

Sustainable Trails

Annotated Bibliography

For use with discussions regarding impacts of trail networks

All citations are in Chicago format.

Quoted sections of studies or papers are indented and italicized.

Highlighted or important parts of a quoted section are shown in **dark red** color text.

Notes or context that might help explain a quote listed below the quoted section in **dark green** color.

Adjacent Properties

Property Values

Corning, Sarah E., Rasul A. Mowatt, and H. Charles Chancellor. "Multiuse trails: Benefits and concerns of residents and property owners." *Journal of Urban Planning and Development* 138, no. 4 (2012): 277-285

Of particular interest is the emphasis placed upon the role the trails played in the social life of RPOs. The trails enhanced the RPO social life with family, friends, and neighbors. This is another important component for trail managers and planners to consider and foster through trail planning. It is also an important marketing component for those selling property adjacent to trails. - Conclusion (pg. 284)

Lin, I-Hui, Changshan Wu, and Christopher De Sousa. "Examining the economic impact of park facilities on neighboring residential property values." *Applied Geography* 45 (2013): 322-331

Parent, Olivier, and Rainer Vom Hofe. "Understanding the impact of trails on residential property values in the presence of spatial dependence." *The Annals of Regional Science* 51 (2013): 355-375

"It is well documented in the relevant literature that location matters for home buyers and as such is a major component in determining property values. In the presented

paper, we showed that multi-purpose trails have a significant influence on the price of houses when they lie within close proximity to the trail, where the distance to the trail is calculated based on street network distances. More specifically, we estimated the influence of the Little Miami Scenic Trail in Hamilton County, Ohio, to devalue the average priced house in our sample by \$3.98 when moving away from the trail by one foot.” - Conclusion (pg. 373)

Gnagey, Matthew, and Therese Grijalva. "The impact of trails on property values: a spatial analysis." *The Annals of Regional Science* 60 (2018): 73-97

“Overall, we conclude there is a large premium for better access to trails, measured as shorter driving times to trailheads, and there is no negative price impact for houses located directly adjacent to the trailheads.” - Conclusion (pg. 90)

Crompton, John L., and Sarah Nicholls. "The impact of greenways and trails on proximate property values: An updated review." *Journal of park and recreation administration* 37, no. 3 (2019).

Elovirta, Salla. "Estimating the effect of being close to outdoor activities on cottage prices: The case of." (2022)

“This study has shown the significant connection between cottage location in relation to outdoor activities, and cottage prices in Northern Finland. Thus, the thesis contributes to two very little researched topics, cottage or second home prices, and cottage markets of Northern Finland. Both of these areas are relevant to research even more, especially now post-Covid when the demand for outdoor activities seems to have increased, at least temporarily. Next steps for this line of research would be to modify the analysis so that the DiD assumption of parallel trends pre-treatment is fulfilled, then to conduct the analysis again preferably with more data overall. In future research more post-Covid years should be included in the data to find out more about the longevity of the effects, which is still hard to predict at present.” - Conclusion (pg. 55)

Ecological Impacts

Erosion & Soils

Cessford, Gordon. *Off-road impacts of mountain bikes: A review and discussion.* No. 92. Wellington: Department of Conservation, 1995

*“The significance of assessing use-impacts on tracks needs to be reconsidered, as it is not established that mountain bikes have any greater impact on tracks than do any other non-motorised activities (e.g., walking, running, tramping, horses etc.). Also, actual impacts upon tracks represent more of a management maintenance concern than a significant impact on the environment. It is questionable whether these impacts should be the key factors in decisions to allocate or limit opportunities for mountain biking. **If major damage***

is anticipated due to susceptible track conditions, the presence of any use would seem to be problematic.” - Conclusions (pg. 29)

Goeft, Ute, and Jackie Alder. "Sustainable mountain biking: a case study from the southwest of Western Australia." *Journal of Sustainable Tourism* 9, no. 3 (2001): 193-211

Zwick, Rodney R., and Hale, Jeff. "Mountain Bike Trail Compaction Relation to Selected Physical Parameters." *Lyndon State College & Institute for Northeast Kingdom Studies* (2001): 399

“The study has multiple implications for managers of mountain bike trail systems in the eastern United States. Similar to previous studies in the west, mountain bike trails compact quickly. Little traffic causes compaction to accelerate fairly rapidly - there was observable evidence of compaction within three days of the trail opening and significant compaction occurred within six weeks, at which time stasis appears to have been reached. Managers will need to monitor trails during periods of this stasis, as this appears to be the point at which forest duff levels are pulverized and susceptible to erosion. As established trails are compacted, managers may prefer to confine trail to existing tracks by altering side conditions, harden the track to minimize erosion, and by educating riders to stay within established track. Wet soils resulted in greater compaction, suggesting that managers may wish to limit access during prolonged wet conditions.” - Implications (pg. 402)

Lathrop, Jason. "Ecological impacts of mountain biking: a critical literature review." *University of Montana, Montana* (2003)

Marion, Jeffrey L., and Yu-Fai Leung. "Environmentally sustainable trail management." In *Environmental Impacts of Ecotourism*, pp. 229-243. Wallingford UK: CABI Publishing, 2004

White, Dave D., M. Troy Waskey, Grant P. Brodehl, and Pamela E. Foti. "A comparative study of impacts to mountain bike trails in five common ecological regions of the Southwestern US." *Journal of Park & Recreation Administration* 24, no. 2 (2006)

“The findings from our study thus reinforce results from previous research that certain impacts to mountain bike trails, especially width, are comparable or less than hiking or multiple-use trails, and significantly less than impacts to equestrian or off-highway vehicle trails. Although our study focused on only two impacts, when combined with the findings of previous studies (Goeft & Alder, 2001; Wilson & Seney, 1994), a consensus seems to be emerging that recreation impacts to mountain bike trails are largely confined to the main tread and mountain biking is likely a sustainable activity on properly managed trails, at least in the environments studied thus far.” - Conclusions (pg. 37)

Marion J, Wimpey J. Environmental impacts of mountain biking: science review and best practices. International Mountain Bicycling Association; 2007

“Trail design and management are much larger factors in environmental degradation than the type or amount of use. Many studies have demonstrated that poorly designed or located trails are the biggest cause of trail impacts. As evidence, consider that use factors (type, amount, and behavior of trail visitors) are generally the same along the length of any given trail, yet there is often substantial variation in tread erosion, width, and muddiness. These impacts are primarily attributable to differences in grade and slope alignment angle, soil type and soil moisture, and type of tread construction, surfacing, and drainage. This suggests that a sustainable trail that is properly designed, constructed, and maintained can support lower-impact uses such as hiking and mountain biking with minimal maintenance or degradation.” - Conclusion (pg. 15)

Callahan, Joshua. Erosion and trail building: A case study of the East Tennessee State University trail system. East Tennessee State University, 2008

“Trail design and construction plays a major role in erosion and sedimentation of a trail system along with natural erosional processes and the trail users themselves. Thus, implementing a plan for maintenance and construction is a requirement for the sustainability of any trail system, including that at East Tennessee State University. The increasing population at ETSU and in surrounding areas is a concern because users will accelerate erosion on a trail if sustainable construction techniques are not followed. Once trail users incise ruts in a trail, the problem of trail erosion is exacerbated because both the users and natural erosional processes like sheet and gully wash during periods of rainfall will accelerate the rate at which gullies are incised. This study was based on the premise that identifying problem areas on the ETSU trail system due to erosion as a result of improper trail construction technique would aid in the decision-making processes of trail maintenance. If the recommendations of this study are followed, the sustainability of the trail system will be improved. Increased user traffic may also be accommodated.” - Conclusion (pg. 70)

Naber, Michael David. Integrating trail condition assessment with recreation demand modeling of mountain bikers in the research triangle, North Carolina. North Carolina State University, 2008

“All recreation activities influence the resources where they take place. This inevitable feature of recreation has direct costs to resource managers. Knowledge about the influence of site environmental attributes may help land managers plan for the best use of the resources managed. Information on the influence of site environmental attribute indices could help resource managers plan trail improvements and address significant impacts like those described in this research (trail erosion, widening, and root exposure).” - Conclusion (pg. 77-78)

Davies, Claire, and David Newsome. "Mountain bike activity in natural areas: impacts, assessment and implications for management: a case study from John Forrest National Park, Western Australia." (2009)

Newsome, David, and Claire Davies. "A case study in estimating the area of informal trail development and associated impacts caused by mountain bike activity in John Forrest National Park, Western Australia." *Journal of ecotourism* 8, no. 3 (2009): 237-253

Olive, Nathaniel D., and Jeffrey L. Marion. "The influence of use-related, environmental, and managerial factors on soil loss from recreational trails." *Journal of environmental management* 90, no. 3 (2009): 1483-1493.

"A complex interplay of factors, both casual and non-causal, has been suggested by previous research as influencing soil erosion on trails. Regression modeling of environmental, managerial, and use related influences revealed that trail position, trail slope alignment angle, grade, water drainage, and type of use are all significantly influential variables in the best trail soil loss model. Improved understanding and insights regarding the relative influence of these variables permits the selection of more effective trail management actions, and can be used to justify difficult decisions or to garner staffing and funding support within land management agencies. For example, these study results suggest that trail erosion can be minimized by avoiding "fall-line" alignments, steep grades, and valley-bottom alignments near streams, by installing and maintaining adequate densities of tread drainage features, applying gravel to harden treads, and by reducing horse and ATV use or restricting them to more resistant routes. Surveys of existing trail alignments can identify segments or trails requiring reroutes with improved alignments. It is important to recognize that some trail segments cannot be maintained to prevent resource degradation and that substantial one-time investment in realignments will be more than compensated by avoiding substantial soil loss and long term savings in repeated, and often unsuccessful, maintenance work." - Conclusion (pg. 1491)

Clement, Stuart. "A longitudinal assessment of impact on two mountain bike trails built to sustainable standards." In *Australian Cycling Conference 2010*, p. 91. (2010)

"In summary, the physical properties (transect profiles and used tread widths) of trails built to IMBA guidelines indicate that for the most part trails can withstand the combination of up to 30 riders per day and 700 mm of rain per annum for at least one year with little impact on the trail surface or the width of the used portion of the trail. Some maintenance is highly likely to be required in those parts of trails that deviate too far from the guidelines." - Conclusions (pg. 106)

Bibliographer's Note: Though from Australia, this study is an important one as it established that a trail built to modern guidelines have lower impacts than trails not built to said guidelines. The study is also important as it uses the concept of transect profiles and measured treadway widths. Both the methods of measuring soil movement (transects & measurements) and comparing trails built to modern guidelines to those that were not, became foundational to how other studies would determine impacts.

