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The Relationship between Amount of Visitor Use and Environmental Impacts

CONTRIBUTING PAPER

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Identifying capacity involves predicting the maximum amount of use that can be accommodated with little risk of exceeding thresholds. To do this, one needs to understand the relationship between amount of use and the response of indicator variables for which thresholds have been established. Substantial research has been done on the relationship between amount of use and impacts to biological and physical attributes (referred to collectively, if somewhat inappropriately, as biophysical attributes). This paper is an attempt to summarize what is known, make this research more accessible to the reader, and, particularly, to suggest how a planner can use existing information to identify capacity. It is not about how to most effectively minimize impacts. A sizeable amount of literature documents that visitor management techniques, other than limiting amount of use, are more effective in limiting impact.

Predicting acceptable maximum use levels is challenging because of the idiosyncratic nature of the use-impact relationship. The exact nature of the relationship varies from place to place, depending on the biophysical attribute of concern, the nature of recreational use, weather, layout of the land, existing infrastructure, and many other variables. That said, there are a number of general conclusions that can be made about the use-impact relationship.

Most fundamentally, increasing recreation use will typically result in an increase in biophysical impact, if all other variables are held constant. However, the magnitude of increase in impact that results from an increase in use can be relatively small (e.g., Cole 1982). For example, doubling the use of a trail may result in an increase in an attribute such as trail width of only a few percent—or possibly no increase at all.

Of even more importance, other changes in recreation use characteristics (e.g., the behavior of users, where use occurs, how use is managed) can have much more dramatic effects on type and extent of impact than a change in amount of use. See, for example, several excellent recent review articles (Marion 2016 and Marion et al. 2016). Moreover, changes in these other use characteristics will modify the relationship between amount of use and type and extent of impact. This suggests that, if the goal is to limit or reduce impact, there are likely to be more effective ways to accomplish this goal than limiting use. Even where it is decided that use must be limited, the most effective way to limit or reduce impact is likely to be a combination of use limits and other visitor and site management strategies.

To predict how changes in amount of use will influence amount of impact, it is helpful to consider the two very different ways that increasing use can result in increased impact (Cole 1994, 2009). First, as amount of use increases, people tend to spread out more, resulting in an increase in the area affected by use. Increasing use typically leads to an increase in the areal extent of impact. Second, as use increases, each place that recreationists visit gets used more frequently and by more people, resulting in more intense impact of those places. That is, increasing use leads to an increase in the intensity of impact per unit of area. The total magnitude of impact grows with increasing use because either the areal extent or the intensity of impact, or both, increases. To predict the effect of increasing use on amount of impact, one must generally predict effects on both the areal extent and intensity of impact.

Predictions about the relationship between amount of use and the areal extent of impact are easier to make than predictions about the relationship between amount of use and intensity of impact. The relationship between amount of use and areal extent of impact does not vary as much from place to place, and predictions rely more on understanding human behavior than on understanding how biophysical attributes respond to changes in intensity of use.

Areal Extent of Impact.

There is little scientific literature helpful in predicting how the areal extent of impact is likely to respond to changes in amount of use. Rather, planners will have to rely on logical thinking and common sense, based on an attempt to understand how recreationists use the area. The existing recreation infrastructure and management strategies will have a strong influence on the use/areal extent relationship. So will environmental features such as the distribution of area attractions (where people are trying to reach) and the ease of travel off the existing infrastructure (e.g., off-trail travel).

To illustrate how one can employ logical thinking to make predictions, consider that there are some situations in which the increase in areal extent of impact should be proportionally equal to the increase in use. For example, if camping is confined to established campsites and all campsites are always occupied, doubling the amount of camping would require doubling the number of campsites needed and, therefore, the areal extent of camping impact. At the other extreme, there are some situations in which increasing use may have virtually no effect on the areal extent of impact.

An example might be a place where hiking is only allowed on established trails. As long as amount of use is not so high that it forces people to violate regulations, a doubling of use might have no effect on areal extent of impact. Most situations will lie between these two extremes, with increased use resulting in an increase in areal extent of impact but of a magnitude much smaller than the increase in use. For example, doubling the use of a day-use river segment might result in a few more places where people stop for lunch, resulting in perhaps a 5-10% increase in the areal extent of impact.

