long distance hikers' reports on technology use calls for interface designs that might leverage a graceful degradation model to support user resilience in a given environment.

3.4 Technology and Hiking

Particularly in CSCW and HCI, there is increasing interest in the experience of technology in the context of nature [22–24], and more specifically how technology could be used on trails [47]. Related work from HCI includes reflections from researchers that examine the paradoxical perceptions of use and non-use of technology in wilderness settings–particularly as part of thru-hiking experiences. As part of her dissertation fieldwork, which included a 2,650 mile hike through the PCT, Ellie Harmon highlighted how people could feel disconnected even when sending a text message while in the backcountry [25]. Dix characterizes the research opportunity in his 1,050 mile walk through the Wales Coast Path as a "socio-economic transect of a modern nation" as it traverses through both metropolitan and back-country settings [18]. Dix intimately narrates the woes of walking as a methodology, both in terms of physical pain and technological limitations. These researcher accounts from the trail pay close attention to how technology is used and (in many cases) not usable; we are able to use these accounts as a point of comparison as we examine the role of technology in our interviews with long-distance hikers.

Of particular relevance is work from leisure studies, in research that examines how thru-hikers use technologies as part of their activities on the trail [40, 53, 54]. By interviewing hikers about smartphone use on the Appalachian Trail, Rogers et al. found that hikers who used smartphones on the trail relied more heavily on crowdsourced information about trail resources and conditions to make wayfinding decisions than they were to use GPS [53]. However, these interviews also reveal an important tension between hikers' reliance on crowdsourced information and their fundamental desire to limit what they know ahead of time to enhance their sense of adventure [54]. Related work on technology use also notes that there are gendered difference in use and that female hikers were more likely to report that having access to a smartphone on the trail helped them to feel *safe* [40]. Our interviews reveal similar themes surrounding wayfinding, crowdsourcing, and safety. Critically, our work seeks to characterize these uses of technology in nature within a sociotechnical resilience framework.

4 METHODS

We conducted semi-structured interviews to characterize hikers' interactions with technology and their surroundings. The following section describes this process in depth as well as the theoretical framework that guided our analysis.

4.1 Guiding Theories

We identified resilience practices adopted by hikers in response to certain types of adverse scenarios. In this section we will outline the theories behind these two concepts (resilience and adversity), and then will provide a unifying framework for pairing resilience factors with a corresponding type of adversity.

4.1.1 Framing Resilience Factors. Individuals, communities, and systems are challenged to engage in *resilience practices* to adapt to acute and chronic disruption. The concepts of resilience, resilience practice, and resilience theory have emerged from human studies such as psychology, with a focus on understanding how adversity affects individuals [65] to social work, with a focus on individuals in social systems [65]. Over 40+ years resilience has been studied across these and other diverse fields [38] leading to some divergence in the basic definition. As HCI and CSCW scholars continue to explore resilience across different domains of adversity (e.g., [44, 57, 66, 71]), a common definition may be helpful. We find the definition proposed by social work scholar van Breda in his critical review of resilience theory [65] to be valuable for our work:

> *Resilience is "[t]he multilevel processes that systems engage in to obtain better-than-expected outcomes in the face or wake of adversity."*

For our purposes – and perhaps for CSCW and HCI more broadly – there are three salient features of this definition. First, as van Breda explains, *multilevel* means that resilience extends beyond the level of an individual to "multiple domains or levels of the social ecology" [65]. This is especially useful for examining the interaction of individual and community resilience, as we will do in our analysis. Second, *systems* indicates that the unit of analysis may be scaled to the very small (e.g., cells) and to the very large (e.g., communities) and can include "non-human systems." In our work, nature and technology both play a significant role in adversity and in adaptation, hence a definition that spans the human and the non-human is powerful. Finally, the inclusion of both *processes* and *outcomes* in the definition brings together the point of contention in the resilience literature about whether resilience is best defined as a process or as an outcome. van Breda's definition expresses that resilience is a process that can lead to an outcome, neatly bridging the process-outcome divide. We use this definition in our analysis to identify resilience practices of hikers as they engage with technology, community, and nature, and we offer that it might be productively adopted by CSCW and HCI scholars.

4.1.2 Framing Adversity. In addition to resilience theory, we find the taxonomy for adversity proposed by Bonanno and Diminick to be useful for bringing different settings of adversity studied in HCI and CSCW together under a common conceptual framework [10]. Since the 2008 time period, the CSCW engagement with resilience has taken place on two primary lines, the first dealing with *crisis disruptions*, which are generally sudden, frequently unexpected, and relatively short-lived [59, 72]. The second line of engagement is more recent and concerns *everyday resilience*, referring to disruptions that persist and are generally long-lived [57, 71], such as those experienced by citizens in a war zone [57] or people with low socioeconomic status [71]. The Bonanno and Diminick taxonomy distinguishes between *acute adversity*, characterized by a defined starting point, a relatively short duration, and an impact on part (but not all) of life, and *chronic adversity*, characterized by longer duration and an impact nearly all of life. Further, within chronic adversity there are two variations, *distal-onset*, where there is no clear starting point and thus no clear prior good state to return or bounce back to, and *proximal-onset*, where there is a defined starting point. In reference to examples from the CSCW and HCI literature, Vyas and Dillahunt's examination of low socio-economic status populations [71] fits into the chronic adversity with distal-onset category, while Semaan et al.'s work on multi-year wars [44, 46] fits the chronic adversity with

proximate-onset category. Natural disasters such as those studied by Palen [51, 59, 66, 72] can be acute or chronic with proximal-onset, depending on the type of disaster and the situation of the individuals or community in question. We leverage these taxonomies of adversity as we seek to generalize long-distance hikers' resilience practices to design implications for enabling resilience more broadly in Section 6.

4.1.3 Identifying Resilience Factors and Adversities. Our goal is to characterize which types of adversity incite which resilience response. We find the Threat-Tactic structure used by Dosono and Semaan [19] helpful for organizing these practices. In examining identity work of Asian American and Pacific Islander communities on Reddit, Dosono and Semaan frame emergent themes by outlining decolonizing practices as *tactics* that are used in response to colonizing *threats* that jeopardize the work of the community. Following this approach, we frame each theme in our findings by bracketing with the *adversity* that threatens the activity (i.e., completing the thru-hike) and the key resilience *factors* utilized in response.

