Listening to the Wild: Risk and Preparedness in Hiker-Wildlife Conflicts during Outdoor Recreation

ANONYMOUS AUTHOR(S)

Human-wildlife conflicts pose significant challenges in outdoor recreation, endangering both hikers and wildlife while disrupting ecological balance. Despite the prevalence of wildlife-related risks—ranging from confrontations with large animals to exposure to disease-carrying insects, existing outdoor hiking tools focus narrowly on navigation and search route conditions, lacking systematic solutions for mitigating human-wildlife conflicts. This study addresses this gap through thematic and requirement analyses of trail journals and expert interviews to identify risk factors and inform the design of recommender systems for safer hiking practices. Our findings highlight the need to inform and educate hikers about prevention and deterrence methods, coupled with the development of context-aware recommender systems that share real-time information. These systems should provide customized warnings tailored to specific wildlife risks and conditions, ensuring hikers are well-prepared and capable of making responsible decisions. This research contributes actionable insights for hikers, policymakers, and trail managers to promote sustainable outdoor recreation.

CCS Concepts: • **Human-centered computing → Empirical studies in HCI**.

Additional Key Words and Phrases: Human-Wildlife Conflict, Outdoor Safety Technology, Hiker, Nature-HCI, HCI outdoor.

ACM Reference Format:
Anonymous Author(s). 2025. Listening to the Wild: Risk and Preparedness in Hiker-Wildlife Conflicts during Outdoor Recreation. 1, 1 (February 2025), 11 pages. https://doi.org/XXXXXXX.XXXXXXX

1 Introduction

The escalating impacts of climate change [1, 32], and habitat destruction [64] have heightened the urgency of promoting sustainable coexistence between humans and wildlife [65]. Hikers venturing into wilderness areas with minimal gear and support, represent a group uniquely vulnerable to conflict and harm linked to interactions with wildlife. Their activities often lead to unintentional disturbances, such as altering wildlife behavior and habitat use [39, 57], and improper actions like going off-trail or failing to follow wildlife safety guidelines [35, 46, 73, 78]. These disruptions not only pose risks to biodiversity but also endanger hikers themselves, with encounters ranging from minor inconveniences to serious threats, such as bear confrontations or tick-borne diseases like Lyme disease [38, 76]. From a conservation perspective, human presence on trails can disrupt wildlife behavior and cause ecological damage. For example, while some species avoid areas near trails [7, 73], others exhibit approach or positively selected human-made trails when hikers stray off designated paths [35]. These issues are exacerbated by the costs of maintaining trail systems and repairing damages caused by off-trail activities, which often depend on volunteer labor [27]. However, there is little exploration of the risk factors linked to hiker-wildlife interactions in the HCI community. Existing outdoor recommendations for hikers focus on route suggestions, gear advice, and navigation support [28]. Popular trail apps like AllTrails [3] and FarOut [17] provide awareness of a limited range of threats such as route conditions, and mosquito tracking [2] but lack

ACM XXXX-XXXX/2025/2-ART
https://doi.org/XXXXXXX.XXXXXXX

a systematic approach to mitigating hiker-wildlife conflict in both the short term and long term. This study addresses this gap with qualitative analyses of trail journals and semi-structured expert interviews. It investigates the current state of hiker-wildlife interactions to uncover its influencing factors and how these factors can inform the design of recommender systems to foster safer, more informed, and responsible hiking practices. The primary research questions of our study are as follows:

(RQ1). What risks do human-wildlife conflicts pose to hikers?

(RQ2): How can we assist hikers in preparing for and responding to wildlife interactions and conflicts, and how can recommender systems be utilized effectively as a mediator in these scenarios?

By educating hikers to become better stewards of nature, this research contributes to the overall goal of sustainable harmonious coexistence of humans with wildlife. Specifically, the findings of this study can inform the development of context-aware recommender systems that bridge the gaps in current hiker-wildlife conflict datasets and tools. As outdoor recreation expands globally, this study determines the design factors that support recommender systems to allow hikers to remain highly aware of wildlife threats, be educated and follow responsible hiking practice. The contributions of this study extend beyond the individual hiker to policymakers, trail managers, and environmental stakeholders, offering understanding for encouraging sustainable outdoor recreation.

2 Related Work

2.1 Human-Nature Interactions and Role of Technology

Digital technologies have been used widely in outdoor contexts, from urban parks to remote wilderness [31], from enhancing human-nature connections [49, 61, 77], overseeing environmental conditions [62], to promote education [26, 66], and enable sustainable management [50]. However, research in HCI Outdoors has primarily centered on urban areas. in temperate climates, with limited studies in extreme or less developed environments like semi-primitive areas or those with tropical, dry, or polar climates area[32]. Human-nature relations emphasizes the dual role of technology as both a barrier and a bridge to nature [77]. While technological advances have disconnected humans from natural experiences, they also offer tools for re-engagement, such as ecological education [14, 59, 74], citizen science tools [54], and conservation technologies [53, 62, 70]. Frameworks proposed by Jones et al. stress balancing digital interventions with nature's restorative effects by fostering connections to place, time, and community [30]. This research seeks to expand human-nature interactions by addressing the challenges of semi-primitive areas with limited infrastructure and diverse climates like the Appalachian Trail [37]. It aims to develop design principles that promote environmental awareness and conservation through technology that respects and preserves the intrinsic value of nature. The findings will inform sustainable, context-appropriate, and nature-conscious technological solutions, contributing to the broader HCI discourse.