Pickering, Catherine Marina, Wendy Hill, David Newsome, and Yu-Fai Leung. "Comparing hiking, mountain biking and horse riding impacts on vegetation and soils in Australia and the United States of America." *Journal of environmental management* 91, no. 3 (2010): 551-562

Biophysical impacts from hiking are better researched than from horse riding and mountain biking. There are impacts in common to all three activities, although differences in the severity of the impact, with horse riding appearing to have greater impacts per user than hiking. For mountain biking it is hard to assess relative impacts as there is little research, particularly using quantitative experimental methods and more realistic riding styles. There are activity specific impacts that can damage the environment, but again further research is required. We hope that this review helps managers, researchers, users and conservation organisations by highlighting what is known, even if a significant finding is, that there is still much more we need to find out. - Conclusions (pg. 557)

Quinn, Michael, and Greg Chernoff. "Mountain biking: a review of the ecological effects." *A Literature Review for Parks Canada–National Office (Visitor Experience Branch)* (2010): 1-38

“Another management concern may be related to designing trails for appropriate use. There are some design practices that make sense for all recreational uses, but others that are more use-specific. We speculate that very few trails in National Parks have been designed specifically with mountain biking and the minimization of associated environmental effects in mind – moreover, the majority of mountain biking currently occurs on old fire roads, hiking, or pack trails. Trail creation, maintenance, modification or access limitation that recognizes the different effects and designs to minimize these effects and promote best practices should be considered (Flickinger 1994). This gives rise to a suite of design-related research questions: If we recognize, for example, that erosional effects are most severe when cyclists climb steep hills and hikers descend steep hills, what reductions to erosion can we expect if we limit hiking to trails with minimal steep descents, and cycling to trails with minimal steep climbs? Can a reduction in environmental effects be achieved by offering (or mandating) best practice education programs for trail users? Do seasonal closures have the potential to reduce environmental effects? Can designing trails with mountain biking in mind (e.g., banking corners, surface treatment, minimizing fall line descents, ensuring proper trail drainage, etc.) tangibly reduce environmental damage? There is potential to use spatially explicit modeling techniques to evaluate the potential benefits of these types of management practices (e.g. Itami et al. 2003).” - Discussion – Research Questions, Management Implications (pg. 25)

Solutions, Stuart Clement, and South Australia. "Gap Creek Circuit Mountain Bike Trail: Long Term Environmental and Use Impacts." (2010).

“Since the position of the transect points was random some were sited on corners, some on straight parts of the trail, some on sloping sections, and some at grade reversals. The number of variables associated with transect point position (eg. on a corner, on a straight etc) coupled with only 20 points for each trail means that grouping to produce meaningful statistical analysis within and between each group is not possible... Ten (50 per cent) of the

twenty transect points did not exhibit any change to the profiles and five (25 percent) showed minor, insignificant change (soil movement) over the course of the study. A further two showed noticeable change (both with soil loss) and the remaining three (fifteen per cent) exhibited significant change (all with soil loss).” - Conclusion (pg. 44)

Pickering, Catherine Marina, Sebastian Rossi, and Agustina Barros. "Assessing the impacts of mountain biking and hiking on subalpine grassland in Australia using an experimental protocol." *Journal of Environmental Management* 92, no. 12 (2011): 3049-3057

Hardiman, Nigel, and Shelley Burgin. "Mountain biking: downhill for the environment or chance to up a gear?." *International journal of environmental studies* 70, no. 6 (2013): 976-986

Kidd, Kathryn R., W. Michael Aust, and Carolyn A. Copenheaver. "Recreational stream crossing effects on sediment delivery and macroinvertebrates in southwestern Virginia, USA." *Environmental management* 54 (2014): 505-516

Ballantyne, Mark, and Catherine Marina Pickering. "The impacts of trail infrastructure on vegetation and soils: Current literature and future directions." *Journal of Environmental Management* 164 (2015): 53-64

“There were several papers from urban and peri-urban natural areas (39%) reflecting both the rapid development of cities and increasing numbers of trail networks in remnant natural vegetation close to cities (Matlack, 1993; Stenhouse, 2004; Ballantyne et al., 2014a). With urban areas occupying at least 3% of the earth's terrestrial surface, remnant natural vegetation close to cities is increasingly important for both conservation and recreation (Swanwick et al., 2003; Florgård and Forsberg, 2006; Tratalos et al., 2007). Trails should be designed and constructed more strategically to balance conservation and recreation in these remnants. With such close proximity to dense human populations, urban natural areas may be particularly prone to the creation of dense informal trail networks (Ballantyne et al., 2014a). Managing this is especially important in order to limit further landscape-scale degradation on what are already ‘at risk’ ecosystems (Leung et al., 2011; Ballantyne et al., 2014a).” - 4.1. Research on trail impacts is geographically limited (pg. 60)

Pickering, Catherine Marina, and Patrick Norman. "Comparing impacts between formal and informal recreational trails." *Journal of Environmental Management* 193 (2017): 270-279

Marion, Jeffrey L., and Jeremy Wimpey. "Assessing the influence of sustainable trail design and maintenance on soil loss." *Journal of Environmental Management* 189 (2017): 46-57

“In summary, this research reveals that trail grade and slope alignment angle appear to have the greatest influence on soil loss from recreational trails. A Trail Sustainability Rating System is offered to trail designers and managers to more clearly guide the development and evaluation of trail sustainability and to illustrate the tradeoffs between these influential factors. In most instances a limited number of trail segments will be identified as “unsustainable” and managers can replace them with alternative reroutes that feature side-hill alignments and low grades. If reroutes are not an option, rockwork, graveling and installing additional drainage features can be effective actions to decrease trail soil loss. While grade reversals are a preferred tread drainage option, measures like out-sloped treads, drainage dips, and water bars can also be effective, though only when frequently maintained. We note that trail segments supporting higher impact uses, such as horses and motorized traffic, require greater adherence to sustainability guidelines, and in particular, can benefit from larger amounts of substrate rock or gravel application.” - Conclusion (pg. 25)

Martin, Ross H. "The Geomorphic Nature of Mountain Bike Impacts on Selected Trail Systems near Austin, Texas." (2017)

“Considering these findings in aggregate suggests a framework for understanding trail condition and morphology. Impacts by mountain bikers, and other user types, are realized differently depending on environmental circumstances. Variations in soil type and texture, vegetation types, and topography result in different trail morphologies. Impacts and alterations of the trail surface can induce secondary geomorphic processes; including overland flow and erosion, and aeolian erosion when dry. Trail surface slope and curvature are an effect of trail building, layout, and planning; a socio-political system. Maintenance and management paradigms impact trail conditions by controlling use rates and which user types are allowed on trails. Impacts by mountain bikers, in particular, do not seem to be greater in scale than impacts imposed by management decisions. This study cannot make a distinction about whether mountain bike impacts are greater than or less than other trail user types, but it does show that trail condition is strongly influenced by both political and environmental factors. This suggests that many degraded trail segments, often blamed on mountain bikers, in reality could be a result of the environmental conditions and the politics surrounding management actions.” - Conclusion (pg. 85)

Martin, Ross H., David R. Butler, and John Klier. "The influence of tire size on bicycle impacts to soil and vegetation." *Journal of Outdoor Recreation and Tourism* 24 (2018): 52-58

“The nature of impacts to vegetation and soil by bicycles and hikers is similar, but the rates at which the impact occurs vary with user type, soil types, vegetation coverage, topography and climate. Bicycle tire width plays an important role in soil compaction. Narrower tires inflated to higher pressures produce greater impact than wider tires with lower inflation pressures, and corresponding contact patch pressure.” Conclusion (pg. 57)

Salesa, D., and A. Cerdà. "Soil erosion on mountain trails as a consequence of recreational activities. A comprehensive review of the scientific literature." *Journal of Environmental Management* 271 (2020): 110990

Stavi, Ilan, and Hezi Yizhaq. "Applying geomorphic principles in the design of mountain biking singletracks: Conceptual analysis and mathematical modeling." *Land* 9, no. 11 (2020): 442

"Mountain biking has become a significant sector of outdoor sport, recreation, and ecotourism activities in many countries. Hence, existing singletracks receive increasing pressures, and new singletracks must be established. This conceptual study demonstrates the need to consider hydrologic and geomorphic principles while planning, establishing, and maintaining singletracks. If singletracks are properly designed, their durability is expected to increase, requiring less maintenance over time. At the same time, poorly designed and unmaintained singletracks may have an adverse impact on geo-ecosystem functioning and sustainability. Here, we demonstrate the geophysical conditions and rider characteristics that landscape designers and land managers should consider when planning nature-based, outdoor recreation opportunities." - Conclusion (pg. 13)

Cherrington, Jim, and Jack Black. "Spectres of nature in the trail building assemblage." *International Journal of the Sociology of Leisure* 3 (2020): 71-93

"Perhaps the most significant conclusion that can be drawn from these findings with regard to leisure in nature is that trail builders do not consciously position themselves as ecological subjects. Yet their praxis reveals that they are already acting ecologically, without the need to identify as such (Morton 2018). By digging, sculpting, lifting and re-purposing non-human 'matter' and working alongside nonhuman organisms (smelly boar and inquisitive deer) the participants are able to tune to the dynamic and effervescent qualities of the symbiotic real. By either enabling (i.e malleable dirt) or constraining (i.e shale-filled dirt) human agency these organisms and materials reveal a variety of human-nonhuman interdependencies that are part of a living, dynamic relation. 'Tuning' to the symbiotic real is continued in the ongoing 'battle' that the trail builders maintain with water. Indeed, in their often futile battle to lessen or 'manage' the effects of water on a trail, the participants are reminded of Nature's destructive power as well as the ambiguous, animate and spectral canvas upon which their trails are rendered and enacted." - Conclusion (pg. 89)

Campbell, Tom, Lewis Kirkwood, Graeme McLean, Mark Torsius, and Geraint Florida-James. "Trail use, motivations, and environmental attitudes of 3780 European mountain bikers: What is sustainable?." *International Journal of Environmental Research and Public Health* 18, no. 24 (2021): 12971

"European mountain bikers care about the sustainability of the natural environment, and their attitudes and self-reported behaviours suggest a willingness to reduce their impact and actively protect nature. In particular, mountain bikers feel a responsibility for maintaining the trail network. There is an opportunity for national governing bodies and

relevant stakeholders to capitalise on this goodwill by establishing mechanisms for mountain bikers to engage with trail maintenance either through monetary support or volunteering with trail associations. Similarly, the possibilities to exploit this financial and social capital towards broader environmental concerns should be explored and may also prove a worthwhile avenue for future research.” - Conclusion (pg. 12-13)

Evju, Marianne, Dagmar Hagen, Mari Jokerud, Siri Lie Olsen, Sofie Kjendlie Selvaag, and Odd Inge Vistad. "Effects of mountain biking versus hiking on trails under different environmental conditions." *Journal of Environmental Management* 278 (2021): 111554

“Our study shows that on-trail use by hikers and mountain bikers have relatively limited effects in terms of trail widening and deepening. However, the effects are variable: where trails cross wet areas, such as mires, bogs or other plant communities with poor drainage, more trail degradation is to be expected with increased use from both hikers and mountain bikers. Our study also demonstrates that higher trail degradation can be expected if a large proportion of the users are mountain bikers, particularly in wet trail parts. Management and maintenance of trails, in terms of re-routing or trail surface hardening, could thus be necessary to avoid negative impacts of increased use. For such management actions to be successful, however, they need to be targeted towards the actual user groups and carried out in accordance with hiking and mountain bike trail standards.” - Conclusion (pg 8)

Hanus, Matthew S. "The Impacts of Mountain Biking on the Underlying Soils at a North East Trail System." (2021)

Martin, Ross H., and David R. Butler. "Trail morphology and impacts to soil induced by a small mountain bike race series." *Journal of Outdoor Recreation and Tourism* 35 (2021): 100390

Dragovich, Deirdre, and Sunil Bajpai. "Managing Tourism and Environment—Trail Erosion, Thresholds of Potential Concern and Limits of Acceptable Change." *Sustainability* 14, no. 7 (2022): 4291

Jula, Mihai, and Mircea Voiculescu. "Assessment of the mean erosion rate using dendrogeomorphological approaches on exposed roots along hiking and biking trails in the Bucegi Mountains, Romanian Carpathians." *Catena* 217 (2022): 106435

“Our study is the first attempt to evaluate trampling and biking erosion process in a mountainous area in Romania. In particular, we evaluated the mean erosion rates caused by tourist activity, using dendrogeomorphological and anatomical indicators for P. abies along two hiking trails and one mountain biking trail for a period of 63 years. The results obtained indicate similar erosion rates caused by two different disturbing agents, i.e., hikers and bikers.”