4.2 Data Collection

We used snowball sampling to identify interview subjects, beginning with a Facebook post to a public hiking group seeking contacts in the section- and thru-hiker community. We interviewed 16 people in total, of which 12 were long-distance hikers, whose demographics and relevant hiking experiences are captured in Table 1. We stopped our interviews once we reached a point of saturation [14]. While we focus in this paper on long-distance hikers, when we began our interviews we included day and overnight hikers. As we progressed in interviews, we preferentially worked to secure interviews with long-distance hikers. We based our analysis on the interviews with long-distance hikers, but included a select few of the day and overnight hikers' comments for specific instances in which they were relevant. The interviewees are labeled based on which type of hiker they are (D=day, O=overnight, S=section, T=thru) to make it easier to understand the context for the comments in the findings. There are two familial relationships in our table, one father-son pair (S2 and S4) and one brother-sister pair (T1 and T2). All of our interviewees were White/Caucasian, except for one who identifies as Asian-American, which reflects the limitations of our snowball sampling methodology as well as the predominant demographic of the long-distance hiking community, which skews significantly towards White/non-Hispanic demographics [43].

We gathered data mainly through semi-structured interviews, as approved by our IRB, conducted virtually using BlueJeans Meetings between March and June of 2020. Each interview lasted between 30 and 60 minutes, was conducted entirely in English, and was recorded with permission of the interview participant. We also studied user-generated content in three forms: social media posts and comments (reddit and Facebook), trail website recordings (AllTrails), and comments in the Guthook Guides application. [1] We took notes from these platforms to get an understanding of the most popular avenues for information seeking by long-distance hikers in preparation for our interviews. This also helped us corroborate insights gathered during the interviews.

At a high level, the structure of our interview questions mirrored Kotut et al.'s organization [36], namely around the type and sources of information that hikers use before, during, and after their hike. We also asked specifically about safety preparation prior to hiking, and frequently heard

[1] *Guthook Guides* [8] (or simply *Guthook*, now renamed *FarOut*) is the most widely used mobile app for carrying out long-distance hikes. *Halfmile* [2] used to be another popular app for thru-hikers, but has since been repurposed as a collection of maps for the PCT. Both of these apps were created by thru-hikers, and they each feature their author's "trail names," respectively. *Gaia GPS* [1] and *AllTrails* [5] are popular mobile apps for planning shorter hikes, especially day hikes.

Gender	Age	Experience	Label
F	47	Day hiker	D1
F	63	Day hiker	D2
M	19	Day and occasional overnight hiker	O1
F	30	Day and overnight hiker	O2
M	31	John Muir Trail (2019) and long-distance hiker	S1
M	25	AT section hiker (2011, 2012, 2013)	S2
M	58	Urban and long-distance hiker	S3
M	63	AT section (2011, 2012, 2013) and long-distance hiker	S4
F	20	AT thru-hiker (2018)	T1
M	22	AT thru-hiker (2016)	T2
F	29	PCT thru-hiker (2019)	T3
F	31	PCT thru-hiker (2019)	T4
M	32	AT thru-hiker (2012)	T5
M	32	AT (2011) and PCT (2017) thru-hiker	T6
F	34	Triple-crown hiker	T7
M	53	Triple-crown hiker	T8

Table 1. Interview participants

about safety practices during hikes. In addition to information seeking and consumption, we also asked about contributions to information, as might occur during and after hikes.

4.3 Data Analysis

Our team comprised three interviewers. Each interviewer took notes during and immediately after the interview. We all translated the free-form notes into sticky notes–asynchronously–to use in synchronous discussions and affinity mapping, to support a grounded theory approach to our analysis. In a few cases there were two researchers on the interview call and they each took separate notes and contributed independently to the sticky note repository. The breadth of our interviews provided expansive data and called for multiple passes of mapping and revisiting to narrow our focus. We conducted three rounds of thematic analysis using affinity mapping. Our first round yielded broad categories, reflective of the breadth of interview topics and hiker types in our participant pool. In the second round, we extracted and expanded themes related to safety as a particular feature of the hiker experience. Finally, informed by the prior rounds, we identified adversity and responses to adversity as salient to the hiker experience, while also providing a lens for understanding resilience and technology beyond trails.

Over the course of weekly meetings, we extracted four salient themes related to how hikers develop resiliency through: the exchange of *real-time and hyper-local information*, their use of technology for *emotional support*, their approach to manage *limitations to technology*, and the culture of *self-reliance* and *community-building* in hiking.

4.4 Limitations

The limitations of our study are largely with respect to representation. A 2018 Appalachian Trail survey indicates that 95% of long-distance hikers are White/non-Hispanic, with an average age of 34 and a median age of 29 [43]. In the AT survey, 55% of hikers identified as male and 45% as female. While we believe that our interviewees are representative of the majority population who engage

with long-distance hiking, we do note that there are emergent sub-communities of hikers that identify as minorities in the hiking community including Latinx hikers [37], Indigenous women hikers [28], and hikers with disabilities [31]. Moreover, long-distance hiking generally (and thru-hiking specifically) requires a certain amount of economic privilege since the activity can require expensive gear and substantial leisure time [6]. By not having diverse representation amongst our interviewees, our findings may lack critical aspects of minority experiences with adversity on the trail (or even getting to the trail) and their resilience practices for managing adversity. While incorporating these experiences into our understanding of hiker resilience practices will undoubtedly lead to a more robust understanding of resilience practices in socio-technical-natural systems, we leave this to future work and count on our initial investigation as being substantially representative of the demographic of those who attempt long-distance hiking.

A minor limitation concerns the time period over which our participants completed long-distance hikes, which spans 2011 to 2019. Technology changes during that time period included the availability and prevalence of satellite phones, and the move from paper or Excel-based situational reporting to smart phone applications such as Gaia and Guthook Guides (now FarOut). Several of our participants completed hikes spanning these years and they provided useful insight into technology changes, which helped us use the historical time span to our advantage in the analysis.