2.2 Human-Wildlife Conflict and Risk Management

Human-wildlife conflicts often arise from competition for space and resources, leading to risks such as property damage, disease transmission, and physical attacks [55, 71, 72]. Effective risk management involves understanding the spatial dynamics of these interactions and implementing measures such as exclusion techniques (e.g., fencing) to protect human interests while preserving wildlife habitats [11]. Perception of risk significantly influences how individuals and communities respond to wildlife interactions. Communication strategies that leverage narratives and imagery can effectively shape public attitudes and foster support for wildlife management policies [21]. Tailoring these strategies to specific audiences, considering their prior attitudes and cultural contexts, further enhances their impact [21]. Studies in Namibia illustrate how local perceptions of risk can inform

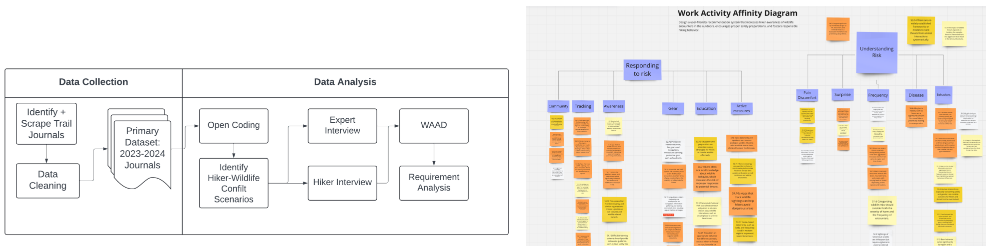

Fig. 1. (Left) Research methodology overview: collecting trail journals, analyzing trail journals, interview, affinity diagramming and requirement analysis. (Right) a screenshot of the work-activity affinity diagram (WAAD) representing frequent topics, factors and rationales linked to hikers' risk awareness and response in the outdoors.

conservation planning and risk communication efforts, making them more effective and culturally sensitive [33]. Managerial technologies in outdoor settings provide real-time risk assessments and enable proactive safety measures [4], enhancing the safety of outdoor activities [40, 43, 67]. Embedded systems for real-time data collection and intelligent analysis have been employed in outdoor sports safety management, predicting potential risks and issuing timely warnings [16]. Similarly, crowdsourcing is pivotal in disaster risk management, where volunteers collect critical in-situ information that aids policymakers and rescue teams in risk reduction efforts [34, 50]. And multiple other technology and applications have been developed for ensuring user safety in the HCI outdoors, such as route finding [69], hazard sensing [4, 23], hazard visualization [22, 68].

2.3 Recommender Systems and Outdoors

Recommender systems are well-known for their ability to assist users with decision-making by filtering and prioritizing information, preventing information overload, and accounting for individual tastes and preferences [29, 52]. Recommender systems for outdoor activities support crucial user tasks, including optimizing routes, recommending gear and finding local attractions. Popular apps like FarOut [17] and Alltrails [3] incorporate recommender systems to support selecting routes, planning dates, and navigating. However, their trail informatics features, such as ground condition tracking and mosquito activity tracking [2] do not have the ability to highlight risk factors for different geographies, seasons, and animal types. Wildlife safety apps like Repawts [58] do not focus on personalized threat response and prevention measures. In academic work, recommendation systems for outdoor contexts have also been studied to address a range of user needs [28]. For example, they propose routes that not only meet hikers' requirements but also help manage trail congestion and promote environmental education. These systems employ network analysis and multi-criteria decision analysis to suggest viable routes, considering factors such as trail difficulty and the conservation needs of the area [51]. However, existing recommender systems for hikers are limited in highlighting the risks associated with trail or route difficulties [28, 36]. We believe that by integrating advanced recommender systems with traditional wildlife risk management strategies, it is possible to mitigate human-wildlife conflicts more effectively. This integration could promote safer and more informed hiking practices. Our goal is to contribute to the future development of such recommender systems in this domain.

3 Methodology

This section outlines the steps to investigate hikers' interactions with wildlife, focusing on scenarios resulting in negative experiences. Building on previous work in the Nature-HCI domain [60, 77], our approach integrates quantitative analysis of hiker trail journals, expert and hiker interviews, and Work Activity Affinity Diagram (WAAD) techniques [24] (See Figure 1). We analyzed Appalachian Trail hikers' journals for 2023 and 2024 in text-written format, which are publicly available on TrailJournals.com [75]. These journals, authored by hikers documenting their experiences, provided data on interactions with wildlife. Using open coding [63], we identified scenarios involving animals, insects, and plants, focusing on negative encounters. Key aspects analyzed included the types of wildlife involved, coping strategies used, and the severity and frequency of incidents. To validate journal insights, we interviewed 4 experts and 6 experienced hikers. Experts included conservationists, wildlife ecologists, and national park managers, who shared theoretical and management-oriented perspectives. Hikers provided firsthand accounts of wildlife interactions, coping mechanisms, and challenges. Interviews were transcribed into work activity notes and analyzed using work-activity affinity diagramming (WAAD) [24]. A team of 5 UX design experts with varying hiking experiences collaborated to identify user needs and challenges from the WAAD. These needs informed our requirement analysis [8] to identify key functionalities and constraints for a recommendation system to help hikers better manage wildlife encounters.

4 Findings and Discussion

In this section, we present key findings from trail journals and expert interviews to provide a comprehensive understanding of hiker-wildlife interactions, including perceptions, coping strategies, and systemic challenges within two main categories: understanding the risk of hiker-wildlife Interactions and responding to these risks. We also discuss key design requirements for a recommender system to promote awareness and prevention of hiker-wildlife conflict.