Stevenson, Leah C., Anja Pabel, Colin MacGregor, Lisa Law, and Jenni A. Judd. "The influence of trail design on the impacts of walkers, mountain bikers and multi-use trail users: An environmentally Responsible Approach." *Journal of Responsible Tourism Management* 2 (2022): 31-54

"In the mountain bike park, outward drainage was used in most sections of the trail, which allows water to shed. These sections of trails had little evidence of water accumulation and no evidence that trail users were riding outside the designated trail area. However, some drains on the multi-use mountain bike trail used inward drainage to allow water into a depression on the inside of the trail before being channelled across to the outside of the track. These inward drains were used in wet sections of the trail that transverse across a hillside. As a result, additional re-enforcing of the outside of the trail was needed, creating a wider 'environmental' footprint. These sections of trail stayed wetter and tyre depressions were evident." - Drainage (pg. 44)

Grapentin, Stephan, Norman Bielig, Anne Heidemüller, and Tilman Sobek. "How Soil, Flora and Fauna React To Mountain Bikers—An Overview of the Current State of Research." (2023)

"However, based on the current state of research, it is not possible to justify the assumption that mountain biking has a larger negative impact compared to other nature sports. Until new, methodologically valid research results are available, the focus should therefore rest on three pillars:

- 1. developing awareness - here, first of all, professional circles as multipliers for respective users should develop a common awareness about the value of natural and recreational areas.*
- 2. creating awareness - is the task of all stakeholders and institutions involved in the exercise and governance.*
- 3. acting consciously - is the result of the two previous tasks and ultimately a call for everyone moving in the natural space.*

The enjoyment of nature as the main motive of mountain biking suggests a high motivation to deal with topics of the natural environment and biodiversity. Initiatives such as the Trail Rules of the German Mountain Bike Initiative or the self-commitment MTB of the alpine associations, information campaigns such as the bike booklet of DAV, MTD, ZIV (2018) and environmental education measures of the natural parks are tried and tested means that still offer a lot of potential for expansion." - Conclusion (pg. 9)

Marion, Jeffrey L. "Trail sustainability: A state-of-knowledge review of trail impacts, influential factors, sustainability ratings, and planning and management guidance." *Journal of Environmental Management* 340 (2023): 117868

"Additional research is needed to expand and evaluate existing trail sustainability evaluation capabilities (Marion and Wimpey, 2017; Marion et al., 2022), and to incorporate additional attributes. Research to expand and refine GIS capabilities to identify and create metrics for comparing alternative sustainable alignments and relocations and tread drainage alternatives is also needed, though there will always remain a critical need for

ground-truthing, field assessments, and collaborations by qualified trail professionals. Increased collaboration between trail scientists and practitioners is needed to identify knowledge gaps and further develop new integrated guidance to better inform management decision-making. Finally, studies that evaluate the efficacy of alternative tread hardening and drainage practices are exceedingly rare, suggesting the need to prioritize their pursuit and funding (Burroughs et al., 2017). The most optimal and sustainable trail design guidance and management decision-making will be achieved by integrating the best available trail science and trail professional knowledge. Towards this end, the existing trail planning, design, and management books can be enhanced by incorporating key findings and guidance from the expanding trail science literature.” - Sustainable Trail Planning and Management (pg. 18-19)

Powers, Steven, Seth Carswell, Shannon Barker, and Renee Lavin Powers. "Impacts of Leaf Removal from Trails on Trail Condition and Erosion." *Journal of Park & Recreation Administration* 41, no. 3 (2023)

Fang, Wei, and Sai-Leung Ng. "Trail degradation caused by mountain biking and hiking: a multi-dimensional analysis." *Journal of environmental management* 351 (2024): 119801

This study fills the knowledge gaps by unveiling the multi-dimensionality of trail degradation and examining the effects of managerial and use-related factors by multivariate statistical techniques. While different managerial and use-related factors affect various degradation dimensions to different degrees, beneficial (“Soil Compaction”, “Recovery Feature”) and negative features (“Trail Morphometry”, “Soil Texture”, “Erosion Feature”) may co-exist in the process of trail degradation. Furthermore, hiking generates “all-around” degradation while the influences of mountain biking mainly concentrate on tread surface; management strategy should be formulated with the consideration of their effect on specific degradation dimensions. This study would benefit both trail professionals and park managers in decision-making and future research. - Conclusions and limitations (pg. 7)

Fauna & Flora

Miller, James R., and N. Thompson Hobbs. "Recreational trails, human activity, and nest predation in lowland riparian areas." *Landscape and Urban Planning* 50, no. 4 (2000): 227-236

“For lowland riparian habitats, decisions on locations for new trails should be based on available information regarding the habitat requirements of sensitive species. In the absence of such information, we offer a few general guidelines that also apply to established trails. To minimize adverse impacts on wildlife, trails should be located on one side of the stream only and human activity should be restricted to a well-defined corridor. Fences will help to accomplish the latter and there are designs (e.g., split-rail) that do not seem wholly out of place in semi-natural areas. It is also crucial that dogs be prohibited from ranging freely. The rationale underlying various restrictions should be made clear to

the public via signs at entry points in the hope that greater understanding will foster greater cooperation. Periodic wildlife surveys are highly desirable in order to detect adverse impacts over time and the ability to interpret survey data is greatly enhanced if parallel studies are also conducted in riparian areas kept free of human activities. Such monitoring, in conjunction with more rigorous scientific investigations, will better enable us to assess the compatibility of recreation and nature conservation in greenways, and ultimately to devise more effective strategies for maintaining native species in human dominated areas.”
- Discussion (pg. 223)

George, Shalene L., and Kevin R. Crooks. "Recreation and large mammal activity in an urban nature reserve." *Biological Conservation* 133, no. 1 (2006): 107-117

“Research on urban deer typically has focused on topics such as space use (Kilpatrick and Spohr, 2000), movement patterns (Grund et al., 2002), human conflicts (McCullough et al., 1997; Wagner et al., 1997), and responses to hunting pressures (Kilpatrick and Lima, 1999), but fewer studies have investigated possible recreational impacts on urban deer populations. Mule deer are known to behaviorally respond to human recreationists, including both mountain bikers and hikers (Taylor and Knight, 2003) but more so to pedestrians than to motorized vehicles (Freddy et al., 1986), and particularly during daylight compared to evening hours (Altmann, 1958; Taylor and Knight, 2003) or when a dog was present (Miller et al., 2001). Although we did not find a clear and consistent pattern of avoidance of human recreation by deer, the probability of detecting deer during the day was lower with increasing levels of human recreation.” - Discussion (pg. 113-115)

Reed, Sarah E., and Adina M. Merenlender. "Quiet, nonconsumptive recreation reduces protected area effectiveness." *Conservation Letters* 1, no. 3 (2008): 146-154

“A variety of management strategies have been proposed to minimize the impacts of recreation on wildlife, such as limiting the number of visitors via a permit system (Garber & Burger 1995), restricting public access to certain times of the year (Klein et al. 1995), or closing a portion of a protected area to recreation and setting it aside as a biological preserve (Ikuta & Blumstein 2003). However, recreation impacts vary nonlinearly with use in a variety of ecosystems (for example, Cole 1986), such that a small number of visitors can have a disproportionate impact on sensitive species. In addition, many public agencies have limited resources for monitoring recreational use and enforcing compliance with management policies (Forrest & St. Clair 2006). These limitations suggest that it may be more effective to allocate recreational uses and conservation targets among different sites, and this approach will require a diverse suite of land conservation strategies.” - Discussion (pg. 153)

Davis, Craig A., David M. Leslie Jr, W. David Walter, and Allen E. Graber. "Mountain biking trail use affects reproductive success of nesting Golden-cheeked Warblers." *The Wilson Journal of Ornithology* 122, no. 3 (2010): 465-474

“The direct impact of mountain biking on Golden-cheeked Warblers may be minimal, but

the indirect impact from fragmentation and alteration of habitats from mountain bike trails may reduce the quality of nesting habitat for Golden-cheeked Warblers. In particular, Golden-cheeked Warblers nesting in habitats fragmented and altered by mountain biking trails may be more vulnerable to nest predation (Reidy et al. 2009) and possibly encounter lower prey abundance (Jokimaki et al. 1998, Kilgo 2005). Conservation efforts that curtail construction of new mountain biking trails in Golden-cheeked Warbler habitat and reduce the amount of forest open edge habitat created by existing mountain biking trails should promote recovery objectives.” - Discussion (pg. 472)

Bibliographer's Note: One of the most quoted studies regarding impacts to animals by mountain bikes by those attempting to suggest outsized impact to animals from mountain bikes versus hikers. However, this study's context should be fully explained. Land managers in central Texas, in particular at Fort Hood Military Reservation and Travis County, where green-lighting trails within the range of the golden-cheeked warbler, and endangered species, without doing the required impact studies beforehand. Making that oversight worse, the land managers and builders of the trails were not following nationally recognized trail-to-area ratios. The result was a haphazard, too dense, trail network within lands used by the golden-cheeked warbler as habitat. A Biological Opinion issued by the U.S. Fish and Wildlife Service, as part of the Balcones Canyonlands Conservation Plan, recommended removing existing trails as well as preventing the addition of more trails. This was a controversial opinion, especially among current trail users who felt disappointed in losing trails they had worked hard on. This study was then commissioned to provide a scientific basis for those decisions. This foregoing history explains why this study states both there was a definite impact to golden-cheeked warblers by mountain bikes and that mountain bikes had a minimal impact, two seemingly different opinions. The mountain bike impacts, as noted in the report, were very minor by themselves. But the far too dense trail network magnified those impacts in an exponential way, as it states in the conclusion, quoted above. It should be noted here that this habitat fragmentation as a result of trails and human interaction is why the trail-to-area ratios exist. However, the synopsis of this report is often quoted by aforementioned persons or groups seeking to claim large fauna impacts by mountain bikes. The issue there is that the synopsis text removes all the historical and specific context and instead implies a direct, large, impact to golden-cheek warblers by mountain bikes, something the full study does not do. Without understanding the context of this specific study, one could draw an incomplete conclusion. This contextually inadequate synopsis is regularly used in a misleading way as “proof” of impacts of mountain bikes to birds or other animals.

Barber, Jesse R., Chris L. Burdett, Sarah E. Reed, Katy A. Warner, Charlotte Formichella, Kevin R. Crooks, Dave M. Theobald, and Kurt M. Fristrup.