Another limitation of our sampling approach is that participants opted-in to our study or might self-select based on positive experiences. We only spoke to hikers who had successfully completed a long-distance hike. While this does bias perspectives on adversity and resilience practices, in some ways, the positive-experience bias helps us filter and focus on resilience practices that work and actually demonstrate successful adaptation. We leave a broader investigation of "failure" to adapt to adversity to future work.

5 FINDINGS

Our goal in this section is to characterize the human, technological, and environmental factors that contribute to resilience in a fluid socio-technical-natural system. This directly addresses **RQ1**, which is concerned with understanding these very factors, which in turn may appear at both an individual and/or collective level. The first three findings reflect on both individual and collective factors throughout, whereas the fourth and final finding addresses these separately. We frame each finding theme by bracketing the participant data with the type of adversity represented and the key resilience processes utilized, following the Threat-Tactic structure used by Dosono and Semaan [19].

5.1 Real-time and Hyper-local Information

> "Sometimes you really want to have elevation data to know if a 10 mile day is going to be killer or if you'll knock it out before breakfast." (S2)

***Adversity:* The trail environment is highly dynamic and often unpredictable over space and time.**

Hikers must learn to manage a variety of situations and adapt to changes in their environment, which may happen in a matter of minutes or over a stretch of meters, i.e., real-time and hyper-local. Thus, it may seem surprising that a significant number of our participants had little to no formal preparation routine before their long treks. When asked about preparation, only two participants appeared to follow any particular set of guidelines, such as reading guidebooks. "The first thing I do is I try to read blogs from experienced hikers[...] And I get a feel for what sorts of problems I can expect." (T8). The rest took a more ad hoc and practically sanguine approach. "Trails give you the info you need, you don't get this from a book or website." (S4) Preparing for a long-distance

hike may often feel like a futile task because, once you have your essentials in place (i.e., gear and tools), there is only so much you can anticipate.[2] "Even if you're the best prepared sometimes you just get unlucky." (T5) Thus, "preparing" for a long-distance hike according to our participants involves two steps: (1) purchasing the necessary and appropriate tools for themselves, and (2) being mentally capable and willing to adapt to drastic situational and environmental changes.

Hikers select and customize the tools they carry to meet a specific purpose for the stage of the day or the place they are in the overall trek. For instance, S4 explains that before smartphones became the predominant navigational tool, he would use sets of pocket-sized paper maps, which partitioned the trail into smaller sections at a time. These would allow him to keep a more manageable outlook on what lay ahead by focusing on the immediate surroundings. Long-distance hikers can average about 20 miles a day, and they often are not concerned with anything far beyond a 20-30 mile radius, since the conditions may change within the span of a day or even a few hours. Yet sometimes the technology is not always best suited for the task. T6 went through the effort of cutting up a paper guidebook into 33 smaller pieces based on sections of the trail. T6 then packed these paper pieces into care packages filled with other items, such as food, and mailed them to post offices for his resupply stops along the trail.

Although most participants still opt to carry paper maps, they will rely on smartphones and other intelligent, GPS-enabled devices the majority of the time. "The number one tool that I use more than anything is a smartphone. It's probably one of the most common devices used by most hikers simply because there are so many functions in the smartphone that can be used as information on the trail." (T8). However, similarly to the hyper-focused maps that S4 and T6 would carry, hikers today keep a selection of navigational and tracking apps based on the type of hike or even dependent on a specific moment on the hike. For instance, T7 will use Gaia GPS trail maps for shorter day-hikes, but she resorts almost exclusively to Guthook Guides for long-distance hikes. In cases where a high-level of detail is necessary, T7 will even zoom in on portions of these digital maps to print them out in full color as a secondary reference. Most of our participants also developed a habit or daily routine where they would check for certain information based on the time of day, e.g., search for water sources around lunchtime (T4); or the current weather conditions, e.g., verifying one's location in the presence of snow (T6).

Higher-tech tools in particular outshine their analog counterparts when it comes to supporting situational awareness, for they provide the most accurate and timely information, especially when it comes to critical resources such as water sources on the trail. The reason why it was difficult to effectively support this type of information before is due to its hyper-local and hyper-temporal qualities, where streams may run dry or water caches placed by trail angels may run out. In the past, hikers would buy printed guides in advance, with lists of places to locate water. Trail coalitions, such as the Pacific Crest Trail Association (PCTA), would also share curated spreadsheets with the location and status of water sources, as collected from various crowdsourcing efforts via email and text. Yet, these collections would suffer from outdated information, as the availability or quality of any one water source could change any moment after printing, and the cost of updating the resources made it so that the sheets would be amended only once before the start of each hiking season. Online crowdsourced apps such as Guthook revolutionized how hikers access and update critical information in real-time.

Unfortunately, these advances in technology make technology failures and misuse all the more critical. For instance, access to technology may make hikers less inclined to use their skills and

[2]It is worth noting that most participants hiked either a portion or the entirety of the AT, the PCT, or a similar long-distance trail. Only two of the participants thru-hiked the CDT, which as one participant explained, you must "plan it to a T" due to infrequent and unreliable sources of water throughout many long segments.

knowledge. Hikers may become so dependent on technology, that the added sense of security becomes a foolish risk. T7 described a moment where a friend who was ahead of her group on a particularly difficult and dangerous river crossing ended up using their satellite device to get rescued. Luckily for this person, they did not face any real or imminent threat to their livelihood. Since the technology was readily at hand, they simply decided *not* to invest the time and effort to figure out the best way to overcome this challenge. An even more alarming example could be the time when T6 witnessed a hiker from another group who was seriously injured from a fall. Although everyone surrounding the injured hiker had a smartphone at their disposal, they had all embedded so much trust in their technology, that when it came time to use it, no one actually knew who to call or what to do.