4.1 Understanding the Risks of Hiker-Wildlife Interactions

4.1.1 Severity and Frequency of Wildlife Encounters. Hikers and experts emphasized the contrast between large mammals, which pose the most serious potential threats, and smaller creatures, which are more frequently encountered. Large animals such as bears, moose, and venomous snakes were commonly documented in journals as significant hazards, with hikers describing encounters that could endanger life. Experts confirmed these observations but emphasized that such interactions are rare and highly situational. Factors such as seasonality, regional behavior patterns, and human activity significantly influence the likelihood of these encounters. For example, bears in Shenandoah National Park are generally non-aggressive and avoid humans, whereas bears in the Smoky Mountains, accustomed to human food, exhibit more dangerous behaviors. Conversely, diminutive organisms such as ticks, mosquitoes, and flora like poison ivy are identified as prevalent irritants, a conclusion consistently supported by journal entries and expert interviews. Ticks are particularly concerned due to their role in transmitting Lyme disease and other pathogens. Unlike large mammals, these small hazards require ongoing, daily management, including tick checks, the use of repellents, and wearing protective clothing. While these nuisances are less life-threatening, their persistent presence makes them a major source of discomfort and health risks for hikers. Poison ivy, frequently mentioned in journals, was also noted by experts as a recurring issue plants for hikers, especially in the eastern United States.

4.1.2 Emergency Preparedness. The amalgamation of journal articles and interview data has elucidated a plethora of systemic obstacles impeding the efficacy of wildlife risk management. A paramount challenge identified is the accessibility of knowledge and resources. Numerous hikers have confessed to embarking on their journeys ill-prepared, often devoid of critical safety implements such as bear spray or repellents. Experts have pinpointed the root of this issue in the inadequate educational outreach prevalent, particularly at trailheads. At these initial points of contact, unprepared visitors are unlikely to independently pursue pertinent wildlife safety information, exacerbating the problem.

Technological tools are recognized for their significant contributions, yet their utility is not without constraints. Hikers commonly employ applications to monitor wildlife sightings and environmental hazards, a practice that experts acknowledge enhances both planning and situational responsiveness. Nevertheless, challenges persist, including the frequency of outdated entries, the imprecision of spatial data, and the dynamic nature of wildlife, all of which can compromise the reliability of such information. Moreover, experts express concerns regarding the potential misuse of such apps by hikers seeking wildlife encounters, inadvertently increasing risks by attracting people to potentially dangerous areas. Despite these concerns, platforms that leverage community engagement and citizen science, such as iNaturalist [47], are recognized for their capacity to provide enriched spatial and temporal data, thus supporting the needs of those tracking specific species in natural settings.

4.2 Responding to the Risks of Hiker-Wildlife Interaction

4.2.1 Conflict Deterrence and Prevention. Hikers documented several strategies to mitigate wildlife risks, which were largely corroborated by expert perspectives. Maintaining vigilance and observing surroundings were commonly mentioned approaches, enabling hikers to detect potential threats before they escalated. Noise-based deterrents, such as clapping, talking loudly, or using bells, were frequently employed to avoid surprise encounters with larger animals. Repellents and tools like bear spray were also highlighted as essential for managing risks from large animals and insects. Food storage and waste management emerged as critical preventive measures, with hikers emphasizing proper handling and disposal to avoid attracting wildlife. Experts confirmed the importance of these strategies, stressing that improper food storage can lead to behavior changes in animals, increasing their likelihood of approaching humans and becoming dangerous to other hikers. However, both journals and interviews noted that these strategies were not always practical. Wildlife encounters were often described as unpredictable. In many cases, insufficient preparation or lack of knowledge exacerbated these risks. Hikers frequently reported not knowing how to predict animal presence or respond appropriately during encounters. Experts emphasized the significance of this gap, particularly for novice hikers, who are more likely to respond inappropriately to wildlife threats.

4.2.2 Education and Outreach. Both journals and interviews underscored the pivotal role of education and preparation in reducing hiker-wildlife conflicts. Successful encounters documented in journals frequently involved hikers with prior knowledge of wildlife behavior, proper food storage techniques, and situational awareness. In addition to reflecting on individual experiences, trail journals can serve as a valuable resource for educating and motivating good behavior. Journals provide a peer-driven platform for promoting best practices among hikers by sharing detailed accounts of successful strategies and mistakes. Experts emphasized the need to enhance hiker preparation through targeted outreach efforts, particularly for novice hikers less likely to seek or possess critical knowledge before entering the trail. Digital platforms, including social media, were identified as effective channels for engaging broader audiences with wildlife safety information. Experts suggested using simple, visually engaging materials such as info-graphics or step-by-step protocols to educate hikers on best practices. Additionally, timely reminders, such as preparing mosquito repellents before hikes or conducting daily tick checks, were considered practical interventions to reinforce preventive behaviors.

4.3 Designing Recommender Systems to Mitigate the Risks of Hiker-Wildlife Interaction

We consider recommender systems a viable platform for reducing hiker-wildlife interaction problems by enhancing hiker safety and ecological awareness. This is due to their ability to process large volumes of information [20, 28], tailor content based on context adapt to rapidly changing environments [28, 79], and incorporate educational features effectively [51].