Where recreationists are allowed to travel and recreate wherever they wish, predicting the effect of increasing use is more uncertain than in situations in which recreationists are required to keep to established sites and routes. As previously noted, in these situations, increasing use is likely to increase areal extent of impact, but the increase in impact is likely to be much smaller than the increase in use. This follows from the fact that, despite increased use, most people will still attempt to visit the same places and do the same things they always did. Given this, one might predict that increases in use will have no effect on areal extent of impact until increases are so great that people are "forced" to seek less preferred places or leave more easily traversed travel routes (i.e., areal extent of impact increases exponentially with increasing use, rising slowly at first before increasing dramatically). For example, increasing use of a lightly used trail is unlikely to physically force people off the trail. However, there is a point at which use density becomes so high that people are physically forced off the trail. Another logical conclusion is that the magnitude of increase in areal extent with increasing use should be greater in places where it is easy to travel off established travel routes and/or where there are a large number of attractive places in which to visit and recreate. For example, the effect of increasing use on areal extent of impact is likely to be greater on flat, even, and dry terrain than in steep, rugged, and rocky terrain; places with impenetrable vegetation; or wetlands. It is likely to be greater in places where many of the vistas, lakes, or other attraction sites in the area are not accessed by established trails.

Intensity of Impact.

A large number of studies have documented the relationship between amount of use and intensity of impact. Despite some conclusions about the general nature of this relationship, specifics are highly idiosyncratic, varying particularly with the amount and nature of recreation use, the biophysical attribute of concern, and its durability. Most studies have examined the effects of relatively high levels of recreation use on attributes that are profoundly impacted by even modest levels of use. This follows from the tendency to study situations in which impacts are considered problematic and to study variables that are readily observable and highly responsive to the disturbance being applied. For example, a large proportion of available research has examined the effects of pronounced trampling on vegetation.

Disturbance ecology studies—of many stressors other than recreation—have found that most of the data relating a "dose" of stress to an environmental response fit a sigmoid curve. There is no reason to think that the sigmoid curve should not apply in situations in which the "dose of stress" is amount of recreational use and the environmental response is some type of recreation impact (figure 1). This conclusion may seem somewhat at odds with the conclusions of numerous recreation impact studies that have found the use-impact relationship to be asymptotic (Cole 1995b) or the observation that not all recreation use-impact relationships fit the asymptotic model (Monz et al. 2013). These discrepancies disappear when one considers that—with a sigmoid curve—the shape of the curve that relates amount of use to amount of impact is dependent on which portion of the curve is being studied. Referring to figure 1, some portions of the curve are linear, others show accelerating impact with increasing use, and some show declining increases in impact (a plateauing of impact) with increasing use. So the shape of the curve will be dependent on the range of use levels that were examined. No studies have examined all use levels from zero to infinity.

Thus, given this variability in even the shape of the use-impact relationship, how can a planner predict how impact will respond to changes in amount of use? The first guideline is to try to decide which portion of the sigmoid curve applies to the situation at hand. This is dependent on the amount and type of use that is occurring and the durability of the ecological attribute that is being impacted by recreation (i.e., the indicator variable for which a threshold has been established). The lower the amount of use is and the more durable the ecological attribute is, the more likely the left-hand side of the sigmoid curve applies (figure 2). For example, as Monz et al. (2013) point out, even a very large increase in the number of people walking on a highly durable substrate such as solid rock will result in a minimal increase in amount of impact to the rock. Even for a more fragile attribute, such as many vegetation types, increasing trampling frequency tenfold, from once every 10 years to once every year, may result in a minimal increase in vegetation impact.

Figure 1. The sigmoid curve that characterizes the relationship between amount of recreation use and the resultant intensity of environmental impact.