"Anthropogenic noise exposure in protected natural areas: estimating the scale of ecological consequences." *Landscape Ecology* 26 (2011): 1281-1295

“While landscape scale investigations of noise pollution are urgently needed, soundscape ecology must continue to simultaneously operate at small scales to determine the mechanisms through which noise exerts its ecological effects. It is clear that masking

is a significant problem in elevated background sound levels (Barber et al. 2010) and continued research on hearing abilities in noise (e.g., critical ratios and upward spread of masking) is important. However, other forces besides masking appear to also play dominant roles. The finding that played back intermittent road noise elicits a much stronger avoidance reaction in sage grouse than continuous oil drilling noise (a better masking stimulus) is compelling evidence that other factors, such as stress, are critically important (Blickley et al. 2011). Furthermore, attentional and informational masking effects (Kidd et al. 2008) can impact information transfer even when classical masking paradigms do not apply (e.g., Chan et al. 2010).” - Conclusion (pg. 1293)

Lowney, Anthony. "Impact of mountain bike trails on red squirrel population (*Sciurus vulgaris*) in Whinlatter Forest, Cumbria." *Bioscience Horizons* 4, no. 1 (2011): 99-107

This study provides evidence that suggest red squirrel populations within WFP have increased since the construction and opening of the mountain bike trails. Data confirms that squirrels are not evenly distributed throughout WFP. However, the causes leading to this distribution may or may not be influenced by the presence and use of the mountain bike trails. Although red squirrel densities are much lower on and around the bike trails it is believed that the principal determinant for squirrel abundance is habitat type... Red squirrels were recorded at higher densities within larch and Douglas fir habitats. Larch is one of the few habitat types where red squirrels outcompete grey squirrels,³³ and although no evidence was recorded to suggest that mountain bike trails have a negative impact on red squirrel populations further alteration to these habitats should be discouraged. Future management practice should encourage trail users to remain upon the mountain bike trails as this will encourage habituation... This study does not provide evidence that mountain bike trails negatively affect red squirrel populations.” - Conclusion (pg. 106)

Nemec, Kristine T., Craig R. Allen, Aaron Alai, Greg Clements, Andrew C. Kessler, Travis Kinsell, Annabel Major, and Bruce J. Stephen. "Woody invasions of urban trails and the changing face of urban forests in the Great Plains, USA." *The American Midland Naturalist* 165, no. 2 (2011): 241-256

“Because urban areas receive more intentional and accidental introductions than areas with less human influence, they are particularly vulnerable to invasions by non-native plant species (Kowarik, 1995). Non-native woody plant species, including those recorded in this study, can impact ecosystem processes and community structure in forests by altering nutrient cycling, increasing litter decomposition rates, reducing the abundance of native plant species and reducing nest success (Schmidt and Whelan, 1999; Borgmann and Rodewald, 2004; Knight et al., 2007). Therefore land managers should strive to reduce the abundance of non-native species in urban forests if they want to maintain a high biodiversity of native species (Dearborn and Kark, 2010). Landscaping is one major pathway for the spread of non-native plant species in urban areas (Allen et al., 2006) and the public should be educated about the negative impacts of non-native species (Reichard and White, 2001). In addition, volunteer groups could be used to remove non-native species that are observed growing along urban trails. The City of Lincoln has used

volunteer groups in the past for cutting buckthorn growing in natural areas (T. Genrich, City of Lincoln, pers.comm.) and could use the same approach for removing non-native vegetation along trails. Although labor intensive, removing individual plants of non-native species before they have become abundant and have caused major changes to the local ecosystem offers the best chances for preserving biodiversity in the long run (Zavaleta et al., 2001; Webster et al., 2006). Complete eradication is likely unrealistic, particularly if the trails serve as corridors for the dispersal of non-native propagules, and repeated removal efforts may be needed to reduce the regeneration of non-native species (D'Antonio and Meyerson, 2002; Vidra et al., 2007; Heneghan et al., 2009). Because removal of non-native species often disturbs the soil and encourages the growth of non-native species adapted to disturbance, native species should be planted to replace any plants that are removed (D'Antonio and Meyerson, 2002; Vidra et al., 2007; McGlone et al., 2009). Replanting may reduce the need for subsequent non-native species removal as the native species occupy space and use resources, making invasion by other species more difficult (Shea and Chesson, 2002).” - Conclusion (pg. 250-252)

Pankiw, Nicholas Alexander. "Recreational trail impacts and their spatial influence on species diversity and composition." Master's thesis, Ryerson University, Toronto, Ontario (2011)

“Lastly, multiple regression analysis revealed that managers can mitigate changes to species composition by choosing routes with high side-slopes and also by avoiding areas with south facing aspects. Such measures may prevent the establishment of exotic species in trail edges and physically prevent users from trampling off the trail tread. In contrast, trail characteristics such as trail depth and trail width were found to not directly influence species diversity. While actions taken to mitigate the latter may be an effective solution for sustaining trail tread and preventing erosion, both trail characteristics likely have little influence on the composition and the preservation of indigenous species... Overall, species diversity in trail-influenced environments is likely to be significantly reduced as there are typically fewer species tolerant of trail-related impacts compared to original occupants. This may explain why diversity was not higher in trail-influenced environments as expected based on the Intermediate Disturbance Hypothesis. In light of this, creating dual purpose areas which provide recreational opportunities and are charged with conserving species diversity will likely not achieve the latter. If conserving species diversity is of utmost concern, managers should consider either closing trails or concentrating their use since spatial impacts are large and changes to composition are inevitable.” - Conclusion (pg. 120-121)

Steven, Rochelle, Catherine Pickering, and J. Guy Castley. "A review of the impacts of nature based recreation on birds." Journal of Environmental Management 92, no. 10 (2011): 2287-2294

“For managers of protected areas and other nature based recreation destinations the most important results of this review is that even relatively ‘low’ impact activities such as walking or hiking where visitors do not deliberately disturb animals can have negative effects on birds ranging from changes in physiology to reduced reproductive success. Therefore, when zoning, providing facilities, and managing the use of facilities, they need to take into

account the source, range and intensity of potential impacts and methods to manage these impacts (Hill et al., 1997) that address short and long term responses (Steidl and Powell, 2006). As such managers may need to reduce the use of some areas all the time or at critical times such as nesting and fledging, limit the number of users to small groups, and/or limit the types of activities particularly those that are likely to have greater impacts such as dog walking (Buckley, 2004).” - Management Implications (pg. 2291)

Burgin, Shelley, and Nigel Hardiman. "Is the evolving sport of mountain biking compatible with fauna conservation in national parks?" *Australian Zoologist* 36, no. 2 (2012): 201-208

Kenny, Colleen. "The effects of recreation and disturbance on the invasibility of forest interiors." PhD diss., University of New Hampshire, 2014

Goad, Erica H., Liba Pejchar, Sarah E. Reed, and Richard L. Knight. "Habitat use by mammals varies along an exurban development gradient in northern Colorado." *Biological Conservation* 176 (2014): 172-182

Rodríguez-Prieto, Iñaki, Victoria J. Bennett, Patrick A. Zollner, Mike Mycroft, Mike List, and Esteban Fernández-Juricic. "Simulating the responses of forest bird species to multi-use recreational trails." *Landscape and Urban Planning* 127 (2014): 164-172

“Our study highlights the importance of considering multispecies or wildlife communities when devising management strategies and designs for a site. We found that different species varied in their sensitivity to recreation and this sensitivity was not necessarily correlated with their conservation status (i.e., the most threatened species was not the most sensitive). Thus, we caution that implementing management strategies and site designs based on a single high profile species could have far-reaching implications for the survival and breeding success of other species within the local community. Identifying and comparing differences between individual species and populations within a wildlife community can therefore provide valuable insights in how we can devise more resilient long-term strategies that aim to preserve biodiversity (McIntire, Schultz, & Crone, 2007). This approach supports conservation practitioners’ objectives to not only conserve species of concern, but also local biodiversity (McLane et al., 2011).” - Conclusion (pg. 170)

Van Winkle, Jill Elise. "Informal trails and the spread of invasive species in urban natural areas: spatial analysis of informal trails and their effects on understory plant communities in Forest Park, Portland, Oregon." PhD diss., Portland State University, 2014

“We found that trailheads and trails both alter native plant communities. Trailheads represent the first point of contact between visitors and wildlands. Though our results suggest trailheads are not significantly more invaded than adjacent sites without

trailheads, trailheads are heavily invaded, and management should focus on trailheads as locations from which introductions of new plant species can spread along trail corridors to the backcountry. The greater number and cover of alien plants along trails than in the adjacent vegetation suggest that trails are indeed corridors along which alien plants move. Furthermore, the apparent success of alien plants that disperse along trail corridors depends upon vegetation type. Control of alien plants should consider the potential impact of trailheads, where there are large numbers of aliens, and efforts to minimize or mitigate invasion along trails may be most effective if focused on the most invaded vegetation types.” - Conclusion (pg. 517)

Fariás, Torbidoni. "Minimization of environmental impacts at sports events in the countryside: mountain bike competitions." *Apunts. Educació Física i Esports* 122 (2015): 68-80 (Spanish)

Ansong, Michael, and Catherine Pickering. "The effects of seed traits and fabric type on the retention of seed on different types of clothing." *Basic and Applied Ecology* 17, no. 6 (2016): 516-526

“The results presented here highlight how seed from a range of weeds can remain attached to clothing despite shaking, and hence have the potential to be dispersed over long distances by walkers. As mammals, including humans, often move long distances, epizoochory, particularly when humans are involved, may be more important than is generally recognized in biological invasions. Epizoochory, for instance, may play an important role in meta-population dynamics as well as in the spatial distribution of seed at a small scale (Auffret & Cousins, 2013a) and hence could affect species success in a rapidly changing climate.” - Conclusion (pg. 10)

Larson, Courtney L., Sarah E. Reed, Adina M. Merenlender, and Kevin R. Crooks. "Effects of recreation on animals revealed as widespread through a global systematic review." *PloS one* 11, no. 12 (2016): e0167259

Pickering, Catherine, Michael Ansong, and Erin Wallace. "Experimental assessment of weed seed attaching to a mountain bike and horse under dry conditions." *Journal of outdoor recreation and tourism* 15 (2016): 66-70

“Similar factors are likely to affect seed dispersal from mountain bikes: that is seed loads could vary among different parts of bike, with the weather conditions during the ride including if conditions are wet, with where the bike was ridden, including on or offtracks. It is also likely that most seed would be dispersed over short distances by bikes, but some seed may be dispersed over long distances, either falling off, being brushed off, or being deliberately removed along the way from where it originally attached to the bike. However, it is also possible to ride bikes short distances in dry conditions through areas with weed seedling without collecting any seed on the bike, as occurred for one replicate mountain bike transect in the experiment.” - Conclusion (pg. 69)

Weiss, Fabio, Tyler J. Brummer, and Gesine Pufal. "Mountain bikes as seed dispersers and their potential socio-ecological consequences." *Journal of Environmental Management* 181 (2016): 326-332

Hardiman, Nigel, Kristina Charlotte Dietz, Ian Bride, and Louis Passfield. "Pilot testing of a sampling methodology for assessing seed attachment propensity and transport rate in a soil matrix carried on boot soles and bike tires." *Environmental Management* 59 (2017): 68-76

"Secondly, although our use of the circular test track allowed us to simulate a realistic walking and riding pattern and beads were available for attachment from on top of/ within shallow surface soil, similar to conditions likely to be the case in a natural environment, the methodology employed in the "long" (~150 m) test distance, necessitating repeatedly walking/riding the same track, meant that some beads might have become attached, detached and subsequently reattached on boot soles and bike tires. Although we were unable to quantify this, we regularly observed soil dropping back onto the track from both boots and bike tires during circuits. This was especially marked for the bike under "wet" conditions, with soil (possibly containing beads) picked up on the tires often unable to pass through the caliper brake pads and subsequently ejected back onto the track. This issue was probably less likely to occur for boot soles because, as previously noted, boots predominantly tended to pick up soil and beads in the heel treads, with soil tightly compacted and requiring beads to be physically extracted by the researchers, with very few beads (estimated <5 %) attaching to the remainder of the soles." - Caveats and Conclusion (pg. 74)