4.3.1 Recognizing Risks to Enhance Awareness and Preparation. One major insight from our analysis is the importance of helping hikers recognize risks before encountering them. A tailored recommender system, functioning as an "outdoor guide," could proactively offer real-time alerts based on specific factors such as geographical location and seasonal conditions. This system might enhance its utility by incorporating visual tools, like threat maps or overlays, which are accompanied by concise explanations detailing the risks associated with particular conditions or behaviors. It shortens the time and effort the information collection and decision making process for hikers. Such features ensure that hikers understand the presence of dangers and their underlying implications in timely fashion. Preparation also emerged as a critical phase where personalized guidance can significantly improve safety. By analyzing plans for a particular route and time of year, the system could offer gear recommendations along with explanations of each item's importance. A beginner might learn how essential insect repellent is on certain trails, while an experienced hiker could discover optimal ways to pack for various trail conditions. Tutorials—tailored by skill level—could even teach basics like map-reading or safe wildlife interactions. However, these enhancements are not without potential drawbacks. Flooding users with constant alerts can cause fatigue, prompting them to disregard vital information [41]. Finding a way to balance the benefits and costs of notifications is the way to ensure optimum result [48]. In the meantime, overly detailed overlays and maps, while helpful, may distract from the trail, and providing exhaustive tutorials or equipment lists could overwhelm beginners or those seeking a more casual experience [5, 6, 9, 45].

4.3.2 Adapting to Changing Conditions. Hiking conditions exhibit considerable uncertainties [60], necessitating systems that facilitate user adaptation to fluctuating trail environments. Our research underscores the critical importance of context-aware intelligence systems that leverage real-time data to modify recommendations dynamically. For example, when a trail closure occurs due to wildlife activity, such a system could proactively offer an alternative route that aligns with the user's intended destination. As mention in the previous section, different gear should be bought for different time and location. The addition of offline capabilities ensures that these insights remain available even in areas with limited connectivity. Moreover, the system's utility extends beyond simple navigation, offering vital support in emergency scenarios through clear, sequential guidance. In a venomous snake encounter, the system could instruct hikers to remain stationary, display the locations of nearby medical facilities, and provide essential first-aid instructions. Explaining each recommended action enhances user confidence in critical situations, enabling a swift and effective response. By customizing these recommendations to fit specific circumstances and the user's contextual needs, the system assures that hikers can navigate routine and emergent challenges with assurance. But tailored recommendations require extensive user data, which could raise concerns regarding privacy and the degree of personalization [15].

Such advanced functionalities involve trade-offs. Leveraging immediate trail-closure information and wildlife sightings relies on frequent data updates and stable connectivity, which might be unavailable in remote regions and drain digital device battery quick to make it last short. Auto-recommended detours reduce the cognitive load associated with route planning. Still, they can lead to frustration if users prefer different paths or to over-reliance if they become too dependent on system guidance. Balancing these benefits against potential pitfalls is key to maintaining trust and usability [10]. Tailored recommendations require extensive user data, which could raise concerns regarding privacy and the degree of personalization [15]. To address these challenges, strategic caching or periodic synchronization can keep data as current as possible, even when connectivity is intermittent. Low-power usage modes could preserve battery life on extended treks and optional manual overrides allow users to make their own route decisions. Above all, clear explanations for each recommendation ensure hikers remain in control and understand the rationale behind every suggestion. Combining adaptive intelligence with user empowerment can promote safety, flexibility, and confidence under ever-changing conditions.

4.3.3 Encouraging Responsibility and Sustainability. The WAAD analysis highlighted the vital role of technology in promoting responsible hiking practices. A recommender system can guide hikers toward sustainable actions—such as choosing eco-friendly campsites, staying clear of fragile ecosystems, or reducing noise in sensitive wildlife areas. These tips would seamlessly integrate into the system's other features, providing justifications illustrating how each choice contributes to environmental preservation. By weaving sustainability into routine recommendations, the system reinforces the importance of minimal impact principles. Personalization is crucial to ensuring these messages resonate. Novice hikers, for instance, could receive basic reminders tied to Leave No Trace principles [46]. At the same time, experienced users might explore advanced content on long-term trail erosion or climate change effects. This tailored approach helps users understand the immediate and broader consequences of their actions. Over time, they can develop the knowledge and the habits necessary for low-impact outdoor activity. To further bolster engagement, the system could offer tutorials, visualizations, and interactive guides that make complex concepts more accessible and memorable. For example, an animation might illustrate how to observe wildlife without disturbing their habitats, or a step-by-step walk-through could show how to minimize ecological footprints when setting up camp. Embedding educational moments into everyday interactions empowers hikers to explore the outdoors ethically and with greater confidence.

Indeed, these features entail trade-offs. The efficacy of proactive prompts, such as reminders to remain on designated trails, remains uncertain in remote outdoor settings where traditional communications might falter. Additionally, highly interactive system elements that demand constant screen interaction could inadvertently distract users from crucial environmental cues, deviating from established HCI Outdoor design principles [49]. Striking an appropriate balance among these factors is crucial to developing an impactful, user-friendly system that promotes responsible behavior while enhancing the enjoyment of the natural environment.

