RECREATION TRAILS IN MAINE AND NEW HAMPSHIRE: A COMPARISON OF MOTORIZED, NON-MOTORIZED, AND NON-MECHANIZED TRAILS

Ethel Wilkerson
Manomet Center for Conservation Sciences
Brunswick, ME
ewilkerson@manomet.org

Andrew Whitman
Manomet Center for Conservation Sciences

Abstract.—We sampled 112 trail segments in Maine and New Hampshire to assess the impact of motorized and non-motorized recreation on trail conditions and stream sedimentation. On each segment, we assessed physical trail conditions (width, cross-sectional area, occurrence of excessively muddy and rutted/eroded sections), presence of trash, and sedimentation at stream crossings. Motorized trails were significantly wider and had significantly greater cross-sectional area, more rutted sections, and more trash than both non-motorized and non-mechanized trails. Non-mechanized trails had the highest density of excessively muddy sections. All trail types (non-mechanized, non-motorized, and motorized) had sections that contributed sediment to streams and 9 percent of stream crossings had catastrophic sediment additions (significantly altered stream morphology). The data also show significant differences in physical parameters among trail types, but both past land use and current recreational use may contribute to these differences.

1.0 INTRODUCTION

Public recreation is one of the four greatest threats to the health of U.S. forests (Bosworth 2007). In the Northeast, recreational uses on private and public forest lands are rapidly increasing, especially use of off-road vehicles (ORVs) (Maine ATV Task Force 2003, Jensen and Guthrie 2006). As the demand for recreation grows, managers must balance the need for high quality recreational experiences (Manfredo et al.1983) with protection of environmental values (Kuss and Grafe 1985, Hendee et al. 1990). Poorly managed recreation can have a large impact on soils (Leung and Marion 2000), water quality (Rinnella and Bogan 2003), biodiversity (Cole 1995), and wildlife (Marion and Leung 2001). Degradation of trails can also impact the quality and enjoyment of recreation experiences (Marion et al. 1993, Conrad 1997). A large majority of motorized trails in the Northeast are located on private land (Maine ATV Task Force 2003), and poor management of these trails may also jeopardize future recreational access to private land.

The goal of this study was to assess the environmental impact of motorized and non-motorized recreation trails in northern New England. Only a limited number of studies have made cross-comparisons of recreational impacts among use categories (e.g., Whittaker 1978, Wilson and Seney 1994, Deluca et al. 1998, Olive and Marion 2009). This study provides baseline information about on-the-ground trail conditions. It can help managers understand the environmental impact of different recreation types and identify specific management activities that can protect soils and water quality.

2.0 METHODS

We sampled 112 trail segments totaling 335 km of recreation trails in Maine and New Hampshire (Fig.1). These trails fell into three categories:

1) Motorized trails – trails primarily for all-terrain vehicles (ATVs) or snowmobiling (n=55, 164 km);
2) Non-motorized trails – trails permitting hiking and mountain biking (n=26, 70 km); and
3) Non-mechanized trails – trails permitting hiking only (n=31, 101 km).

We collected data along a trail segment either 2 km or 5 km in length. The beginning of each segment was a randomly selected distance from the start point, usually a trailhead or road crossing. We adjusted all continuous data by the length of the trail segment.

At 11 random locations along each trail segment, we measured tread width, maximum tread depth, and cross-sectional area (CSA). Width was measured

Table 1.—Average tread width, cross-sectional area (CSA), and tread depth for motorized, non-motorized, and non-mechanized recreation trails

	Tread Width (m)		CSA* (cm^3)		Max Tread Depth* (cm)	
	Mean	SE	Mean	SE	Mean	SE
Non-mechanized	0.62[c]	(0.04)	164.2[c]	(19.4)	4.0[b]	(0.2)
Non-motorized	1.59[b]	(0.22)	427.0[b]	(50.0)	4.5[b]	(0.3)
Motorized (all)	2.03[a]	(0.10)	736.4[a]	(41.7)	7.6[a]	(0.4)

* excludes sample locations with gravel surfaces
[a,b,c] Different letters represent significant differences among groups.