Reilly, M. L., Mathias W. Tobler, D. L. Sonderegger, and P. Beier. "Spatial and temporal response of wildlife to recreational activities in the San Francisco Bay ecoregion." *Biological Conservation* 207 (2017): 117-126

"One of the greatest threats to conservation is a decline in public support due to less engagement in outdoor recreation (Zaradic et al., 2009). One's experience with nature influences one's willingness to financially support conservation (Zaradic et al., 2009). Many conservation plans view management as balancing the losses and gains of species as an implicit part of managing biodiversity (Zipkin et al., 2010). Outdoor recreation has numerous benefits including those for human health and the economy (Reed et al., 2014) and influences support for land and wildlife conservation (Zaradic et al., 2009). Research suggests that people who engage in hiking and backpacking contribute roughly \$200–\$300 annually to conservation (Zaradic et al., 2009). Thus, limiting access of these groups to protected areas could negatively impact conservation. Of the species included in our analyses, none are categorized as sensitive, threatened, or endangered. It is therefore our stance that the impacts are small in relation to the multiple gains such as human health benefits and continued political and financial support for land and species conservation." - Conclusion (pg. 9)

Rew, Lisa J., Tyler J. Brummer, Fredric W. Pollnac, Christian D. Larson, Kimberley T. Taylor, Mark L. Taper, Joseph D. Fleming, and Harold E. Balbach. "Hitching a ride:

seed accrual rates on different types of vehicles." *Journal of Environmental Management* 206 (2018): 547-555

"Plant propagules accrue indiscriminately on all vehicles types. These results support the long-held paradigm of vehicles as seed dispersal vectors. Therefore, as universal plant dispersal vectors, vehicles provide a potential risk for new invasions or, conversely, a conservation technique for native species in exceptional situations. Seed accrual is affected by environmental factors (driving surface, surface conditions, and season), thus mitigating seed accrual and subsequent dispersal should vary temporally and spatially according to conditions. Finally, portable vehicle wash units are effective in the removal of soil and seed waste from dirty vehicles, provided the wash is of sufficient length (>6-9 min), very muddy vehicles will need longer washes. Similar to the watercraft interception programs, we recommend that non-native plant interception programs be employed during high risk times, in high risk areas, on high risk vehicles: consequently, vehicle wash units should be employed during wet times of year or after storms, especially when plants are shedding seeds, and near activities with high levels of soil disturbance (e.g. during wildfire control operations, utility installation) and surrounding areas of conservation interest (e.g. National Parks), and washing should focus on vehicles that have recently driven great distances, on unpaved surfaces, or off-road." - Conclusions (pg. 554)

Grooms, Bennett P., and Rachael E. Urbanek. "Exploring the effects of non-consumptive recreation, trail use, and environmental factors on state park avian biodiversity." *Journal of Environmental Management* 227 (2018): 55-61

Patten, Michael A., and Jutta C. Burger. "Reserves as double-edged sword: Avoidance behavior in an urban-adjacent wildland." *Biological Conservation* 218 (2018): 233-239

"Our study supports the hypothesis that human presence triggers avoidance by wildlife, which ultimately lends support to the hypothesis that human disturbance can act as a kind of "predation" by reducing animal occurrence (Fig. 5; Beale and Monaghan, 2004). Nevertheless, with appropriate management avoidance behavior may be minimized because knowledge of this negative relationship can guide management decisions related to human access during sensitive periods for wildlife, such as during breeding season and when food and water resources may be limiting. Daily access was restricted on virtually all of the protected area during our study, yet human presence nevertheless led to measurable avoidance behavior across seven species or large to medium sized mammal species, with expected joint probabilities under an assumption of independence met at a mere three of fifty cameras. Locally, guidelines for managed-access areas have been adjusted to cluster or zone human activities, to limit nighttime activity and the number of high-use days in sensitive areas, to enact and enforce rest periods immediately after high-use days, and to set recommended maxima for visitor numbers per day. New measures will require a balance of wildlife needs with recreational demands because human use of wildlands is essential to bolster or foster appreciation of wildlands, particularly in urbanized regions. In short, effective management of human access over time is essential to sustain natural communities and wildlife dynamics and to provide high quality visitor experiences on these lands in perpetuity." - Discussion (pg. 239)

Thomas, Sarah L., and Sarah E. Reed. "Entrenched ties between outdoor recreation and conservation pose challenges for sustainable land management." *Environmental Research Letters* 14, no. 11 (2019): 115009

"Both recreation and conservation are valid and valuable objectives for western public lands and open spaces. But that does not mean that they always need to be achieved in the same places. Instead, we recommend that recreation and conservation objectives be balanced across reserves in a network of protected areas. Biologists and ecologists can support recreation planning processes through the application of conservation planning principles (Ban et al 2013). Decisions to designate public access should take into account not only the characteristics and benefits of the individual site, but also that site's value in relation to the agency's broader objectives, overall portfolio of protected lands, and other planned acquisitions. There are several good models of local agencies' adoption of a conservation planning process to achieve multiple objectives in a reserve network. For example, the Sonoma County Agricultural Preservation and Open Space District adopted an acquisition plan that prioritized protection efforts in four distinct categories: farms and ranches, greenbelts, natural areas, and recreation (SCAPOS 2006). In some regions, achieving an integrated vision that balances recreation and conservation objectives may require cooperation among multiple jurisdictions." - Conclusion (pg. 6)

Smith, Kyle, and Tineke Kraaij. "Research note: Trail runners as agents of alien plant introduction into protected areas." *Journal of Outdoor Recreation and Tourism* 31 (2020): 100315

Marion, Solene, Althea Davies, Urška Demšar, R. Justin Irvine, Philip A. Stephens, and Jed Long. "A systematic review of methods for studying the impacts of outdoor recreation on terrestrial wildlife." *Global Ecology and Conservation* 22 (2020): e00917

"We conducted a systematic review of the literature on studying human-wildlife interactions, in the context of non-consumptive outdoor recreation, focusing specifically on terrestrial wildlife. Our study found a wide range of methods which can be used to study the interaction between terrestrial wildlife and outdoor recreation, and we identified the strengths and limitations of the various methods. We identified temporal patterns in the use of different methods over the past 40 years. Direct observation methods were most commonly used but, increasingly, telemetry and camera traps are being used, reflecting the uptake of modern technologies. Based on our findings, we propose a set of five criteria for researchers to consider when designing studies aiming to capture human disturbance of wildlife from outdoor recreation. Our review and the five criteria we have developed can be used to help researchers to implement good scientific practice when studying how outdoor recreation influences wildlife. We recommend that, in future, greater emphasis is placed on how to capture the human component of this interaction, considering both short- and long-term effects of disturbance on wildlife." - Conclusion (pg. 13)

Miller, Anna B., Roland Kays, and Yu-Fai Leung. "Wildlife response to recreational trail building: An experimental method and Appalachian case study." *Journal for Nature Conservation* 56 (2020): 125815

"The results of our case study on the impacts of trail building on the terrestrial wildlife community support the coexistence of recreation and wildlife in ecosystems similar to our study site. Alterations in both population-level and community-level effects were strongest in the trail building phase, returning to near pre-building levels after the trail was complete. The largest exceptions to this pattern were in the slightly decreased species richness in the near trail zone and the decreased site use by eastern gray squirrel in the on-trail zone after trail building. Although the trail might result in habitat reduction for gray squirrels, this species is a habitat generalist and will likely find other suitable habitat nearby. Alternatively, if leeringness of humans is the driving factor for the reduced presence of gray squirrel near the trail site, we expect that the species will become habituated to human presence and their presence will return to pre-building levels. Likewise, if other species become habituated to the presence of the trail and the recreational activity that it brings, species richness in the near-trail zone will likely return to pre-trail levels." - Implications (pg. 108)

Carvalho, Ana Vitória Ribeiro Dias Feliciano de. "Impact of recreational trails in flora distribution and composition: study case in Brijuni National Park, Croatia." PhD diss., 2021

*"This study was done with the purpose of understanding if recreational trails have any associated impacts on their surrounding flora distribution and composition, as well in the prevalence of generalist species, since several literature and scientific studies seem to be finding a relation between these two factors. A study case was proposed to BNP. Results of this study indicate that trails in BNP are in average good state condition, which by itself affects their usage and their surrounding areas, but not significantly since these do not show a higher status of degradation and poor conditions. Conclusion proved by the assessment of flora distribution and composition around recreational trails, that are, by their evaluation, not substantially affected by trails in BNP. Nonetheless, trail areas with higher degraded status do seem to be preferable to generalist species, especially problematic individuals such as *Scolymus hispanicus*. Culminating to the conclusion that, trails in BNP are not highly affecting their surrounding vegetation, however degradation of trails and poor conditions are observed. Further care and management should be evaluated in BNP trails, to assure good to a very good condition of trails and consequently ecological conditions for flora and all beings in the park, following in this way the purpose of IUCN Protected Areas, and maintaining a magical piece of land and biodiversity, for these as to the upcoming generations to enjoy."* - Conclusions (pg. 49)

Dertien, Jeremy S., Courtney L. Larson, and Sarah E. Reed. "Recreation effects on wildlife: A review of potential quantitative thresholds." *Nature Conservation* 44 (2021): 51-68

"There were few examples of recreation infrastructure thresholds, beyond those describing distance to trail. Despite the small sample size, the findings were consistent: infrastructure, even at low densities, can be a contributing factor to altering the habitat use of birds and

mammals (Braunisch et al. 2011; Harris et al. 2014; Richard and Côté 2016). At a regional scale, recreation infrastructure can also further exacerbate underlying human-wildlife conflicts (Ménard et al. 2014) and fragment habitats (Whittington et al. 2005). Better understanding of how the density and effect distance of buildings and trails influences the behavior and survival of wildlife species is paramount for the creation of informed regulatory guidelines.” - Discussion (pg. 62-63)

Erfanian, Mohammad Bagher, Juha M. Alatalo, and Hamid Ejtehadi. "Severe vegetation degradation associated with different disturbance types in a poorly managed urban recreation destination in Iran." *Scientific Reports* 11, no. 1 (2021): 19695 (original in Farsi; translated into English by authors)

“This study is the first to examine the impacts of recreational disturbances on plant communities in a part of the Khorassan-Kopet Dagh floristic province, in the Irano-Anatolian biodiversity hotspot. The results showed that different recreation-related disturbances (hiking trails, campsites, dirt roads) have negative impacts on the (semi-)natural vegetation in the area. The results also revealed the importance of considering phylogenetic diversity when assessing the impacts of recreation activities on plant communities. The main impacts identified here should be targeted in future monitoring and protection programs for Khorshid Park. Other recreation destinations in Mashhad city and throughout Iran should be monitored and managed.” - Conclusions (pg. 7)

Lewis, Jesse S., Susan Spaulding, Heather Swanson, William Keeley, Ashley R. Gramza, Sue VandeWoude, and Kevin R. Crooks. "Human activity influences wildlife populations and activity patterns: implications for spatial and temporal refuges." *Ecosphere* 12, no. 5 (2021): e03487