4.3.4 Leveraging the Wisdom of the Community. Hikers are not just users but also critical contributors to a broader knowledge ecosystem. By reporting real-time insights—such as bear sightings or trail closures—they enrich the system's data, enabling timely alerts for others. To ensure reliability, the platform can cross-reference these community submissions with official data and employ credibility badges, fostering both shared responsibility and trust. Because collecting accurate wildlife data is inherently risky and costly, leveraging citizen science and crowd-sourcing features [18, 25, 77] can help maintain a comprehensive, up-to-date database that benefits both users and wildlife conservation efforts. Engaging the public in data gathering and updates improves accuracy and deepens user involvement and advocacy for conservation efforts. As hikers contribute their observations, they become more invested in the stewardship of the environments they explore. Designing ethical, user-centric citizen science platforms is equally important. Flexible access permissions and governance models, such as those demonstrated by CitSci.org [44], can preserve privacy while maintaining openness. At the same time, mechanisms like badging and credentialing can distinguish official alerts from community-contributed updates, providing visual cues about each source's expertise or credibility [12, 13, 42, 56] and fostering greater trust. However, publicizing sightings of dangerous animals introduces an ethical dilemma: while sharing this information can alert hikers to potential risks, it may also attract thrill-seekers who intentionally approach those animals or aid poachers in illegal hunting or other activities [19]. Blurring exact locations is one potential solution, but it diminishes transparency, possibly eroding trust in the data's accuracy. Balancing user safety, protecting wildlife, and ensuring the reliability of community-sourced data remain core challenges in designing effective, ethical risk-monitoring systems.

5 Limitations and Future Work

Our study's reliance on trail journal analysis and expert interviews may overlook nuanced, user-specific needs or preferences. Additionally, hardware and infrastructure-related limitations were not considered during the analysis, potentially impacting the feasibility of proposed solutions in specific contexts. Future work should emphasize iterative ideation and prototyping, engaging diverse user groups and experts through participatory design workshops to refine system features and usability [24]. Evaluation of these prototypes should combine expert reviews with real-world user testing to ensure practical applicability, ecological sensitivity, and alignment with the diverse conditions encountered in outdoor environments.

6 Conclusion

Through an intensive qualitative analysis of hiker trail diaries and expert input from the domain, we analyzed the risk factors for hiker-wildlife encounters and identified design opportunities for a recommender system to mitigate risks. We found that the risk to hikers posed by wildlife is a function of both the severity and frequency of the encounter. Extremely dangerous animals are less frequently encountered than parasite-carrying insects or poisonous plants which can cause illnesses and pain and diminish the quality of the hiking experience on a larger scale. Preparation for emergencies is a critical component of hiking safety. However, inadequate preparation often leaves hikers ill-equipped to handle wildlife threats, both in terms of a lack of proper equipment as well as a lack of proper knowledge. To counter these threats, hikers should educate themselves on active prevention and deterrence methods specific to the wildlife they encounter. Community-sourced insights and interventions can effectively augment existing wildlife threat awareness tools in order to improve their relevance, actionability, and personalization.

References

[1] B. Abrahms. 2021. Human-wildlife conflict under climate change. *Science* 373 (2021), 484 – 485. doi:10.1126/science.abj4216

[2] Alltrail. [n. d.]. Introducing: Advanced conditions. https://support.alltrails.com/hc/en-us/articles/16592729155476-Introducing-Advanced-Conditions

[3] Inc Alltrail. 2025. Alltrail. https://www.alltrails.com/.

[4] Ashwaq Alsoubai, Jinkyung Park, Sarvech Qadir, Gianluca Stringhini, Afsaneh Razi, and Pamela J. Wisniewski. 2024. Systemization of Knowledge (SoK): Creating a Research Agenda for Human-Centered Real-Time Risk Detection on Social Media Platforms. In *Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems* (Honolulu, HI, USA) *(CHI '24)*. Association for Computing Machinery, New York, NY, USA, Article 115, 21 pages. doi:10.1145/3613904.3642315

[5] Eoin Mac Aoidh, Michela Bertolotto, and David C Wilson. 2012. Towards dynamic behavior-based profiling for reducing spatial information overload in map browsing activity. *Geoinformatica* 16 (2012), 409–434.

[6] David Bawden and Lyn Robinson. 2020. Information overload: An overview. (2020).

[7] Sonny S Bleicher and Michael L Rosenzweig. 2018. Too much of a good thing? A landscape-of-fear analysis for collared peccaries (Pecari tajacu) reveals hikers act as a greater deterrent than thorny or bitter food. *Canadian Journal of Zoology* 96, 4 (2018), 317–324.

[8] Terry Anthony Byrd, Kathy L Cossick, and Robert W Zmud. 1992. A synthesis of research on requirements analysis and knowledge acquisition techniques. *MIS quarterly* (1992), 117–138.

[9] Jacky Cao, Kit-Yung Lam, Lik-Hang Lee, Xiaoli Liu, Pan Hui, and Xiang Su. 2023. Mobile augmented reality: User interfaces, frameworks, and intelligence. *Comput. Surveys* 55, 9 (2023), 1–36.

[10] Shiye Cao and Chien-Ming Huang. 2022. Understanding user reliance on AI in assisted decision-making. *Proceedings of the ACM on Human-Computer Interaction* 6, CSCW2 (2022), 1–23.

[11] N. Carter, Andrés Baeza, and N. Magliocca. 2020. Emergent conservation outcomes of shared risk perception in human-wildlife systems. *Conservation Biology* 34 (2020). doi:10.1111/cobi.13473

[12] Cheng Chen and S. Sundar. 2023. Is this AI trained on Credible Data? The Effects of Labeling Quality and Performance Bias on User Trust. *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems* (2023). doi:10.1145/3544548.3580805

[13] Shun-Ling Chen. 2019. How Empowering Is Citizen Science? Access, Credits, and Governance for the Crowd. *East Asian Science, Technology and Society: An International Journal* 13 (2019), 215 – 234. doi:10.1215/18752160-7497711

[14] Gene Chipman, Allison Druin, Dianne Beer, Jerry Alan Fails, Mona Leigh Guha, and Sante Simms. 2006. A case study of tangible flags: a collaborative technology to enhance field trips. In *Proceedings of the 2006 conference on Interaction design and children*. 1–8.