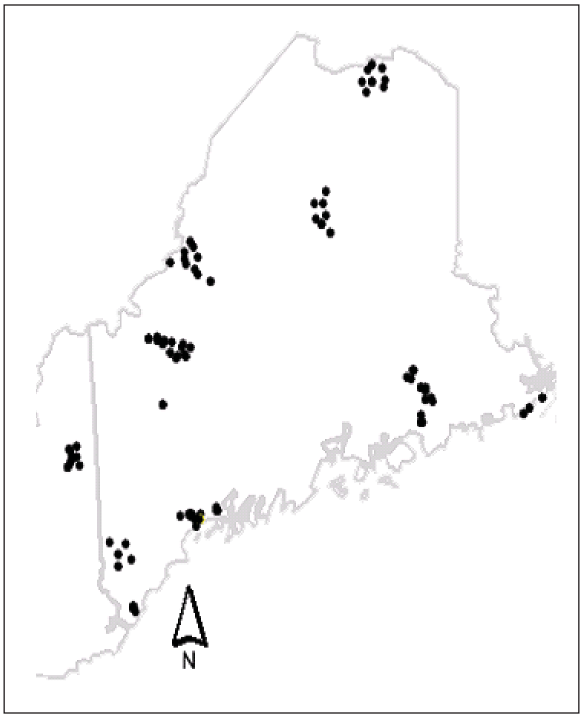

Figure 1.—Map of sampling locations in New Hampshire and Maine.

between the two most pronounced outer boundaries of visually obvious human disturbance created by trail use (Marion 2007). CSA was determined by measuring tread depth at five evenly spaced points along the entire trail boundary (adapted from Hammitt and Cole 1998). The addition of gravel to the trail surface alters the CSA of the trail and makes measurement of tread width and tread depth difficult. Therefore, we excluded sampling locations with gravel surfaces from the analysis of tread depth and CSA. With the exclusion of sampling points with a gravel surface, we retained 51 percent of sample sites on motorized trails, 83 percent on non-motorized trails, and 96 percent on non-mechanized trails. Along the entire trail segment, we tallied: the number of excessively muddy sections ≥3 m in length with seasonal or permanently wet soils with imbedded foot prints or tire tracks ≥1.2 cm deep (based on Marion 2007); highly rutted and/or eroded sections of trail ≥ 3 m in length with tread depth >13 cm (based on Marion 2007); and number of pieces of trash visible from the trail.

When trails crossed a stream or river >1 m wide, we recorded the type of crossing structure (ford, culvert, or bridge) and classified the amount of sediment entering the stream as: "none" (no visible sediment entered the stream), "trace" (sediment entered the stream channel, but deposited sediment did not form an identifiable sediment fan), "measurable" (deposited sediment formed a sediment fan), or "catastrophic" (deposited sediment significantly altered channel morphology or stream flow) (classifications adapted from Ryder et al. 2006).

We used an ANOVA (PROC GLM in SAS [SAS Institute, Cary, NC 1999]) to evaluate the effect of trail type (independent variable) on trail measurements (tread width, CSA, maximum tread depth, excessively muddy and eroded/rutted trail sections, and frequency of litter). If the overall model was significant, we used a multiple comparison test (least-squared means) to test for significant differences among the trail types (motorized, non-motorized, non-mechanized).

3.0 RESULTS AND DISCUSSION

3.1 Tread Width

Motorized trails had an average tread width of 2.03 m (Table 1). Motorized trails are significantly wider than other trails because of the large size of ATVs and snowmobiles and the need for adequate space for passing and safely maneuvering these vehicles, which can travel at high rates of speed. Trail widths were similar to

Table 2.—Average cross-sectional area (CSA), maximum tread depth, and frequency of excessively wet and rutted/eroded sections of trail on ATV, snowmobile, and year-round motorized trails (ATV and snowmobile)

	CSA* (cm^3)		Max Tread Depth* (cm)		Excessively Wet (freq/km)		Rutted/Eroded (freq/km)	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
ATV	944.3[a]	(120.8)	9.4[a]	(0.8)	4.0[a,b]	(0.5)	1.7[a]	(0.3)
Snowmobile	542.3[b]	(62.5)	6.7[b]	(0.7)	5.5[a]	(0.9)	2.0[a]	(0.7)
Motorized, Year round	822.0[a]	(73.9)	7.8[a,b]	(0.6)	3.0[b]	(0.6)	1.3[a]	(0.4)

[a,b] Different letters represent significant differences among groups.

guidelines for recreation trails in Maine, which call for ATV trails to be 1.5 m wide and snowmobile trails to be 1.8-2.4 m wide (Demrow 2002). Non-motorized trails had an average tread width of 1.59 m.