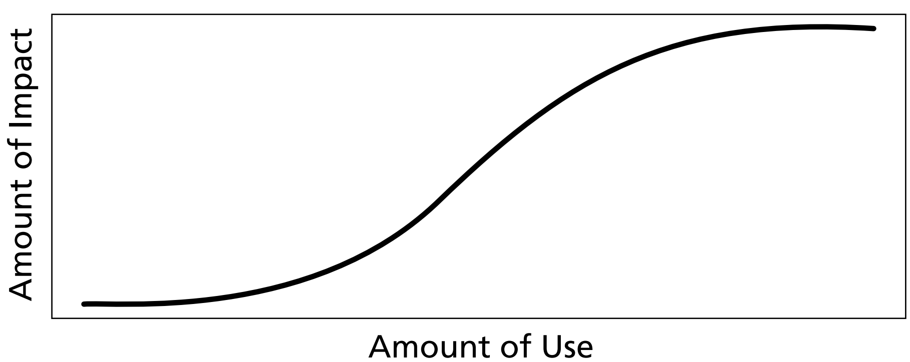
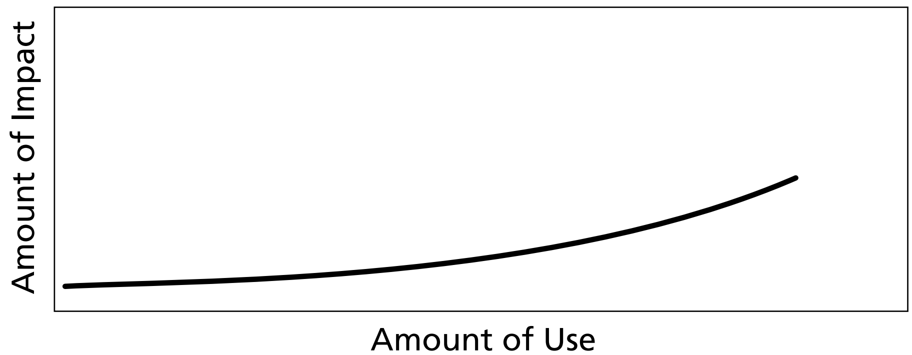


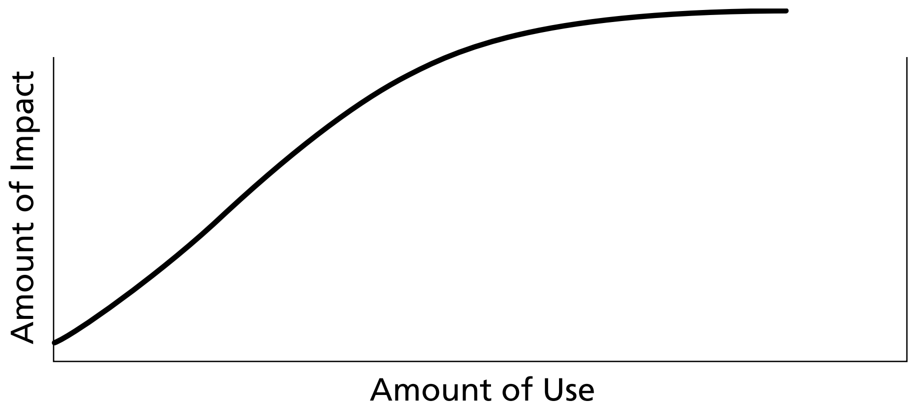
Figure 2. The relationship between amount of recreation use and the resultant intensity of environmental impact—the left portion of the sigmoid curve in figure 1—that applies where use is low and/or the environmental attribute of concern is highly durable. Note that across this entire range of use, impact increases exponentially; however, some portions are linear.



The problem with this latter example is that capacity is generally not an issue if use levels are that low. The higher use is and the less durable the ecological attribute is, the more likely the middle and right-hand side of the sigmoid curve applies (figure 3). This is where the nature of the relationship is asymptotic. Where use is low, small increases in amount of use can cause pronounced increases in impact; however, the rate of increase in impact decreases as use intensity increases.

Returning to figure 1, in situations toward either the far left or right sides of the figure, changes in amount of use are associated with rather small changes in amount of impact. If this is the situation that likely applies, planners might simply estimate that an increment of change in use will result in a small change (perhaps 10% or less of a change in impact). There is no way to get away from the fact that this will be an educated guess. One must make an informed prediction and then make adjustments based on monitoring data. But if one is correct that impact intensity is little affected by amount of use, whether the appropriate proportion is 5% or 20% makes little difference.

Figure 3. The relationship between amount of recreation use and the resultant intensity of environmental impact—the middle and right portion of the sigmoid curve in figure 1—that applies where use is not low and/or the environmental attribute of concern is not highly durable. Note that across this entire range of use, the relationship is asymptotic; however, some portions are linear.