[15] Angela Di Fazio. 2024. Enhancing Privacy in Recommender Systems through Differential Privacy Techniques. In *Proceedings of the 18th ACM Conference on Recommender Systems*. 1348–1352.

[16] Weiti Du and Ke Sun. 2024. Evaluation of Outdoor Sports Safety Risk Management Based on Embedded Systems. *International Journal of High Speed Electronics and Systems* (2024). doi:10.1142/s0129156424400408

[17] Inc FarOut. 2025. FarOut. https://faroutguides.com/.

[18] Tavis D. Forrester, Megan Baker, Robert Costello, Roland Kays, Arielle W. Parsons, and William J. McShea. 2017. Creating advocates for mammal conservation through citizen science. *Biological Conservation* 208 (2017), 98–105. doi:10.1016/j.biocon.2016.06.025 The role of citizen science in biological conservation.

[19] R. M. Frey, T. Hardjono, Christian Smith, Keeley Erhardt, and A. Pentland. 2017. Secure sharing of geospatial wildlife data. (2017), 5:1–5:6. doi:10.1145/3080546.3080550

[20] Ni Luh Wiwik Sri Rahayu Ginantra, Gita Widi Bhawika, Ahmad Zamsuri, Fadjar Budianto, and GS Achmad Daengs. 2020. Decision Support System in recommending climbing tourism destinations with Profile Matching method. In *IOP Conference Series: Materials Science and Engineering*, Vol. 835. IOP Publishing, 012054.

[21] Sara K Guenther and Elizabeth A. Shanahan. 2020. Communicating risk in human-wildlife interactions: How stories and images move minds. *PLoS ONE* 15 (2020). doi:10.1371/journal.pone.0244440

[22] Hongling Guo, Yantao Yu, and M. Skitmore. 2017. Visualization technology-based construction safety management: A review. *Automation in Construction* 73 (2017), 135–144. doi:10.1016/J.AUTCON.2016.10.004

[23] Matthew R. Hallowell, J. Teizer, and W. Blaney. 2010. Application of Sensing Technology to Safety Management. (2010), 31–40. doi:10.1061/41109(373)4

[24] Rex Hartson. 2012. *The UX Book: Process and Guidelines for Ensuring a Quality User Experience*. Elsevier.

[25] Taha Hassan. 2019. On bias in social reviews of university courses. In *Companion Publication of the 10th ACM Conference on Web Science*. 11–14.

[26] David Hills, Imre van Kraalingen, and Glyn J. Thomas. 2023. The Impact of Technology on Presence in Outdoor Education. *Journal of Experiential Education* 47 (2023), 301 – 318. doi:10.1177/10538259231202452

[27] Karen S. Hockett, Jeffrey L. Marion, and Yu-Fai Leung. 2017. The efficacy of combined educational and site management actions in reducing off-trail hiking in an urban-proximate protected area. *Journal of Environmental Management* 203 (2017), 17–28. doi:10.1016/j.jenvman.2017.06.073

[28] Iustina Ivanova and Mike Wald. 2023. Recommender systems for outdoor adventure tourism sports: hiking, running and climbing. *Human-Centric Intelligent Systems* 3, 3 (2023), 344–365.

[29] A. Jameson, M. Willemsen, A. Felfernig, M. Degemmis, P. Lops, G. Semeraro, and Li Chen. 2013. Human Decision Making and Recommender Systems. *ACM Trans. Interact. Intell. Syst.* 3 (2013), 17:1–17:7. doi:10.1145/2533670.2533675

[30] Michael Jones, Tuomas Kari, Daniel Reich, Barrett Ens, Siyi Liu, Solomon B Pobee, and Florian Mueller. 2024. Toward a Framework for the Design of Interactive Technology for Nature Recreation. *International Journal of Human–Computer Interaction* (2024), 1–21.

[31] Michael D Jones, Zann Anderson, Jonna Häkkilä, Keith Cheverst, and Florian Daiber. 2018. HCI outdoors: understanding human-computer interaction in outdoor recreation. In *Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems*. 1–8.

[32] Michael D Jones, Meredith Von Feldt, and Natalie Andrus. 2022. Outside Where? A Survey of Climates and Built Environments in Studies of HCI outdoors. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems*. 1–15.

[33] J. S. Kahler and Meredith L. Gore. 2015. Local perceptions of risk associated with poaching of wildlife implicated in human-wildlife conflicts in Namibia. *Biological Conservation* 189 (2015), 49–58. doi:10.1016/J.BIOCON.2015.02.001

[34] N. Kankanamge, Tan Yigitcanlar, A. Goonetilleke, and M. Kamruzzaman. 2019. Can volunteer crowdsourcing reduce disaster risk? A systematic review of the literature. *International Journal of Disaster Risk Reduction* (2019). doi:10.1016/J.IJDRR.2019.101097

[35] Roland Kays, Arielle W Parsons, Megan C Baker, Elizabeth L Kalies, Tavis Forrester, Robert Costello, Christopher T Rota, Joshua J Millspaugh, and William J McShea. 2017. Does hunting or hiking affect wildlife communities in protected areas? *Journal of Applied Ecology* 54, 1 (2017), 242–252.