Resilience Factor: **Hikers use analog and, increasingly, digital technology to obtain situational information that enables them to adapt to their environment. However, when resilience strategies overly rely on technology in nature, they are fragile.**

5.2 Emotional Support

> "There's this elitist mindset [that] if you use your phone, you're not a 'real hiker.' I don't like that one bit. Especially because when you're thru-hiking you're spending five months all day, every day, walking. I will listen to the sounds of nature; clearly I want to be here! I don't like the idea that someone is better or not better because they listen to music while they walk." -T1

Adversity: **Long-distance hiking requires individuals to spend substantial time alone in remote (and at times precarious) environments. The stress from chronic isolation and vulnerability can take a toll on hikers' emotional well-being.**

Much like the popular saying that compares experiences in life to a marathon, as opposed to a sprint, long-distance hikers must endure chronic and arduous emotional stress while on the trail. From our interviews we found two ways in which technology may ease or even prevent emotional fatigue and keep hikers' spirits high. The first is as a meditative distraction, and the second is for peace of mind. Although these use-cases may not seem "essential" to others inside or outside the hiking community, we found that even mundane uses of technology on the trail were enough to motivate participants for another day of trekking.

Some of our participants kept a habit of reading and/or writing at the end of their day as a way to reflect on experiences and to just make the time go by. Hikers will go out of their way to secure technology they packed strictly for "pleasure" – as opposed to "utility," such as wayfinding or basic communication. For instance, despite the added weight and battery life considerations, S4 would always pack their iPad mini in a waterproof case, and T8 kept their iPod Shuffle handy and well-equipped with music. T1 enjoyed listening to audiobooks and music as they walked, which helped them keep up a steady pace. T4 was almost apologetic when she explained:

> "I mean this isn't a tool, but I was heavily, emotionally reliant on Spotify to download podcasts. But that was purely entertainment purposes. You spend a lot of time out there alone with your own thoughts so I listened to a lot of stuff."

Yet sometimes simply *carrying* a certain piece of equipment or knowing that your tools were in working condition was enough comfort. Some hikers like S1 sought to use their devices as little as possible while they trekked. Similarly, T4 expressed that she would "ritualistically" check on her phone during specific times of the day. Sometimes, she would check comments on Guthook or update her walking progress on private spreadsheets. T4 acknowledged that she typically did not worry about long segments without connectivity, but liked to be well-informed of the areas where she could expect to be connected: "Cell service was I'd say more like emotionally important."

Similarly, T5 explained how much carrying his personal locator beacon (PLB) made him feel at ease at the possibility of getting lost or hurt: "It can be personally freeing to have those considerations cared for."

Yet, the peace of mind associated with technology that provides the ability to communicate may easily become a source of stress. S1 liked carrying a satellite phone for emergencies and for the comfort of reaching out to loved ones occasionally. However, they were careful with whom they shared their number so as to not become overwhelmed with too many messages. Technology may also become an emotional burden when it devolves to a single point of failure. Some hikers may rely too much on the notion that, using the same example, satellite phones can be more reliable than regular cellular communication in these remote settings. However, T4 qualified this fact: "You have to warn people that 'it won't always work so if I don't check in, I'm probably *not* dead."'

Resilience Factor: **Technology provides a reprieve from chronic emotional stress by functioning as a communication safety net and providing entertainment and pleasure. Yet the communication capability in particular can be a source of stress by creating both too much accessibility and no guarantee that it will always work.**

5.3 Limitations of Technology

"Tech is iffy. That's the strange part." - D1

Adversity: **Long-distance hiking renders technology vulnerable to failure by removing devices from the power grids they are designed for and placing them in a physical environment that prevents or interferes with network communications.**

We heard about occasional technology failures on the trail, including one PCT hiker whose inexpensive phone died on the *first day* and was not replaced for a month due to inaccessibility of stores. This hiker was from Europe and may have lacked the human support network in the US that could have acted to get her a new phone. Generally, however, the devices themselves were relatively reliable, but managing battery life required significant attentiveness. Many hikers brought battery packs or "bricks" despite the added weight. One interviewee referred to his recharging mechanism device as one of the most important tools he carries (T8). Trips into town, where hikers would stop to resupply and reconnect with the real world, offered valuable opportunities for recharging, so much so that charging capability is advertised and commented upon along with food and "good vibes", for example, "device charging at Mike's place" (Guthook comment).

From our interviews we learned how nature can simultaneously make one's personal technology less resilient, while also presenting alternatives to handle challenges gracefully. Our participants developed new sets of skills to better tailor their use of technology to the conditions of the trail. For example, while devices were reliable, modulo power considerations, cellular phone coverage was highly variable. Through a mixture of word-of-mouth and direct, real-world experiences, hikers quickly learned strategies to find connectivity on the trail, if needed. Their observations ranged from predictable patterns such as "usually if it's on top of a mountain it's pretty good" (O1) to the surprising realization that "in the AT you often have better reception on trail than in towns" (T8). One hiker reported that he "got good at predicting where cell coverage would be" (T2), based on elevation and terrain.

These limitations influenced hikers' selective use of technology while on the trail. For example, S2 told us: "I would try to reserve it [phone use] for when I needed to call into a hostel before I get into town." Meanwhile, T1 proudly shared: "I was a big gremlin about my phone. My phone only died once on the whole AT because I had this massive power block." Furthermore, cell service availability would dictate most of our participant's daily routines, where most would plan certain

times of the day to habitually check for reception in order to update Guthook comments or read through emails. For instance, T4 described her routine:

> "Usually, I was prepared to go all the way to the next town without being in service. I would scrub through all the little landmarks [in Guthook] to see 'oh do any of these have 4G service? Because that would be kinda dope right now'."

Yet, when all else fails, hikers boast of creative resources on the trail, which can include the very elements in nature that restrict their technology use. When asked about their favorite tools for information-seeking during the hike, our participants carefully explained each app and device they carried. However, when answering this question, T7 added while chuckling: "obviously, when I'm on the ground I'll use my eyes and look at signs." A more unusual example of reverting to the most straightforward or "natural" set of tools available is the case of T8 who would often resort to *night hiking* in an effort to curb dehydration from the day's heat: "I make sure that I have adequate batteries for a headlamp or that I plan it for a full moon night where I can see without artificial light." One participant in particular (S4) demonstrated great appreciation for relying on the natural elements:

> "The information systems when you're trekking include the fact that there's a worn path. That there's data there. And people tend to think, when they talk about navigation, they talk about maps and GPS, and they don't talk about signs or just dirt. Just the pathway itself. There's a lot of data there. You can almost always tell which way you're supposed to turn because one is just a little thinner than the other."