The recommended width of mountain bike trails depends on the desired difficulty of the trail. Easy trails are the widest; the International Mountain Bike Association (2004) recommends a width of 0.91-1.8 m. Demrow's (2002) guidelines suggest 1.2 m for easy mountain bike trails, 0.5-0.6 m for more difficult trails, and 0.3 m for the most difficult mountain bike trails. The average width of the trails in this study was greater than these recommendations. One advantage of wider trail width is that it may improve safety and reduce user conflicts because mountain bikers and hikers share most non-motorized trails.

Non-mechanized trails were significantly narrower than both non-motorized and motorized trails. The average tread width was 0.62 m. This width was consistent with Demrow's (2002) recommendations for Maine hiking trails (0.3-0.9 m) and with the measured tread width of hiking trails in Acadia National Park (range: 0.53-0.89 m) reported by Manning et al.(2006).

3.2 Cross-sectional Area and Tread Depth

CSA and tread depth are commonly used indicators of soil loss on trails (Jewell and Hammitt 2000). Motorized trails had significantly greater CSA (736.4 cm^2) and maximum tread depth (7.6 cm) than other trail types (Table 1). Motorized vehicles are heavy and apply 5-10 times greater pressure than does foot travel (Liddle 1997). ATV trails are particularly vulnerable to soil disturbance because tires break down soil structure resulting in erosion, compaction, and rutting (Meyer 2002).

We also found that ATV trails had significantly greater CSA (944.3 cm^2) and maximum tread depth (9.4 cm) than snowmobile trails (CSA: 542.3 cm^2; depth: 6.7 cm) (Table 2). Snow cover generally limits the disturbance of soils by snowmobiles (Liddle1997), but snowmobiles can cause soil disturbance and erosion when weather conditions, topography, or steep slopes reduce snow cover (Stangl,1999). In our study, 74 percent of motorized trail data points were located on seasonal, current, and historic roads and rights-of-way. Past use had likely altered soil properties at many of these locations and we could not determine the contribution of recreational use or nonrecreational uses to the physical dimensions of the trails.

Non-motorized trails had significantly greater CSA (427.0 cm^2) than non-mechanized trails (164.2 cm^2), but maximum tread depth for non-motorized (4.5 cm) and non-mechanized (4.0 cm) trails were not significantly different (Table 1). The greater CSA of non-motorized trails may result from greater tread width, rather than from soil compaction and erosion caused by mountain bikes. Non-mechanized trails had an average CSA similar to hiking trails in Acadia National Park (range: 31.3-223 cm^2 [Manning et al. 2006]).

Few studies have rigorously examined physical characteristics of motorized or mountain bike trails in New England, making comparisons to other studies difficult. However, a study in Kentucky and Tennessee found mountain bike trails had an average CSA 11 times

Table 3.—Percentage of sample points on motorized, non-motorized, and non-mechanized trails with: a gravel surface; a historic, seasonal, or current roadway; or trails specifically designed for recreational purposes

	Gravel Surface (%)		Historic, Seasonal, or Current Roads (%)		Specific Recreation Trails (%)	
	Mean	SE	Mean	SE	Mean	SE
Motorized	49	(5)	74	(34)	26	(5)
Non-motorized	17	(7)	29	(19)	68	(10)
Non-mechanized	4	(1)	8	(37)	91	(3)

Table 4.—Average frequency of excessively muddy areas; highly rutted and eroded trail sections; and occurrence of litter on motorized, non-motorized, and non-mechanized recreation trails

	Excessively Muddy (freq/km)		Rutted/Eroded (freq/km)		Trash (freq/km)	
	Mean	SE	Mean	SE	Mean	SE
Motorized	4.1[a,b]	(0.4)	1.6[a]	(0.2)	5.54[a]	(0.68)
Non-motorized	2.9[b]	(0.7)	1.0[a,b]	(0.4)	2.58[b]	(0.62)
Non-mechanized	6.6[a]	(1.5)	0.8[b]	(0.3)	1.13[b]	(0.42)

[a,b] Different letters represent significant differences among groups.

smaller than the non-motorized trails in this study but the CSA of ATV trails was twice as great (Olive and Marion 2009).

3.3 Excessively Muddy and Rutted/Eroded Trail Segments

Non-mechanized trails had the most sections with excessively muddy soils (6.6 sections/km, Table 4); this figure was significantly greater than motorized (4.1 sections/km) and non-motorized (2.9 sections/km) trails. The high frequency of muddy sections on non-mechanized trails can be attributed to the low percentage of gravel surfaces (4 percent of sampling points, Table 3) and the high percentage of trails (92 percent of sampling points, Table 3) used exclusively for recreation (not forestry, fire protection, or transportation). The geographic location and maintenance of non-mechanized trails may also account for the high density of muddy trail sections. Non-mechanized trails are often in remote areas that make maintenance practices, such as grading or hardening, impractical and expensive.