[36] Katherine V. Kortenkamp, C. Moore, Daniel P. Sheridan, and Emily S. Ahrens. 2017. No Hiking Beyond this Point! Hiking Risk Prevention Recommendations in Peer-Reviewed Literature. *Journal of outdoor recreation and tourism* 20 (2017), 67–76. doi:10.1016/J.JORT.2017.10.002

[37] Lindah Kotut, Michael Horning, Timothy L Stelter, and D Scott McCrickard. 2020. Preparing for the unexpected: community framework for social media use and social support by trail thru-hikers. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. 1–13. doi:10.1145/3313831.3376391

[38] Takahiro Kubo and Yasushi Shoji. 2014. Trade-off between human–wildlife conflict risk and recreation conditions. *European Journal of Wildlife Research* 60 (2014), 501–510.

[39] Jesse S. Lewis, Susan E. Spaulding, Heather M. Swanson, W. Keeley, Ashley R. Gramza, S. Vandewoude, and K. Crooks. 2021. Human activity influences wildlife populations and activity patterns: implications for spatial and temporal refuges. *Ecosphere* 12 (2021). doi:10.1002/ECS2.3487

[40] Jiajie Li, Hongxin Li, Sheng Liu, and Weizhuang Zhang. 2024. Research on risk prediction and management of outdoor sports based on artificial intelligence. *Journal of Human Movement Science* (2024). doi:10.23977/jhms.2024.050207

[41] Tianshi Li, Julia Katherine Haines, Miguel Flores Ruiz De Eguino, Jason I Hong, and Jeffrey Nichols. 2023. Alert now or never: Understanding and predicting notification preferences of smartphone users. *ACM Transactions on Computer-Human Interaction* 29, 5 (2023), 1–33.

[42] Zhan Liu, Matthieu Delaloye, Nicole Glassey Balet, Sébastien Hersant, Frédéric Gris, and Laurent Sciboz. 2022. Trust in the News: A Digital Labelling Solution for Journalistic Contents. *Online Journal of Communication and Media Technologies* (2022). doi:10.30935/ojcmt/11528

[43] Yan Lu. 2024. Machine Learning-based Risk Prediction and Safety Management for Outdoor Sports Activities. *Scalable Comput. Pract. Exp.* 25 (2024), 3934–3941. doi:10.12694/scpe.v25i5.3145

[44] S. Lynn, N. Kaplan, S. Newman, Russell Scarpino, and Greg Newman. 2019. Designing a Platform for Ethical Citizen Science: A Case Study of CitSci.org. *Citizen Science: Theory and Practice* (2019). doi:10.5334/CSTP.227

[45] Mohammed N Mahdi, Abdul R Ahmad, Roslan Ismail, Mohammed A Subhi, Mohammed M Abdulrazzaq, and Qais S Qassim. 2020. Information overload: The effects of large amounts of information. In *2020 1st. Information Technology To Enhance e-learning and Other Application (IT-ELA*. IEEE, 154–159.

[46] Jeffrey Marion. 2014. *Leave No Trace in the outdoors*. Stackpole Books.

[47] Christie A Matheson. 2014. inaturalist. *Reference Reviews* 28, 8 (2014), 36–38.

[48] D Scott McCrickard and Christa M Chewar. 2003. Attuning notification design to user goals and attention costs. *Commun. ACM* 46, 3 (2003), 67–72.

[49] D Scott McCrickard, Michael Jones, and Timothy L Stelter. 2020. *HCI outdoors: theory, design, methods and applications*. Springer.

[50] Shalini Misra, Norhan Abdelgawad, Kris Wernstedt, Morva Saaty, Jaitun Patel, Jeffrey Marion, and Scott McCrickard. 2024. Toward a management framework for smart and sustainable resource management: The case of the Appalachian Trail. *Journal of Environmental Management* 372 (2024), 123422. doi:10.1016/j.jenvman.2024.123422

[51] Luong Vuong Nguyen. 2024. OurSCARA: Awareness-Based Recommendation Services for Sustainable Tourism. *World* 5, 2 (2024), 471–482.

[52] I. Palomares, C. Porcel, L. Pizzato, Ido Guy, and E. Herrera-Viedma. 2020. Reciprocal Recommender Systems: Analysis of state-of-art literature, challenges and opportunities towards social recommendation. *Inf. Fusion* 69 (2020), 103–127. doi:10.1016/j.inffus.2020.12.001

[53] Daniel Pimentel. 2021. The peril and potential of XR-based interactions with wildlife. In *Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems*. 1–9.

[54] Jennifer Preece. 2017. How two billion smartphone users can save species! *interactions* 24, 2 (2017), 26–33.

[55] Ileana Pătru-Stupariu, A. Nita, Mihai Mustățea, Alina Huzui-Stoiculescu, and C. Fürst. 2020. Using social network methodological approach to better understand human–wildlife interactions. *Land Use Policy* 99 (2020), 105009. doi:10.1016/j.landusepol.2020.105009

[56] Neal Reeves, Ramine Tinati, Sergej Zerr, M. V. Kleek, and E. Simperl. 2017. From Crowd to Community: A Survey of Online Community Features in Citizen Science Projects. *Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing* (2017). doi:10.1145/2998181.2998302

[57] M. L. Reilly, M. Tobler, D. Sonderegger, and P. Beier. 2017. Spatial and temporal response of wildlife to recreational activities in the San Francisco Bay ecoregion. *Biological Conservation* 207 (2017), 117–126. doi:10.1016/J.BIOCON.2016.

11.003

[58] Inc repawts. 2025. repawts. https://https://www.repawts.com/.

[59] Yvonne Rogers, Sara Price, Geraldine Fitzpatrick, Rowanne Fleck, Eric Harris, Hilary Smith, Cliff Randell, Henk Muller, Claire O'Malley, Danae Stanton, et al. 2004. Ambient wood: designing new forms of digital augmentation for learning outdoors. In *Proceedings of the 2004 conference on Interaction design and children: building a community*. 3–10.