Resilience Factor: **Hikers adapt to lack of grid power and lack of network connectivity by packing extra battery power, conserving device power resources, and utilizing offline and non-digital technologies (e.g., compasses and maps). Critically, they learn how to navigate in nature using their knowledge about the natural environment (e.g., spatial orientation) and technologies that have been embedded in the environment by other humans on the trail (e.g., signs and trail logs).**

5.4 Hiker Safety

> "As more and more information becomes available [to hikers] a lot of people are like 'well that takes away from the spirit of the CDT' and I think the CDT is hard enough as it is without getting to a water source and discovering it's totally dry." -T7

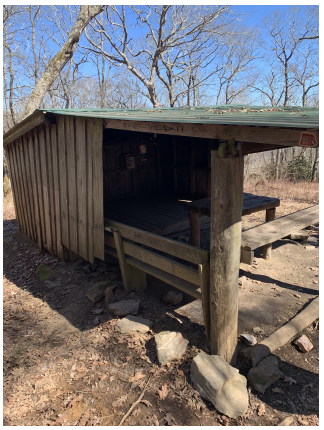
Adversity: **The wilderness can threaten the physical safety of long-distance hikers in a number of ways. Exposure to weather can lead to hypothermia or dehydration; lack of necessary food and water can lead to illness and exhaustion; falls in harsh terrain can cause injury.**

We noticed two major approaches to safety in the hiker community: depending on personal resources, such as one's own experiences and previous knowledge, and depending on the support network developed while on the trail. We describe each of these practices separately in the remainder of this section, while referencing some of the tools introduced in Section 5.1.

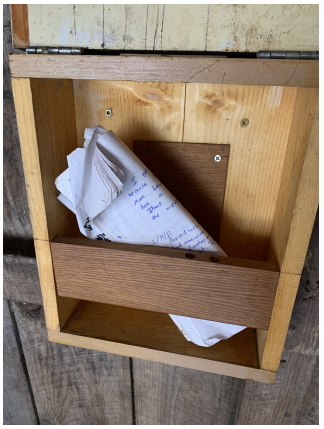
5.4.1 Self-reliance and Personal Resources. Hikers will rely on their intuition and their past experiences to inform their decisions on a trail, especially when it comes to personal safety. "Knowing your own body and how to address certain problems that may happen in the normal course of hiking are really important" (T7). Safety precautions vary among hiker personalities. The majority of the long-distance hikers we spoke to recognize safety as preparing for and anticipating the worst-case scenario, where "death is the worst thing that can happen in some trails" (T8). Yet, hikers are particularly self-reliant and mindful of their physical abilities and problem-solving skills. "I feel

fairly fit, and I've [hiked] enough times that I feel comfortable" (O1). Particularly for long-distance hikers, walking every day allows them to become more cognizant and more "in tune with what it takes to move" (T1). Their desire for adventure also deters them from seeking out information about a hike any further than the essential, such as, distance, elevation gain, terrain, and occasionally weather. "I prefer a level of surprise, I don't want to have already hiked it mentally before I hike it for real" (S4). Moreover, several of the hikers we interviewed stated that a solitary experience was desirable, expressing desires to "keep the best spots secret" (O2), "stay anonymous" (T2), and *"preserve nature"* (O2).

Despite (or perhaps in addition to) their confidence in their abilities, hikers have family and friends they can lean on, who are innately concerned for their well-being. A crucial safety practice shared among most of the participants was having someone back home or off the trail who knew of their whereabouts. Most of the hikers had a nearly daily ritual of checking in with their loved ones. Some even felt pressured by family members to improve their safety practices, such as S4 who received a personal locator beacon (PLB) as a Christmas gift. Occasionally, family demands would supersede hikers' concern for comfort and practicality, such as T3 who hauled a heavy, well-stocked first aid kit. "My mother is a pharmacist and wouldn't allow me to re-pack it!" (T3). However, most support from family was indeed welcomed and comforting. T1 met up several times with family members who contributed financially with meals and resupply items during visits to towns. Some families would even take on the role of trail angels, such was the case for T5: "My parents were with me for the last month doing trail magic and stuff for other hikers."



(a)



(b)

Fig. 2. Typical examples of (a) trail shelters and (b) shelter logs, both photographed by the authors on a portion of the AT. Feb., 2021.

5.4.2 Community-building and Information-sharing. Hikers share knowledge and information about their experience on the trail with others, and especially with first-timers. Trail angels choose points along the trail to provide resources to any hiker passing through that particular place. Indeed, many hikers that we interviewed reported having to rely on these social connections:

> "Everyone you meet is so kind, so selfless, and so willing to help. There's this whole community of people called 'trail angels' that will feed you, they will let you stay at their house, they will drive you to town. And even fellow hikers. If I ran out of food because I didn't pack well for a certain section, I will [sic] not go hungry" (T1).

Shelter logs are a particularly popular medium for hikers to stay connected and "tap into the pulse of people around" (S2). Nearly all the long-distance hikers enjoyed perusing the pages to look for other hikers they knew personally, and even tracked hikers they might have only heard or read about before. S2 appreciated the community aspect built around the logs, and would often feel excitement to meet hikers whose poems he had been reading through his trek. S4 highly regarded the value of shelter logs because they allow information to "move

up and down the trail at lightning speed because people are moving in both directions." Yet, the content in the logs was "mostly funny stuff" (T2), and even S4 indulged in developing a fictional story on these logs. T5 summarized the purpose of the shelter logs:

> "Some of [the logs] were helpful, some of them were silly, some were things that people had heard up ahead. You get some value out of those whether it be actual information or comedy relief."