“The effects of human disturbance and recreation on wildlife activity patterns and populations vary across studies and regions, which can be related to a suite of landscape and wildlife characteristics (Gaynor et al. 2018, Larson et al. 2019). Although our study demonstrated that some wildlife species are influenced by human recreation, there are several considerations when interpreting our results. First, we did not evaluate how different age and sex classes of wildlife were affected by human recreation (Ladle et al. 2019). Some animals might exhibit bolder or more native behavior (e.g., younger animals and males), whereas other animals might be more wary of human disturbance (e.g., adult females, especially with offspring) (Knight and Gutzwiller 1995). Second, wildlife might exhibit different responses to recreation depending upon the type of activity (e.g., motorized recreation, hiking, biking), which is an important consideration for understanding the effects of recreation on wildlife and creating management plans for recreation areas (Knight and Gutzwiller 1995, Larson et al. 2019). Third, wildlife might exhibit different responses to recreation across regional biomes (e.g., dense forested areas vs. open woodlands) and degrees of habituation to people (Knight and Gutzwiller 1995, Kays et al. 2017), which we were unable to evaluate in this study. Fourth, when comparing wildlife activity on game vs. human trails, we assumed that wildlife occurring on game trails exhibited “natural” activity patterns. However, on both game and human trails wildlife could be influenced by additional human and environmental factors (Larson et al. 2019, Suraci et al. 2019). Although plant productivity as measured by NDVI generally had little

effect on wildlife use relative to human recreation, wildlife distributions and activity could be affected by additional biotic and abiotic characteristics. Lastly, we focused on three key metrics of how recreation affects wildlife populations: avoidance of an area, relative use of an area, and altering daily activity patterns. There are, however, other important factors to consider, which we were unable to evaluate with wildlife cameras, such as animal flight response and distance, energy expenditure, physiological response, reproductive success, and fitness (Papouchis et al. 2001, Stankowich 2008, Naylor et al. 2009, Steven et al. 2011, Spaul and Heath 2016).” - Discussion (pg. 12-13)

Ouboter, Dimitri A., Vanessa S. Kadosoe, and Paul E. Ouboter. "Impact of ecotourism on abundance, diversity and activity patterns of medium-large terrestrial mammals at Brownsberg Nature Park, Suriname." PLoS One 16, no. 6 (2021): e0250390

*“Considering the negative impacts of hikers and traffic on the mammal community, especially at certain busy sites, managing authorities might consider applying measures to reduce these impacts. Traffic has had the most impact on the road coming up the mountain and continuing to the lodging facilities, while hikers had the most impact on the trails going to the nearest waterfalls (Leo/Irene Falls) and viewpoint (Mazaroni Top). **Based on the evaluation of the extent and magnitude of tourist presence in the different areas, the following management measures can be proposed to minimize the pressure on wildlife: 1) limiting the total number of tourists to the park per visitation; 2) diverting tourists as much as possible to other trails; 3) limiting access to the park for private vehicles; 4) limiting the access to the park for vehicles beyond the reception of the park; 5. Creating activities at the lodges to divert pressure from the trails (e.g. educational activities, cultural performances, etc.). Measures 1 and 3 may be quite difficult to implement and may have serious financial consequences for the managing authority STINASU. Diverting tourists to other trails to relieve pressure on the busiest ones (measure 2) can also have dubious effects since this will only increase the area that will ultimately be exposed. Measure 4, limiting access for vehicles beyond the reception, could easily be implemented, and would drastically diminish disturbance at the southern part of the park. However, this would not differ for the busiest areas. Measure 5 could possibly relieve a little bit of pressure on the most impacted trails.” - Discussion (pg. 17)***

Wu, Chung-Chi, Cheng-Wei Li, and Wei-Ching Wang. "Low-impact hiking in natural areas: A study of nature park hikers' negative impacts and on-site leave-no-trace educational program in Taiwan." Environmental Impact Assessment Review 87 (2021): 106544

Machowicz, Anna, Carmen Vanbianchi, and Rebecca Windell. 2022. Review of Recreation and Wildlife in Washington: Considerations for Conservation . Winthrop, WA: Home Range Wildlife Research. www.homerange.org.

Pickering, Catherine. "Mountain bike riding and hiking can contribute to the dispersal of weed seeds." *Journal of Environmental Management* 319 (2022): 115693

Aziz, Naeem, Marion A. Holmes, Leland D. Bennion, Rachel A. Reeb, and Sara E. Kuebbing. "Hiking trailheads, but not trailsides, associated with higher cover of non-native plants' trail impact on non-native plant cover." *Applied Vegetation Science* 26, no. 1 (2023): e12716

Kuwaczka, Lukas F., Veronika Mitterwallner, Volker Audorff, and Manuel J. Steinbauer. "Ecological impacts of (electrically assisted) mountain biking." *Global Ecology and Conservation* (2023): e02475.

"The complexity and dynamics of ecosystems used by humans for recreational activities requires large amounts of data and adequate analyses for the identification of underlying patterns. And yet, habituation effects of wildlife will only be captured by before vs after disturbance comparisons. Areas without human influence however, are scarce. Most of the forest and mountain systems are largely influenced by diverse human activities since centuries, particularly in Europe, making it impossible to exclude other influential factors on wildlife activity patterns such as hunting, forestry, agriculture or infrastructure. In addition, every debate regarding the interactions between (e)MTBiking and the environment needs to differentiate between observable impacts and their evaluation, which could be positive and negative and likely differs between stakeholders." - Conclusion (pg. 16)

Chisholm, Trinitas, and J. L. McCune. "Vegetation type and trail use interact to affect the magnitude and extent of recreational trail impacts on plant communities." *Journal of Environmental Management* 351 (2024): 119817

Hydrology

Hilyer, Tyler, Ross H. Martin, and Falynn Turley. "Comparing hydrologic impacts on recreational trails to remotely sensed data." *Remote Sensing Applications: Society and Environment* 32 (2023): 101052

Particulate Pollution

Forster, Nicola A., Susan C. Wilson, and Matthew K. Tighe. "Microplastic pollution on hiking and running trails in Australian protected environments." *Science of The Total Environment* 874 (2023): 162473

"This study provides the first report of MPs on trails in protected and conservation areas. Our results show MP pollution may be present in trafficked and remote sections of

protected environments due to local and diffuse deposition. A wide range of MPs were detected on trail surfaces and in the atmospheric fallout, with the majority being PET, PA, PU, and PS. Microplastic occurrence varied between and within the study areas, and visitation rates, trail characteristics and climactic conditions were identified as key factors influencing MP deposition and transport. Long-term, microplastic pollution is likely to be higher on flat surfaces with vegetation or surface roughness, where microplastic movement is restricted.” - Conclusion (pg. 9)

Social & Usage

Pickering, Catherine, J. Guy Castley, Wendy Hill, and David Newsome.

"Environmental, safety and management issues of unauthorised trail technical features for mountain bicycling." *Landscape and urban planning* 97, no. 1 (2010): 58-67

“The construction and use of unauthorised trail technical features by mountain bikers has clear environmental, safety and management issues, while operating within an as yet unquantified social setting. In recent years there has been an expansion of sporting activities, such as mountain biking, taking place in natural areas and especially those in the peri-urban setting. Such users have specific requirements and it would appear that they do not always have a responsible attitude towards environmental integrity. The solution of what to do, however, is not always obvious and will vary with the environment, location of a site, who is responsible for managing it, the riding community and the broader community. What is apparent is that turning a blind eye to the presence of such features in natural area in and around cities is unlikely to be the optimum solution, for land managers, users of the reserve and conservation.” - Conclusion (pg. 66)

Anderson, Randy, Hannah Kapell, Matt Berkow, Robin Wilcox, and Catherine Sherraden. *Rep. Trail Use Conflict Study*. Oakland, CA: Alta Planning & Design, 2012.

“Conflicts between trail users are shown to be highly influenced by perception, attitudes, and behavior on both sides of conflicting parties. Conflict has been described in the literature as goal interference, which can be either interpersonal (based on physical presence of other users) or social (based on perception of a group; no contact or sighting has to occur) (Jacob and Schreyer 1980; Moore 1994; Carothers, Vaske, and Donnelly 2001; Cessford 2002; Bradsher 2003; Chiu and Kriwoken 2003). Moore (1994) wrote that “conflict has been found to be related to activity style (mode of travel, level of technology, environmental dominance, etc.), focus of trip, expectations, attitudes toward and perceptions of the environment, level of tolerance for others, and different norms held by different users.” Watson, a researcher with the USFS, observes that perceptions of conflict are frequently unrelated to measurable incidents of interference in outdoor recreation, but rather reflect an attitude towards wilderness and stereotypes of other user groups (Watson 2001)” - Trail use conflict is an important social issue (pg. 1-9/23)

Rossi, Sebastian Dario, Catherine Marina Pickering, and Jason Antony Byrne. "Local community perceptions about mountain bike riding in peri-urban national parks." In The 7th International Conference on Monitoring and Management of Visitors in Recreational and Protected Areas, Local Community and Outdoor Recreation, Tallinn University Tallinn, pp. 69-71. 2014

"Similarly to a previous study which found limited conflict among recreational activities for one of these parks (Rossi et al., 2012), local residents did not report high levels of conflict over mountain biking for either park. However, locals who did not visit the parks tended to have a slightly less positive perception of mountain biking, than locals that did. It appears that locals who do not use the parks may experience social value conflicts, where problems are experienced without direct contact among those engaging in different recreational activities (Vaske et al., 1995). Although the perceptions of social conflicts could be a reason for displacement for these two parks, as has been found in other studies (Arnberger and Brandenburg, 2007) evidence was not found supporting this relationship... This suggests that displacement due to mountain biking may not be the major reason for some local residents not visiting these parks. Other factors potentially affecting their visitation patterns include age, place of residence and education. These findings corroborate studies that found that residents with higher level of education are more likely to visit a park if it is closer to home (Payne et al., 2005)." - Discussion (pg. 70)

Rupf, Reto, Wolfgang Haider, and Ulrike Pröbstl. "Hikers and mountain bikers—do they fight like cats and dogs." In The 7th International Conference on Monitoring and Management of Visitors in Recreational and Protected Areas (MMV), pp. 253-255. 2014

"Referring to the title – hikers and cross-country mountain bikers are not as different as many people and managers of destinations and protected areas believe. Most of their motivations and requirements and much of their behaviour are similar (see figure 1). Conflicts are often caused by differing downhill speeds or by the intrusion of a new species of outdoor recreational user in territory that has been traditionally used exclusively by hikers." - Conclusions and Management Implications (pg. 254)

Creany, Noah Eugene. "Kudos and KOM's: the Effect of Strava Use on Evaluations of Social and Managerial Conditions, Perceptions of Ecological Impacts, and Mountain Bike Spatial Behavior." PhD diss., Utah State University, 2020

Mendes, Ricardo M. Nogueira, Estela Inés Fariás-Torbidoni, and Carlos Pereira da Silva. "Squeezing the most from volunteered geographic information to monitor mountain biking in peri-urban protected and recreational areas at a metropolitan scale." Journal of Outdoor Recreation and Tourism 42 (2023): 100624

"This study has also shown that any management actions within peri-urban parks that place an emphasis on sports activities such as mountain biking need to consider the surrounding areas as suggested by Greer, Day, and McCutcheon (2017). People mainly ride close to their place of residence, within their available leisure time, as has been pointed out

by other studies (Fariás-Torbidoni & Morera, 2020), but cycling to other areas is common, and even cycling outside P&RAs. Such behaviours can also relieve pressure on more sensitive areas, meaning that an appropriate offer of recreational uses in a peri-urban context should be planned at a larger scale and not just for each park or individual area.” - Conclusion (pg. 10)