[60] Morva Saaty, Natalie Andrus, Norhan Abdelgawad, Jennifer Chandran, Brett Noneman, Justice Jackson, Kun Alading, Taha Hassan, D Scott McCrickard, Shalini Misra, et al. 2024. " Is Long-distance Hiking an Emotional Roller Coaster?" Evaluating Emotions and Weather Effects on the Appalachian Trail. In *Extended Abstracts of the CHI Conference on Human Factors in Computing Systems*. 1–8. doi:10.1145/3613905.3651024

[61] Morva Saaty, Derek Haqq, Devin B Toms, Ibrahim Eltahir, and D Scott McCrickard. 2021. A study on Pokémon GO: exploring the potential of location-based mobile exergames in connecting players with nature. In *Extended Abstracts of the 2021 Annual Symposium on Computer-Human Interaction in Play*. 128–132. doi:10.1145/3450337.3483481

[62] Morva Saaty, Jaitun V Patel, Norhan Abdelgawad, Jeffrey Marion, D Scott McCrickard, Shalini Misra, and Kris Wernstedt. 2022. Note: Studying Sustainable Practices of Appalachian Trail Community based on Reddit Topic Modelling Analysis. In *Proceedings of the 5th ACM SIGCAS/SIGCHI Conference on Computing and Sustainable Societies*. 560–563. doi:10.1145/3530190.3534848

[63] Johnny Saldaña. 2021. The coding manual for qualitative researchers. (2021).

[64] N. Seoraj-Pillai and N. Pillay. 2016. A Meta-Analysis of Human–Wildlife Conflict: South African and Global Perspectives. *Sustainability* 9 (2016), 1–21. doi:10.3390/SU9010034

[65] Prashant Sharma, N. Chettri, and Kesang Wangchuk. 2021. Human–wildlife conflict in the roof of the world: Understanding multidimensional perspectives through a systematic review. *Ecology and Evolution* 11 (2021), 11569 – 11586. doi:10.1002/ece3.7980

[66] Demi G. Siskind, D. Conlin, Linda Hestenes, Sung ae Kim, A. Barnes, and Dilara Yaya-Bryson. 2020. Balancing technology and outdoor learning: Implications for early childhood teacher educators. *Journal of Early Childhood Teacher Education* 43 (2020), 389 – 405. doi:10.1080/10901027.2020.1859024

[67] M. Skibniewski. 2014. Information technology applications in construction safety assurance. *Journal of Civil Engineering and Management* 20 (2014), 778–794. doi:10.3846/13923730.2014.987693

[68] Robert Soden, Lydia Chilton, Scott Miles, Rebecca Bicksler, Kaira Ray Villanueva, and Melissa Bica. 2022. Insights and opportunities for HCI research into hurricane risk communication. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems*. 1–13.

[69] Soheil Sohrabi, Yanmo Weng, Subasish Das, and Stephanie German Paal. 2022. Safe route-finding: A review of literature and future directions. *Accident Analysis & Prevention* 177 (2022), 106816.

[70] Alessandro Soro, Margot Brereton, Tshering Dema, Jessica L Oliver, Min Zhen Chai, and Aloha May Hufana Ambe. 2018. The ambient birdhouse: An IoT device to discover birds and engage with nature. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. 1–13.

[71] C. Soulsbury and P. White. 2015. Human–wildlife interactions in urban areas: a review of conflicts, benefits and opportunities. *Wildlife Research* 42 (2015), 541 – 553. doi:10.1071/WR14229

[72] C. Soulsbury and P. White. 2015. Human—wildlife interactions in urban ecosystems. *Wildlife Research* 42 (2015), iii – v. doi:10.1071/WRv42n7_PR

[73] Audrey R Taylor and Richard L Knight. 2003. Wildlife responses to recreation and associated visitor perceptions. *Ecological applications* 13, 4 (2003), 951–963.

[74] Bill Tomlinson, Man Lok Yau, Eric Baumer, Sara Goetz, Lynn Carpenter, Riley Pratt, Kristin Young, and Calen May-Tobin. 2006. The EcoRaft project: a multi-device interactive graphical exhibit for learning about restoration ecology. In *CHI'06 extended abstracts on Human factors in computing systems*. 1445–1450.

[75] Inc TrailJournal. 2025. TrailJournal. https://www.trailjournals.com/journals/appalachian_trail.

[76] Rachele Vada, Stefania Zanet, Elena Battisti, and Ezio Ferroglio. 2024. Abundance Trends of Immature Stages of Ticks at Different Distances from Hiking Trails from a Natural Park in North-Western Italy. *Veterinary Sciences* 11, 10 (2024). doi:10.3390/vetsci11100508

[77] Sarah Webber, Ryan M Kelly, Greg Wadley, and Wally Smith. 2023. Engaging with nature through technology: A scoping review of HCI research. In *Proceedings of the 2023 CHI conference on human factors in computing systems*. 1–18.

[78] Katharina Westekemper, Horst Reinecke, Johannes Signer, Marcus Meißner, Sven Herzog, and Niko Balkenhol. 2018. Stay on trails–effects of human recreation on the spatiotemporal behavior of red deer Cervus elaphus in a German national park. *Wildlife Biology* 2018, 1 (2018), 1–9.

[79] JunHo Yoon and Chang Choi. 2023. Real-Time Context-Aware Recommendation System for Tourism. *Sensors* 23, 7 (2023). doi:10.3390/s23073679