In between the far left and far right sides of figure 1 are situations—characterized by either relatively low use of a fragile ecological attribute or relatively high use of a durable attribute—in which changes in amount of use can result in substantial changes in impact intensity. Again, one must predict how much change will result from an increment of change in use, and this prediction is likely to be little more than an educated guess. There may be some situations in which an incremental change in use will result in a similar (or even greater) magnitude of increased impact intensity (e.g., doubling the use will result in a doubling of impact intensity). However, research suggests that, usually, the magnitude of change in impact will be smaller than the change in use.

Putting It All Together.

As the preceding discussion should make clear, research and science are primarily helpful in suggesting a general relationship between amount of use and resultant environmental impact. Empirical research seldom can suggest a specific number with any precision, particularly given that results often must be extrapolated from studies conducted in a different time and place. This leaves the planner with the task of deriving an estimate of capacity based largely on professional judgment, drawing on logical thinking and knowledge about use-impact relationships. The planner needs to consider the likely effects of a change in use level—whether it involves a decrease from current use levels or an increase up to some capacity higher than current use. How would such a change affect the distribution and areal extent of use? And how would it affect the intensity of use across the areas that are being used for recreation?

For example, the planner may assume that a doubling of use would result in a 25% increase in the area used for camping or picnicking or hiking. Given that twice as much use is distributed across only 25% more area, the intensity of use across the area being used increases about 60%. However, if that increase occurs on trails and recreation sites that are already substantially impacted, the effects of this increased intensity may be minimal—aside from the 25% increase in new trail, camp, or picnic sites. Therefore, the planner may estimate that close to double the current amount of use could be accommodated (i.e., capacity could be doubled) if established thresholds for impact allow for an increase in impact of 25-30%.

Consider a similar situation in which it is decided that impacts need to be reduced 25%. One may be inclined to estimate that this could simply be accomplished by reducing use by 25%. However, if there is no attempt to limit recreation use to a smaller number of recreation sites, this change would have little effect on the areal extent of impact. The main effect of the use reduction would be on the intensity of use on established trails and sites. It is possible that, despite the reduction in use, near-maximum levels of impact would continue (as depicted in the right half of figure 3). If so, a 25% reduction would not keep impacts under established thresholds. Use reductions would either have to be much more substantial than 25%, or the 25% reduction in use would have to be supplemented by a closure of 25% of the system of trails and recreation sites.

These examples portray the type of analysis in which planners must engage to arrive at a capacity estimate. Obviously, there is substantial uncertainty in such estimates, because there are so many unknowns and so many required assumptions. That is why the capacity should be considered an estimate that can be made more precise only through adaptive management. Best practice for planners involves identifying capacity, applying that estimate and monitoring results, and adjusting capacity as necessary. It may also be prudent to use the precautionary principle and initially err on the side of the low range of an estimate.

A Guide to the Scientific Literature.

The References section contains most of the sources available on the relationship between amount of recreation use and resultant biophysical impact. Most of these are highly site-specific studies, conducted at one place and time. However, a few overviews of the use-impact relationship are available. Among the most useful are several books or book chapters (Cole 2009; Hammitt et al. 2015; Liddle 1997), state-of-knowledge reviews published in proceedings (Cole 1987; Leung and Marion 2000), grey literature (Kuss et al. 1990), and journal articles (Kuss and Graefe 1985; Liddle 1975; Monz et al. 2013).

By far, the largest numbers of studies have employed an experimental approach, applying various amounts of recreational use and then observing the response. Wagar (1964) was the first to apply this approach. Trampling by hikers is by far the most common type of recreation use explored, but some studies have examined impacts caused by horses and llamas (Cole and Spildie 1998; DeLuca et al. 1998; Newsome et al. 2004), bicycles and motor vehicles (Wilson and Seney 1994), camping (Cole 1995a; Cole and Monz 2003, 2004), and diving (Hawkins and Roberts 1993). Vegetation is the response variable most frequently examined; however, some studies have examined soil response (Lei 2009). Most studies have been conducted in terrestrial environments in North America (Cole 1995b); however, studies have been conducted around the world, most notably in Australia

(Hill and Pickering 2009; Sun and Liddle 1993), and a few have been conducted in aquatic environments (Casu et al. 2006). Several studies have attempted to draw conclusions from experimental trampling about how vegetation durability varies with vegetation type (Bernhardt-Römermann et al. 2011; Cole 1995c; Yorks et al. 1997).