The core ethos of the hiking community (especially for long-distance hiking) is to contribute to and disperse vital information about the conditions of the trail. One recurrent example of critical information on the trail was the location and quality of water sources. There is an inherent risk that one will run low or out of water, resulting in a life-threatening situation. "[The purpose of] Guthook was mostly to check which water sources had water. I would read the comments every night." (T2). In Section 5.1 we explained how crowdsourcing apps revamped the quality and distribution of critical information. The following Guthook entry by `hazelbasilhikes` on May 24, 2020, PCT Mile 68.4, illustrates the culture of sharing among hikers:

> "There's about 1/2 L emergency water in the gallon jug by the square concrete enclosure of the slowly dripping pipe (1 drop/minute). I'm heading straight down the Rodriguez Spur road 1.1 miles to the spring myself. (Take Rd straight ahead. It goes downhill and passes with concrete/water pipe on your left)"

However, we observed varying degrees of contribution and commitment to these higher-tech tools from our participants. A particularly interesting example is that of T4 whose (incorrect) mental model of Guthook's offline behavior prevented her from engaging more meaningfully to the comment section during the majority of her hike:

> "I didn't realize until close to the end of my hike that you could create comments offline and have them shoot up there online. I thought people were taking notes and then when they were in service... like making those comments while they were in service. So I just fundamentally didn't realize that I could be leaving these comments while offline. So towards the end I started [contributing to Guthook], but not at first. Mainly because I was like 'oh I'm not gonna take notes, that sounds too hard.' [...] If I had known earlier... 'Cause it's kind of a fun thing to do. You get to a water source and you're like 'yeah, this is a good water source.' [Fumbled with thumbs to simulate composing a message on a smartphone.] 'I'm gonna let people know it's a good water source!' "

Resilience Factor: **Hikers leverage personal knowledge and resources as well as the broader hiking community to share information, supplies, and general support that will help them safely navigate the thru-hiking experience. Sometimes support is offered through technology (e.g., forums or guidebooks); other times it is shared via *ad hoc*, in-person encounters on the trail.**

6 DISCUSSION

In this section, we discuss our findings in light of existing CSCW work. Our goal is to illuminate specific design implications that when implemented, might foster resilience for a more general set of users that find themselves navigating socio-technical-natural systems that are prone to disruption. This answers **RQ2**, which asks *in what ways do long-distance hikers and their experience provide a lens on resilience more generally?*

6.1 Resilience Processes of Individuals and Communities

Using the resilience framing offered by van Breda [65], we observed resilience processes at multiple levels of the long-distance hiking community. Specifically, we identified individual resilience practices and resilient community structures that interacted with nature both as a source of adversity and as a source of resilience. A major type of individual resilience process was preparation, though the process of preparation is different from what has been observed in "prepper" communities since the adversity being prepared for has distinctive temporal, geographical, and social constraints [3, 34]. As individuals prepare for the trail–a geographically specific environment characterized by chronic adversity–they engage in anticipatory resilience processes by preparing the tools they carry to handle their dynamic environment (Section 5.1), the emotional support items (Section 5.2), and technology backups (Section 5.3). Additionally, recall that hikers also establish a support system around their friends and family off-trail (Section 5.4.1). These preparation practices encompass a resilience process for handling both chronic and acute adversity. In preparation for chronic adversity, such as food shortage or changing temperature, hikers anticipate making their way through the trail on a predetermined schedule and they can prepare their social network to send items to prearranged resupply points adjacent to the trail. In preparation for acute adversity that might jeopardize safety, hikers let their social network know when they can expect to receive updates or carry personal locator beacons so that friends and family can monitor their location periodically.

The social network of long-distance hiking is not limited to the support networks of individual hikers. The trail itself is a factor for resilience by creating opportunities for supportive, social connections to form between individuals and by permanently linking institutions of community support. In Section 5.4.2 we described how sympathetic and experienced hikers as well as trail angels are cornerstones to completing a long trek. Beyond individuals forming social connections, anchor institutions serve as hubs of social support along the trail. Hostels and post offices adjacent to trails hold packages containing resupply items or serve as resource caches where hikers deposit and pick up surplus supplies. Thus, the long-distance hiking community is comprised of individual hikers and their social networks, trail angels, and trail-adjacent institutions that collaborate and share resources (physical and informational) across the trail.

Technology helps strengthen and solidify collaborative relationships within this community in several ways, particularly in the exchange of critical information on the trail (Section 5.1 and Section 5.4.2) Indeed, resilience-enabling crowdsourcing platforms were called for as early as the mid-2000's by CSCW researchers Mark and Semaan, who recommended that "in times of disruption people need to have increased situational awareness of others in their social network...[which] could consist of simple status information letting others know that they are safe" and that accounts for "affordances of technology resources [that] changed as the environment changed" [44]. We observe the manifestation of these collaborative technologies in services such as Facebook's Crisis Response feature [21], Guthook's online/offline tools for hikers [8], and satellite-based personal locator beacons. Notably, these means of collaborative resilience are sourced entirely in the digital realm and do not integrate nature as a collaborative platform–or even as a potential partner in collaboration similar to what has been conceptualized by Liu et al. in collaborative survival design [41]. Recall our example in in Section 5.3, in reference to collaborative wayfinding that takes place through the creation of physical trails in nature, "there's a lot of data there [in the dirt]" (S4). This view of nature as a source of collaboration and community knowledge is related to Traditional Ecological Knowledge (TEK), "an accumulating body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (human and non-human) with one another

and with the environment" [52]. However, we identified tensions around collaboration in several of our interviews. These revealed, for example, that sharing knowledge about a certain location and/or its natural features may interfere with an individual's selfish desire for a secluded and unimpeded experience of their favorite spots in nature (Section 5.4.1). Given the continuous threats to natural environments due to human intervention and climate change, these reticent and possessive attitudes make sense. Furthermore, there is a growing body of work which points to an individual connection with nature as a resilience process for handling chronic adversity [11, 12, 61]. It is at the crux of this tension between collaboration and individualism that we observe a challenge for future CSCW design research: *How might sociotechnical systems for resilience be designed to involve nature as a platform for collaboration? And how can these designs bridge the tensions between individual desires to connect with each other and to engage in private experiences with nature?*

Further connecting to the resilience literature as it relates to HCI and CSCW, we find similar to Semaan [57] that hikers create important and comforting routines that involve technology, such as checking the route for the day or checking in with loved ones. However, they also build resilience without technology, often because they cannot always rely on technology. Thus, while technology is part of building resilience to the prolonged disruption of long-distance hiking, relying on nature, self, and others is also part of building resilience without regular technology. In this way, the conditions of long-distance hiking might be viewed as a form of practice with a future where collapse [62] means that technologies and other resources that we currently rely upon are not available in their current forms.