Monz, Christopher, and Andrew Kulmatiski. "The emergence of “fat bikes” in the USA: Trends, potential consequences and management implications." *Journal of Outdoor Recreation and Tourism* 15 (2016): 20-25

Santos, Teresa, R. Nogueira Mendes, and A. Vasco. "Recreational activities in urban parks: Spatial interactions among users." *Journal of Outdoor Recreation and Tourism* 15 (2016): 1-9

Neumann, Pate, and Courtney W. Mason. "Managing land use conflict among recreational trail users: A sustainability study of cross-country skiers and fat bikers." *Journal of Outdoor Recreation and Tourism* 28 (2019): 100220

Dementyev, Fletcher, Brian Fish, Nana Yaa Sakyi Opoku, Lydia Tesfaye, Jason Chan, Larry Ortiz, Susanne B. Montgomery, Esther J. Walker, and Sean M. Wilson. "Middle school cycling program is associated with improved mental health and wellbeing in adolescents during COVID-19." *Frontiers in Sports and Active Living* 5 (2023)

“Our results indicate that participation in a school-based cycling intervention program has the capacity to improve psychosocial well-being in adolescents aged 11–14. Our results also indicate that the R4F program is associated with improved psychosocial outcomes that are negatively impacted by a number of well-established modifiable and non-modifiable risk factors. Though the R4F program on its own does not fulfill CDC recommendations for daily physical activity, student results demonstrate that program participation was still associated with improvement in youth mental health and well-being and a positive physical education experience.” - Conclusion (pg. 15)

McCahon, Shelby, Todd Brinkman, and Ryan Klimstra. "Estimating encounter probabilities among recreational trail user groups." *Journal of outdoor recreation and tourism* 42 (2023): 100614

“We used trail cameras to develop an objective trail monitoring method that can generate spatially and temporally explicit estimates of trail use activity, occupancy, and encounter probabilities among different user groups. This tool can be adapted and applied to any recreational trail use system (e.g., park, preserve, forest, refuge) to help identify locations and times of high activity, congestion, or overlap between user groups that may have a higher potential for conflict. Maintaining the option to vary the scale of the temporal and spatial variable inputs allows managers to explore characteristics of trail use activity that

are relevant to their recreational trail use system or specific research questions. Managers could utilize this information to 1) address current and future user concerns and interactions, 2) inform management plans, 3) monitor visitor information and management strategies, and 4) guide decision-making processes regarding trail use. These efforts could help minimize potential user conflicts and optimize trail user satisfaction.” - Conclusion (pg. 8)

Economic Impacts

Adjacent Economic Impact

Boozer, Benjamin B., M. Self, and Mr Joseph Jankoski. "An economic and impact analysis of the Coldwater mountain bike trail." Report for the Calhoun County Community Development Corporation; Center for Economic Development: Jacksonville, AL, USA (2012): 73

Freeman, Ray. "Mountain Bike Tourism: Critical Success Factors." (2013)

Meltzer, Nicholas. "Adapting to the new economy: The impacts of mountain bike tourism in Oakridge, Oregon." (2014)

Jordan, Scott. "Assessment of the Effects of Mountain Biking: Marquette Michigan's Ecotourism." (2015)

Savolt, Abby. "Economic Impact of Off Road Cycling in Duluth: An Expenditures Approach." (2017)

Kozumplikova, Alice, Gabriela Chmelikova, Petra Hlavackova, and Ondrej Konecny. "Recreational mountain biking-a new tool in rural development." *Ecocycles* 4, no. 2 (2018): 23-32

Buning, Richard J., Zachary Cole, and Matthew Lamont. "A case study of the US mountain bike tourism market." *Journal of Vacation Marketing* 25, no. 4 (2019): 515-527

Kelsey, Amy, Lisa Chase, and Abigail Long. "Recreation economies and sustainable tourism: Mountain biking at Kingdom Trail Association in Vermont." Vaugeois, N., Phillips, M., & Brouder, P.(Eds.).(2019). *Innovative and promising practices in sustainable tourism*. Nanaimo, BC: VIU Publications. (2019)

Shelly Hadley, Shelly, and David David Trechter. Rep. "Chequamegon Area Mountain Bike Association Economic Impact and User Experience Survey Summary, 2020". Report for Chequamegon Area Mountain Bike Association; Madison, WI: University of Wisconsin Survey Center – UW–Madison, 2020

Abernethy, Brian, Anthony W. Dixon, Patrick J. Holladay, and Win GY Koo. "An Examination of the Travel Behaviors and Site Preferences of Canadian and US Mountain Bike Tourists." (2021)

Buning, Richard J., and Matthew Lamont. "Mountain bike tourism economic impacts: A critical analysis of academic and practitioner studies." *Tourism Economics* 27, no. 3 (2021): 500-509

Bailey, Andrew W., Natalie Chandler, and UTC Tourism Center. "Chattanooga Mountain Biking Impact Report." (2022)

Cherrington, Jim. "Mountain Biking, Culture and Society." (2024)

O'Leary, Ethan, Dovev Levine, Shannon Rogers Ph D, and Andrew Bohannon. "Exploring the Economics of Mountain Biking in Keene, New Hampshire: A Gap Analysis." (2024)

Leichenko, Robin, and Crystal Taylor. "Promoting rural sustainability transformations: Insights from US bicycle route and trail studies." *Journal of Rural Studies* 106 (2024): 103205

Events

Fix, Peter, and John Loomis. "Comparing the economic value of mountain biking estimated using revealed and stated preference." *Journal of Environmental Planning and Management* 41, no. 2 (1998): 227-236

Glupker, Christian, and Paul Isely. "The Economic Impact of Bell's Iceman Cometh Challenge 2022 Mountain Bike Race." (2023)

"All visitors spent approximately \$4.7 million at Iceman, resulting in a total economic output of \$5.8 million, supporting 49 jobs. Approximately 97% of this economic activity is attributed to nonlocal visitors. Iceman operational local spending of \$397,000 added \$858,000 in economic output and support for 8 jobs." - Conclusion (pg. 21)

Miscellaneous

Design

Li, Jiaqing. "Virtual Designing and Modeling of a Mountain Bike Trail." (2020)

Funding

Nowak, Marie, and Tobias Heldt. "Financing recreational trails through donations: Testing behavioural theory in mountain biking context." *Journal of Outdoor Recreation and Tourism* 42 (2023): 100603

In this paper, we have reported on a field experiment testing a normative message intervention. We found that the introduced social information targeting the beliefs associated with donations for MTB trails encourage higher donation rates. We also found that trail users donated more, on average, after they were provided with social information. This is consistent with our prediction and findings of previous research. While engagement in this form of pro-social behaviour seems to be conditional upon the behaviour of others to a certain extent, our research revealed that mountain bikers already held strong personal norms in favour of donations and that these form significant drivers in donation behaviour.
- Conclusion (pg. 8)

Municipal Management

Symmonds, Mathew C., William E. Hammitt, and Virgil L. Quisenberry. "Managing Recreational Trail Environments for Mountain Bike User Preferences" (2000)

The data presented in this study have highlighted some important issues for managers of recreation resources primarily used by mountain bikers. Relating to the four objectives of this study as detailed earlier, the following sections discuss how the findings of this study can be applied to the management of trail impacts, selection of management tools to control these impacts, trail design, and selection of management strategies. - Conclusion (pg. 561)

Cessford, Gordon. "Perception and reality of conflict: walkers and mountain bikes on the Queen Charlotte Track in New Zealand." *Journal for Nature Conservation* 11, no. 4 (2003): 310-316

"The emerging conclusions from research on bike impacts, and the largely positive evaluative results from specific surveys such as that on the Queen Charlotte Track, suggest a positive outlook for developing shared tracks. It seems that the perceptions and realities of impacts can sometimes be quite different, and that greater awareness and experience can lead to a reduction in problem perceptions. The generally more positive perceptions among those who actually encountered bikes suggests that some 'encounter-effect' may

occur that somehow results in reduced negative feelings. This may reflect some unanticipated positive aspect from experiencing bikes and their riders, such as friendly contact, and riding behaviour that was less threatening than expected. Or, it may reflect some form of conciliatory coping response by visitors when faced with perceived conflict situations, as widely documented in conflict literature. Some caution is required regarding possible displacement effects on the more 'bikes sensitive' walkers, such as the older walkers on the Queen Charlotte Track. All of these possibilities suggest fundamental and important research questions for managers to address if considering shared-track options."
- Management Conclusions (pg. 106-107)

Reed, Sarah E., Jodi A. Hilty, and David M. Theobald. "Guidelines and incentives for conservation development in local land-use regulations." *Conservation Biology* 28, no. 1 (2014): 258-268

Maffitt, Charles McKean. "Singletrack connections: integration of mountain bike trails into the Oconee Rivers Greenway." PhD diss., University of Georgia, 2007

"Dr. Walter Cook, retired UGA Forestry Professor and one of the leading proponents behind the Oconee Rivers Greenway, said the following to the Athens Observer on the occasion of the opening of the nature trail named for him: "The thing about a trail is that it allows you to be intimately involved with nature without disturbing it. Trails are important because they draw people out – people who wouldn't normally be outdoors – and they help to spread the environmental ethic that we all should have, which is: If we understand and enjoy a thing, then we will value and protect it" (Hester 1990). Mountain bikers are as aware of this importance as anyone, and today they are at the forefront of greenspace preservation and environmental action. They seek the same intimacy with nature that Dr. Cook describes, and they want to experience it close to home." - Conclusions (pg. 142)

Siderelis, Christos, Michael Naber, and Yu-Fai Leung. "The influence of site design and resource conditions on outdoor recreation demand: a mountain biking case study." *Journal of Leisure Research* 42, no. 4 (2010): 573-590

"We began this study by speculating that users would take more outings to sites having mountain biking trails in natural surroundings, with challenging layout features, and less severely degraded trail condition. The statistical significances of the mean coefficients of the trail condition and site layout from the repeated mixed logit reject this study's two null hypotheses. Further, we mentioned a priori that a correlation might exist between the random coefficients of these choice variables. We empirically accounted for this using a repeated mixed logit with correlated random coefficients ($r = 0.75$). Provided with the results, we can report with confidence that users who place a high value on a site's layout also tend to place a higher value on less degraded condition of the trails. In sum, what motivates users questioned in this study are the complexity and challenge of site layouts in natural surroundings and their awareness of the current trail conditions, which together enhance their continued enjoyments of mountain biking experiences." - Conclusion (pg. 587)

Wytttenbach, Martin, and Reto Rupf. "Urban mountain biking—multiple-uses of trails on the Uetliberg in Zurich, Switzerland." In The 7th International Conference on Monitoring and Management of Visitors in Recreational and Protected Areas (MMV)—Local Community and Outdoor Recreation—Proceedings, pp. 244-246. Tallinn, Estonia: University of Tallinn, 2014

“Overall it can be said that on the Uetliberg, the potential for conflicts between hikers and bikers is high on multi-use trails on weekend days. Conflicts mainly occur due to the speed difference between the activities. Therefore the one-way bike trail takes some pressure off of the main trail network... The local management has succeeded in easing the existing tension by implementing additional specific measures such as restrictions for bikers or sensitization campaigns. Today conflicts mostly occur because of illegal biking infrastructure, the improper use of footpaths, and home-made constructions. Despite this, the multiple usage of trails on the Uetliberg is mostly conflict free. Mutual consideration can help to calm the situation down on days of heavy usage. Providing information through different channels is therefore an important tool and can help to create a gratifying experience for everyone that uses the same paths at the same time... The overall increase in bike sports is likely to continue not only in the city, but also in the countryside. Due to the population growth in and around cities there are likely to be increasing discussions on the provision of more infrastructure, such as official bike trails around cities. Therefore, information on the distribution of activities in recreational areas and specific trail use are a solid basis for political discussions and further monitoring of management measures.” - Conclusions and Management Implications (pg. 246)

Wilkes-Allemann, J., and M. Pütz. "Governance of forest recreation: analysing the case of mountain bike trails." Schweizerische Zeitschrift für Forstwesen 168, no. 6 (2017): 321-328

Magro-Lindenkamp, Teresa Cristina, and Carolina Bartoletti. "Participatory management to engage society with the planning of protected areas: a mountain bike trail planning." (2018)

“Our methodology involves four public meetings for planning and designing the mountain bike trail. The last step of the participatory management approach is the trail construction by volunteers of the different stakeholder groups.” - Conclusion (pg. 32)

Bibliographer's Note: The description of the process in this document follows the rough outlines of the process called Collaborative Ecological Layout (CEL), used in trail planning in the state of Minnesota, United States of America.