Other studies have assessed the influence of amount of use on amount of impact by examining established recreation sites that receive different intensities of use. A number of studies have assessed the degree to which campsite impacts vary with how frequently they are used (Cole 1982, 2013; Frissell and Duncan 1965; Marion and Cole 1996; Marion and Merriam 1985b; Young 1978). Trails that receive different levels of use have also been studied (Coleman 1981; Dale and Weaver 1974; Olive and Marion 2009; Wimpey and Marion 2010). In addition to impacts of nonmotorized use, studies have also examined the effects of motorized use (Adams et al. 1982; Buckley 2004).

References

Adams, J.A., A.S. Endo, L.H. Stolzy, P.G. Rowlands, and H.B. Johnson. 1982. Controlled experiments on soil compaction produced by off-road vehicles in the Mojave Desert, California. Journal of Applied Ecology 19: 167-175.

Bernhardt-Römermann et al. 2011. Functional traits and local environment predict vegetation responses to disturbance: A pan-European multi-site experiment. Journal of Ecology 99: 777-787.

Buckley, R. 2004. Environmental impacts of motorized off-highway vehicles. pp. 83-98. In: Buckley, R., ed. Environmental Impacts of Ecotourism. Wallingford, UK: CABI Publishing.

Casu, D., G. Ceccherelli, M. Curini-Galletti, and A. Castelli. 2006. Short-term effects of experimental trampling on polychaetes of a rocky intertidal substratum (Asinara Island MPA, NW Mediterranean). Scientia Marina 70S3: 179-186.

Cole, D.N. 1982. Wilderness campsite impacts: Effect of amount of use. Research Paper INT-284. U.S. Department of Agriculture, U.S. Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Cole, D.N. 1987. Research on soil and vegetation in wilderness: A state-of-knowledge review. pp. 135-177. In: Lucas, R.C., comp. Proceedings of the National Wilderness Research Conference: Issues, State-of-Knowledge, Future Directions. Gen Tech Rep INT-220. U.S. Department of Agriculture, U.S. Forest Service, Intermountain Research Station, Ogden, UT.

Cole, D.N. 1994. Backcountry impact management: Lessons from research. Trends 31 (3): 10-14.

Cole, D.N. 1995a. Disturbance of natural vegetation by camping: Experimental applications of low-level stress. Environmental Management 19: 405-416.

Cole, D.N. 1995b. Experimental trampling of vegetation. I. Relationship between trampling intensity and vegetation response. Journal of Applied Ecology 32: 203-214.

Cole, D.N. 1995c. Experimental trampling of vegetation. II. Predictors of resistance and resilience. Journal of Applied Ecology 32: 215-224.

Cole, D.N. 2009. Ecological impacts of wilderness recreation and their management. pp. 395-438. In: Dawson, C.P., and J.C. Hendee. Wilderness Management: Stewardship and Protection of Resources and Values. 4th ed. Golden, CO: Fulcrum Publishing.

Cole, D.N. 2013. Changing conditions on wilderness campsites: Seven case studies of trends over 13 to 32 years. Gen Tech Rep RMRS-GTR-300. U.S. Department of Agriculture, U.S. Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Cole, D.N., and C.A. Monz. 2003. Impacts of camping on vegetation: Response and recovery following acute and chronic disturbance. Environmental Management 32: 693-705.

Cole, D.N., and C.A. Monz. 2004. Spatial patterns of recreation impact on experimental campsites. Journal of Environmental Management 70: 73-84.

Cole, D.N., and D.R. Spildie. 1998. Hiker, horse and llama trampling effects on native vegetation in Montana, USA. Journal of Environmental Management 53: 61-71.

Coleman, R. 1981. Footpath erosion in the English Lakes District. Applied Geography 1: 121-131.

Dale, D., and T. Weaver. 1974. Trampling effects on vegetation of the trail corridors of north Rocky Mountain forests. Journal of Applied Ecology 11: 767-772.

DeLuca, T.H., W.A. Patterson, W.A. Freimund, and D.N. Cole. 1998. Influence of llamas, horses, and hikers on soil erosion from established recreation trails in western Montana, USA. Environmental Management 22: 255-262.

Frissell, S.S., and D.P. Duncan. 1965. Campsite preference and deterioration in the Quetico-Superior Canoe Country. Journal of Forestry 63: 256-260.

Hammitt, W.E., D.N. Cole, and C.A. Monz. 2015. Wildland Recreation: Ecology and Management. 3rd edit. West Sussex, UK: John Wiley and Sons.