Tomlinson et al. identified groups of *purposefully marginal* people to be of potential interests for studies on collapse informatics [62]. This includes, but is not limited to, counter-culture type movements, such as folks who engage in survivalist practices, dumpster diving, and zero-waste lifestyles. Similar to hikers, purposefully marginal groups seek to challenge mainstream cultural and societal norms, yet "are not marginalized through economic or other circumstances" [62]. According to Tomlinson et al., the everyday practices of purposefully marginal groups may inform the design of "sociotechnical systems in the abundant present for use in a future of scarcity", which will "support future practices as gracefully as possible" [62]. Critically, Tomlinson et al. take on a holistic view to these everyday practices, and acknowledge the value of examining human needs beyond the basics, and including others such as emotional and aesthetic needs. The fact that long-distance hikers choose to place themselves in this collapsed world, and choose so in part to seek *enjoyment*, and will carefully procure tools for this purpose (Section 5.2), makes them especially useful for understanding and deriving design guidance for an increasingly disrupted world.

Although long-distance hikers differ from purposefully marginal groups in that their practices may only last for a limited amount of time, their preparation for and commitment to completing the hike is comparable to other purposefully marginal practices. In those instances of preparing for the hike and walking the trail they are just as imbued in the process as most other purposefully marginal groups described by Tomlinson et al. Furthermore, it is important to consider how the vast majority of the long-distance hikers we spoke with developed their practices over multiple hikes, spanning multiple years. Indeed, many long-distance hikers will continuously seek further long-distance hiking adventures, essentially incorporating their preparation practices and hiking ventures as a reoccurring practice to their everyday lives. Some of the hikers we interviewed actually became so immersed in this lifestyle that they dedicate their careers to hiking by writing guidebooks or presenting talks about their experiences, which virtually compels them to hike for a living.

Implication: By analyzing resilience practices in the long-distance hiker community, we identify collaborative resilience processes between individuals and communities that

include both preparatory and ad hoc interactions. Long-distance hikers' purposeful entrance into a collapsed world suggests that technologies for resilience must empower agency. Flexible tools that can provide multiple and even custom modes may be best suited for supporting the various changes in priorities and availability of technology use.

6.2 Resilience-Adversity Dependency Loops and Novel Assemblages

Much of technology is rooted in the environment of everyday life, leading to designs and features that inherently rely upon the commodities of urban civilization, such as access to electricity, controlled temperature and humidity, and shelter from harsh conditions. When hikers bring technology onto the trail, they sever ties with these everyday conveniences, introducing the need to manage their technology to make it work properly in this new environment and to manage their expectations of technology.

Our findings identify a complex relationship with technology because it appears as both a tool for achieving resilience and is simultaneously subject to adversity in a setting where power and network connectivity are often unavailable. In contrast to prior work that generally finds technology to be useful for achieving resilience [44, 46, 57], we find that the backcountry nature setting renders technology fragile in ways that require creative alternatives for specific situations. The result is a *resilience-adversity dependency loop*, where chronic adversity is mitigated by technology, yet technology's fragility in nature then becomes a new form of adversity that must be offset by alternative resilience processes.

To make this concrete, consider the example of information-sharing practices around water as identified in Section 5.4.2. Long-distance hikers use networked applications to share information about critical resource location and availability with a broad audience. Yet these applications rely on Internet access to remain up to date. Thus, depending on applications as the primary source of water information is itself a risk. In response, the hiker community has created alternative methods for sharing information that involve north-south communication between those passing each other in opposite directions on the trail and shelter log records (Section 5.4.2).

Resilience-adversity dependency loops are not unique to the backcountry and our societal experience has shown us that technology is often fragile and prone to disruption even as it seeks to mitigate the impacts of disruption. As a recent example, schools and workplaces coped with the COVID-19 pandemic by moving operations to take place remotely via videoconferencing software, such as Zoom, and collaborative platforms, such as Microsoft Teams. However, when remote operations were faced with disrupted Internet connections–due to downed lines, congested network infrastructure–this necessitated a switch to alternative means of collaboration, including a switch to lower bandwidth "voice-only" calls, reliance on asynchronous technologies such as email, or students/workers traveling to Internet hotspots in order to participate in video calls.

As noted in prior work, resilience can involve novel assemblages to compensate for disruptions to the usual tools and processes [44]. Examples of these resilience processes are observed by previous HCI work focused on computer-supported collaboration [4, 44, 46, 50, 71, 77]. Whether the adversity involved natural disaster, warfare, poverty, or just normal disruption, many resilience processes involve creative assemblages of digital technologies (e.g., social media platforms and blogs [4]), collaboration techniques (e.g., large-scale brainstorming [50] and resource sharing [71]), and social structures (e.g., community centers [71] and professional networks [77]). Hikers also create and leverage assemblages of technical, social, and collaborative resources. Hikers combine multiple technologies, interpreted broadly to include low (or no) technology options (e.g., paper maps, shelter logs, printouts of resource spreadsheets), multiple communication pathways (e.g., shelter logs for asynchronous communication, north-south encounters for synchronous communication), and high technology options for real-time, situated information as made possible by

crowdsourcing applications. However, hikers include the natural environment as an additional asset to sociotechnical resilience assemblages. As demonstrated in Section 5.3, *"there's a lot of data in [the pathway itself]"* that can be used in combination with technnologies and social support structures to help long-distance hikers navigate adversity with resilience. Taken together, these information resources produce a sort of backcountry cognition characterized by understanding the trail through distributed, imperfect, redundant information embedded in trail community practices and creative knowledge representation methods.

Implication: The typical model for resilience as "adversity-resilience processes-possible outcome" fails to account for resilience-adversity dependency loops where factors in resilience are themselves subject to risk. Our work highlights how this dependency arises when technology is a mitigating factor yet also fragile and subject to disruption. In such situations, people create novel assemblages of physical, social, and natural resources to use technology yet deal with its fragility.