Cherrington, Jim. "The Ontopolitics of Mountain Bike Trail Building: Addressing Issues of Access and Conflict in the More-than Human English Countryside." Somatechnics 11, no. 3 (2021): 322-339

Instead, this paper has explored the relative benefits of an object-oriented approach to access and space, in which the notion of rights is accorded to human and non-human entities such as rocks, water and trees. Moreover, it highlights how bringing materiality

back into the communicative practices of sport and physical culture can help to clarify what is at stake to who in these claims. In this study, mountain bike trail builders drew upon intimate ecological arrangements to both problematise existing forms of governance and explore alternative political sensibilities. This was manifest in the way that they challenged the commodification of forests, water and surfaces, whilst practicing a form of hacking that was premised upon an emergent, co-creative, and future-orientated attitude towards ecological entanglement within different territorial locations. As such, this paper has responded to calls for more empirical work dedicated to the process of commoning (Bresnihan 2015), whilst adding to a burgeoning corpus of work that is dedicated to unpacking the ontopolitics of sport. - Conclusion (pg. 24)

Kleiner, Annick, Benjamin Wanja Freuler, Arne Arnberger, and Marcel Hunziker. "Biking-hiking conflicts and their mitigation in urban recreation areas: Results of a quasi-experimental long-term evaluation in the Zurich Forest." *Journal of Outdoor Recreation and Tourism* 40 (2022): 100563

"In agreement with Moore (1994), Pickering and Rossi (2016), Arnberger and Haider (2007), Koemle and Morawetz (2016), Cessford (2003), and Reichhart and Arnberger (2010) it can be concluded from the results that under certain physical, spatial and social conditions, shared use of trails is accepted by users and a reasonable choice to avoid trail infrastructure in near-natural areas. However, as overtaking manoeuvres and high speeds lead to conflicts, it seems necessary to separate steep downhill trails especially in heavily used recreation areas for bikers and hikers... The study shows that hard measures are less accepted by the groups affected than soft measures. Nevertheless, they can be important and show acceptance and effect in combination with different spatial and communicative measures. If possible, measures should be developed in consultation with stakeholders and be accompanied by a regular visitor monitoring not only analysing the acceptance of the measures but also ensure actual effects of mitigation measures on attitudes and behaviour of the target groups to ensure a lasting impact." - Concluding Management Implications and Future Research (pg. 8)

Tiessen, Matthew. "To the ravines! Encountering, exploring, and expanding Toronto's mountain bike trails during and beyond the Covid-19 pandemic." *Eracle. Journal of Sport and Social Sciences* 5, no. 1 (2022): 64-93

Wilkes-Allemann, Jerylee, Alice Ludvig, Stefan Gobs, Eva Lieberherr, Karl Hognl, and Andy Selter. "Getting a grip on negotiation processes: Addressing trade-offs in mountain biking in Austria, Germany and Switzerland." *Forest Policy and Economics* 136 (2022): 102683

"Given the above characteristics, our study also has implications for practice: for better negotiating mountain bike trails, our findings can inform local administrations about how they could provide guidelines on how to proceed in this regard (see e.g. the Mountain Bike Concept of the City of Zurich, Switzerland). Finally, further research could propose new ways of managing "urban" forests on behalf of the provision of a variety of forest ecosystem services, as well as investigate role models of how several forest ecosystem

services can coexist in urban forest areas without leading to major trade-offs.” - Conclusion (pg.9)

Wright, Courtney. "Why Mountain Bike Trails Try to Scare You Off." INSIGHT 25, no. 3 (2022): 63-66

Arvidsen, Jan, Mathilde Skov Kristensen, and Evald Bundgaard Iversen. "Why build mountain bike trails? An exploratory mixed-methods study of volunteer motives in Danish MTB-trail building." Journal of Outdoor Recreation and Tourism 43 (2023): 100671

Chiu, Luke, and Lorne Kriwoken. "Managing recreational mountain biking in Wellington park, Tasmania, Australia." Annals of Leisure Research 6, no. 4 (2003): 339-361

Iversen, Evald Bundgaard, Mathilde Skov Kristensen, and Jan Arvidsen. "How can public authorities support co-production of mountain bike trails?." World Leisure Journal (2023): 1-19

Safety

Kim, Peter TW, Dalbhir Jangra, Alec H. Ritchie, Mary Ellen Lower, Sharon Kasic, D. Ross Brown, Greg A. Baldwin, and Richard K. Simons. "Mountain biking injuries requiring trauma center admission: a 10-year regional trauma system experience." Journal of Trauma and Acute Care Surgery 60, no. 2 (2006): 312-318

Ashwell, Zachary, Mary Pat McKay, Jeffery R. Brubacher, and Annie Gareau. "The epidemiology of mountain bike park injuries at the Whistler Bike Park, British Columbia (BC), Canada." Wilderness & Environmental Medicine 23, no. 2 (2012): 140-145

“These results are the first attempt at describing the epidemiology of injury associated with lift-accessed free-ride mountain biking. They demonstrate the spectrum of morbidity of such injuries. At least at Whistler, our findings suggest planning for increased staffing for injuries on weekends and during the month of August, and highlight the need for improved upper extremity protection and more effective head injury protection for this sport. Given the relative rarity of injury from bike-to-bike crashes, injury prevention strategies will need to focus on methods for maintaining control of the bike.” - Conclusion (pg. 144)

Willick, Stuart E., Daniel M. Cushman, Joshua Klatt, Matthew Brobeck, Chris Spencer, and Masaru Teramoto. "The NICA injury surveillance system: Design,

methodology and preliminary data of a prospective, longitudinal study of injuries in youth cross country mountain bike racing." *Journal of Science and Medicine in Sport* 24, no. 10 (2021): 1032-1037

An effective, nationwide injury surveillance system for injuries sustained in youth mountain bike racing was successfully implemented in 2018 across the United States. To our knowledge, this is the largest mountain biking ISS in the world. This ISS also tracks injuries in coaches, who ride with the student-athletes during practices but not races. The first year of data collection provided early insights into injury characteristics in this sport; these preliminary data need to be confirmed through subsequent years of data collection. Overall, student-athlete injury proportions are lower than those seen in many high school sports. The injury proportion for coaches is extremely low. Many injuries are relatively mild, including abrasions and contusions. Some injuries are more significant, including concussions/possible concussions, fractures and dislocations, and result in trips to an emergency room and sometimes hospital admission. Injury characteristics differ between student-athletes and coaches. Although coaches had an overall very low injury proportion, coaches sustained more injuries per injury event, had a higher percentage of fractures and dislocations, required emergency evacuation more frequently, had a higher percentage of hospital admissions, and greater time loss due. Injury proportions were similar between males and females, but both female student-athletes and coaches sustained lower limb injuries more than males. - Conclusion

Zhao, Lin, Margaret Nolan, and Patrick L. Remington. "Mountain bike injury incidence and risk factors among members of a Wisconsin mountain bike club." *WMJ* (2023): 122

"Mountain biking is an enjoyable sport and has significant health benefits for children and adults. However, injuries do occur and sometimes can be serious, requiring medical attention. Our study shows that the risk of injuries is low overall, and that beginner riders are at higher risk of minor injuries, while advanced riders are at high risk of serious injuries. This information should be used to design injury prevention efforts, such as more riding time for beginning riders and improved trail design and signage for more advanced riders." - Conclusion (pg. 123)

Braybrook, Paul John, Hideo Tohira, Tanya Birnie, Deon Brink, Judith Finn, and Peter Buzzacott. "Types and anatomical locations of injuries among mountain bikers and hikers: A systematic review." *PLoS one* 18, no. 8 (2023): e0285614

"Mountain bikers typically sustain contusions, lacerations, and abrasions. When considering more serious injuries, mountain bikers typically sustain injuries to the shoulder girdle including clavicle fractures and shoulder dislocations. The most commonly injured locations were the upper limbs. Hikers' injuries were predominated by blisters of the foot, in addition to sprained ankles. Whilst ankle sprains may not be acutely life altering injuries, they have the potential to carry a high burden of disease due to the increased likelihood for repeated strains. In addition to ankle injuries, knee injuries were also common, especially amongst the more competitive hiking sports such as trail running and orienteering. Hikers predominantly sustain injuries to the lower limbs. A standardised method of reporting

injury should be followed by future authors to enable cross comparisons between cohorts in addition to the reporting of all injuries to give a true indication of the prevalence of severe injury within these sports.” - Conclusions (pg. 14)

Fallon, Thomas, and Neil Heron. "A systematic review protocol of injuries and illness across all the competitive cycling disciplines, including track cycling, mountain biking, road cycling, time trial, cyclocross, gravel cycling, BMX freestyle, BMX racing, e-sport, para-cycling and artistic cycling." (2024)

Martinez-Sañudo, Luís, Arnau Verdaguer-Figuerola, Laia Martínez-Carreres, Santiago Garcia-Giménez, Enrique Cueva-Sevieri, and Xavier Pelfort. "Road Cycling causes more serious injuries than Mountain Biking. A prospective study and Review of the Literature." (2024)

“This study reveals that injuries caused by road cycling accidents are less frequent and more severe than mountain biking accidents. The findings demonstrated a connection between the age of patients and the severity of injuries. Indeed, older patients tend to experience more severe injuries. Consequently, age can be a determinant risk factor in cycling accidents especially in road cyclists.” - Conclusion (pg. 13)

Types of Mountain Biking

Taylor, Steve, Charlie Burrow, and Steve Button. "Challenging hegemonic velocipedic modality in the great outdoors: The seemingly inexorable rise of the electric mountain bike." *Journal of Outdoor Recreation and Tourism* 43 (2023): 100684

“While Kuwaczka et al.’s (2023) study is a welcome addition to the incipient literature on eMTBs’ environmental impacts, further work to determine these potential impacts associated with their use, especially in a range of environments away from the dry, purpose-built test bed of the IMBA (2016a) study, would help to understand how impacts differ to non-motorized mountain bike use. Equally, deeper understanding of the conflict issues would be beneficial, both between eMTB users and other user groups, including regular mountain bikers, and the potential mismatch between perceived conflict and that actually experienced on- the trail.” - Conclusions (pg. 9)