Hawkins, J.P., and C.M. Roberts. 1993. Effects of recreational scuba diving on coral reefs: Trampling on reef-flat communities. Journal of Applied Ecology 30: 25-30.

Hill, R., and C. Pickering. 2009. Differences in resistance of three subtropical vegetation types to experimental trampling. Journal of Environmental Management 90: 1305-1312.

Kuss, F.R., and A.R. Graefe. 1985. Effects of recreation trampling on natural area vegetation. Journal of Leisure Research 17: 165-183.

Kuss, F.R., A.R. Graefe, and J.J. Vaske. 1990. Visitor Impact Management: A Review of Research. Volume 1. Washington, DC: National Parks and Conservation Association.

Lei, S.A. 2009. Soil compaction from anthropogenic activities in a pinyon-juniper (Pinus-Juniperus) woodland of southern Nevada. Journal of the Arizona-Nevada Academy of Science 41 (2): 42-48.

Leung, Y.-F., and J.L. Marion. 2000. Recreation impacts and management in wilderness: A state-of-knowledge review. pp. 23-48. In: Cole, D.N., S.F. McCool, W.T. Borrie, and J. O'Loughlin, eds. Wilderness Science in a Time of Change Conference. Vol 5. Wilderness Ecosystems, Threats, and Management. Proceedings RMRS-P-15. U.S. Department of Agriculture, U.S. Forest Service, Ogden, UT.

Liddle, M.J. 1975. A selective review of the ecological effects of human trampling on natural ecosystems. Biological Conservation 7: 17-36.

Liddle, M.J. 1997. Recreation Ecology: The Ecological Impact of Outdoor Recreation and Ecotourism. London, UK: Chapman & Hall.

Marion, J.L., and D.N. Cole. 1996. Spatial and temporal variation in soil and vegetation impacts on campsites. Ecological Applications 6: 520-530.

Marion, J.L.,Y.-F. Leung, H. Eagleston and K. Burroughs. 2016. A review and synthesis of recreation ecology research findings on visitor impacts to wilderness and protected natural areas. Journal of Forestry 114: 352-362.

Marion, J.L. 2016. A review and synthesis of recreation ecology research supporting carrying capacity and visitor use management decionmaking. Journal of Forestry 114: 339-351.

Marion, J.L., and L.C. Merriam. 1985b. Recreational impacts on well-established campsites in the Boundary Waters Canoe Area Wilderness. Station Bulletin AD-SB-2502. University of Minnesota, Agricultural Experiment Station, St. Paul, MN.

Monz, C.A., C.M. Pickering, and W.L. Hadwen. 2013. Recent advances in recreation ecology and the implications of different relationships between recreation use and ecological impacts. Frontiers in Ecology and the Environment 11: 441-446.

Newsome, D., D.N. Cole, and J.L. Marion. 2004. Environmental impacts associated with recreational horse-riding. pp. 61-82. In: Buckley, R., ed. Environmental Impacts of Ecotourism. Wallingford, UK: CABI Publishing.

Olive, N., and J.L. Marion. 2009. The influence of use-related, environmental, and managerial factors on soil loss from recreational trails. Journal of Environmental Management 90: 1483-1493.

Sun, D., and M.J. Liddle. 1993. A survey of trampling effects on vegetation and soil in eight tropical and subtropical sites. Environmental Management 17: 497-510.

Wagar, J.A. 1964. The Carrying Capacity of Wild Lands for Recreation. Forest Science Monograph 7. Society of American Foresters, Washington, DC.

Wilson, J.P., and J.P. Seney. 1994. Erosional impact of hikers, horses, motorcycles and off-road bicycles on mountain trails in Montana. Mountain Research and Development 14: 77-88.

Wimpey, J.F., and J.L. Marion. 2010. The influence of use, environmental and managerial factors on the width of recreational trails. Journal of Environmental Management 91: 2028-2037.

Yorks, T.P., N.E. West, R.J. Mueller, and S.D. Warren. 1997. Toleration of traffic by vegetation: Life form conclusions and summary extracts from a comprehensive data base. Environmental Management 21: 121-131.

Young, R.A. 1978. Camping intensity effects on vegetative ground cover in Illinois campgrounds. Journal of Soil and Water Conservation 33: 36-39.