6.3 Designing for Graceful Degradation of Technology

As observed in our discussion about resilience-adversity dependency loops, when hikers engage with technologies as a means of supporting their resilience, the technologies themselves are prone to fundamental challenges that alter the technologies' ability to support resilience. These challenges mainly relate to hardware limitations of the technologies that hikers carry with them, e.g., limited power supplies and limited radio transmission ranges. Some challenges are due to the physical environment, e.g., network coverage is not available (see Section 5.3).

These examples highlight how long-distance hikers practice resilience by engaging in additional activity, pausing normal planned activity, or planning future activities based on technological limitations. Each of these adaptations required hikers to make their own assessments about how, when, and where technological limitations would have a critical impact on their knowledge about their environment. Notably, hikers needed to determine whether the necessary adaptations were worth the corresponding resources. For example, a hiker who anticipated that it would be necessary to summit the next ridge to obtain a cellular signal would need to determine if time and energy spent climbing the extra few miles would be worth the benefits of a potential network connection. The calculus of adaptation is further constrained by battery life. Hiker decisions made with the assistance of technology must be made while the technology is available (has power) and making decisions about when and how to use technology necessitates that the user account for future realities surrounding limitations (e.g., low battery, no battery, intermittently turning a device off to conserve the battery).

The task of making decisions with and about technology in a long-distance hiking scenario highlights the need for interfaces that can clearly communicate with the hiker about current and projected technology resource availability. While existing work has codified graceful degradation with respect to data collection activities over space and time in rugged environments, there are no clear design guidelines for graceful degradation of systems meant to present data to users about the environment in these contexts. Our findings reveal that in the case of preserving data access in challenging environments, it is up to human users to adapt their behavior in response to limited interfaces about resource availability (e.g., "battery level is currently 89%" or "one bar of cellular signal") and their anticipated information needs and environmental constraints. Some examples of these behaviors that emerged in our work and the work of others include proactively downloading data from the cloud or taking screenshots of interactive interfaces in anticipation of moving to spaces with limited network availability [20, 73]; turning off devices so that energy is used only when the device is needed to present data [13, 17, 73]; or transitioning from a digital device to a paper guidebook in anticipation of losing power or connectivity (Section 5.3).

Finally, beyond graceful degradation of specific applications or an individual user's device, there is opportunity to push more adaptation into the infrastructure, where it has the potential for widespread benefit. That benefit would be present not only in challenged environments, but in everyday settings, somewhat like the ways that universal design [9] can benefit all users. A specific opportunity for infrastructure resilience highlighted in our work concerns cellular network access. Currently users subscribe to a specific cellular network provider such as AT&T or Verizon and thus their cellular access capability is restricted to the locations where their provider has coverage. If this tight binding between provider reach and device access were decoupled, coverage and redundancy (more than one connectivity option) would increase, thereby increasing resilience over single-provider options. This form of resilience is utilized today, but only in the limited case of emergency calls. To achieve this degree of infrastructure resilience would require spectrum policies and provider agreements that do not currently exist, though the technical elements are reasonably available through software defined radios [64]. The salient point in the CSCW context is that there is a need to reconsider the design of digital infrastructure and policy such that it would enable collaboration in a much broader range of scenarios including those that involve collapse.

In the spirit of CSCW and long-distance hiker ethos, there is an opportunity to ask how technology resources might be better shared to overcome and manage degradation as well as provide resilience. As indicated in Section 5.4.2, sharing of information and supplies is already embedded in hiker behavior. How can technology infrastructure support technology sharing? The literature on disruption tolerant networking (DTN) points to system design that may be especially well-suited for the sharing possible in a hiking setting, where mobility is inherent [29]. DTNs were heavily researched in the late 1990s and early 2000s in recognition that not all network settings enjoy the continuous connectivity that standard Internet protocols are predicated upon [29, 78, 79]. A key idea for overcoming connectivity disruptions is to support the sharing and carrying of data on devices in support of communication needs by others [56]. In the hiking context, the north-south mobility of hikers, as well as into-town/onto-trail mobility offers an ideal opportunity for communication needs to be met collaboratively. Just as word-of-mouth information travels "at the speed of light" on the trail (Section 5.4.2), a communication need such as "hiker X wants to tell their family Y" could be transferred and carried between mobile devices until the ferrying user reaches a region of connectivity. This is another example of pushing resilience into infrastructure, in this case making the network more resilient and co-opting user devices to join networking infrastructure. "Human-centered networking" is a relatively new area of research that seeks to center the design and deployment of computer networks and protocols on the needs, practices, and realities of human users, rather developing networks and protocols that require humans to adapt their behaviors to match what is offered by the infrastructure [30, 32, 58, 67–69]. While this area is relatively new and not heavily reflected in CSCW and other HCI literature, we anticipate that it will grow.

Implication: The responsibility for resilience should not be exclusively the provenance of users, even users well-supported by information and cues about resource availability. Infrastructure resilience bakes design for degradation into underlying systems and applications. Two examples that are salient in the hiking context–or anywhere that cellular access is spotty–are pooling all available cellular access capabilities and realizing a communication paradigm that extends the network into user devices for sharing over space and time.

7 CONCLUSION

By examining the resilience practices of long-distance hikers, we identified a broad range of sociotechnical practices that can be used to adapt to both everyday and acute adversity. These practices involve a community comprised of hikers, "selfless" trail angels, hiker support systems, and trail-institutions. This community enables the resilience of hikers by providing informational

resources through online forums, trail-focused crowdsourcing platforms, trail logs, and in-person exchanges along the trail. By framing the long-distance hiking experience as taking place in a socio-technical-natural system, we were able to identify how human factors, technology, and nature intersect to enhance resilience. Moreover, we were also able to characterize how the intersection of these components can lead to "resilience-adversity dependency loops" where some resilience practices can lead to new adversities that must be managed within the system. Critically, we were able to relate our findings from the long-distance hiking experience to design implications for "the rest of us" who must adapt to sociotechnical realities that are increasingly disrupted by and situated in nature.

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