Excessively muddy areas are of concern to trail managers because they result in soil disturbance and compaction and are vulnerable to rutting and trail widening (Reisinger and Aust 1990, Marion 1994). Muddy sections on motorized trails can degrade quickly from the weight of recreational machines, particularly ATVs. On motorized trails, 48 percent of sample points were on a gravel surface and 73 percent were on historic, seasonal, or current roads (Table 3). We believe the low frequency of muddy sections on motorized trails was due to hardening of the trail surface (application of gravel), location of trails on existing roadbeds with previously compacted soils, and routine maintenance by mechanical equipment to prevent degradation and unsafe conditions.

Areas with severe erosion and/or rutting are of serious concern to managers. They indicate areas with high levels of soil disturbance or loss (Roggenbuck et al. 1993, Vaske et al.1993), which create safety hazards (Leung and Marion 1996, Marion and Leung 2001) and often require costly management actions or trail improvements (Olive and Marion 2009). Motorized trails (1.6 sections/km, Table 4) had a significantly greater frequency of rutted and eroded segments than non-mechanized trails (0.8 sections/km). This difference occurred even though non-mechanized trails had the highest frequency of

Table 5.—The percentage of stream crossing structures with different volumes of sediment input by trail type

Crossing Type	Sediment Volume	Motorized (%)	Non-Motorized (%)	Non-Mechanized (%)
All Crossing Structures	None	44	64	29
	Trace	25	24	33
	Moderate	18	8	32
	Catastrophic	13	4	6
Bridges	None	18	44	18
	Trace	10	8	8
	Moderate	3	4	7
	Catastrophic	3	0	1
Culverts	None	22	20	0
	Trace	13	12	0
	Moderate	9	4	0
	Catastrophic	7	0	0
Fords	None	4	0	13
	Trace	2	4	22
	Moderate	6	0	26
	Catastrophic	4	4	5

excessively muddy trail segments, which are vulnerable to rutting and erosion. Motorized trails, particularly ATV trails, are associated with ruts and erosion due to the mass of the vehicles (Liddle 1997) and large sheer forces of the tires on the soil (Meyer 2002). However, we found snowmobile and ATV trails to have no significant differences in the frequency of eroded/rutted trail segments (Table 2). This finding could be the result of the high proportion of motorized trails on historic, seasonal, or existing roads (74 percent) or a similar maintenance regime (grading, adding gravel). Other studies have found a much greater frequency of rutted/eroded sections on ATV trails (6.94 sections/km [Marion and Olive 2006]), but similar frequencies on mountain bike trails (0.7 sections/km [Marion and Olive 2006]) and hiking trails (1.31 sections/km, [Marion and Olive 2006]; 0.9-1.8 sections/km[Manning et al. 2006]).

3.4 Presence of Trash

Motorized trails in our study a had significantly greater frequency of trash visible from the trail than did other trail types, 5.5 pieces/km compared to 2.6 pieces/km on non-motorized and 1.1 pieces/km on non-mechanized trails (Table 4). Past research has found that recreation users view trash as highly undesirable in natural areas (Roggenbuck et al. 1993, Shafer and Hammit 1995, Floyd et al. 1997). The authors of these earlier studies attribute the low frequency of trash on non-mechanized trails to the success of the leave-no-trace program. The leave-no-trace principles, including “carry-in, carry-out,” have been heavily promoted since the 1980s (Turner 2002). The high frequency of trash on motorized trails indicates an opportunity for trail managers to promote “carry-in, carry-out” with motorized user groups and to investigate why littering is so prevalent on motorized trails (maybe because of lack of trash facilities at parking areas, user behavior, or social norms).

3.5 Stream Crossings

Sediment inputs to streams degrade aquatic habitat (Allan 1995) and visitors to natural areas have a low tolerance for erosion near stream banks (Noe et al. 1997). However, we found that only 38 percent of all crossings had no sediment inputs and sediment inputs occurred on all trail types (motorized, non-motorized, and non-mechanized). Moderate sediment inputs occurred at 18 percent of motorized crossings, 8 percent of non-motorized crossings, and 32 percent of non-mechanized stream crossings (Table 5). The most severe category of sediment inputs, catastrophic, occurred on 13 percent of motorized trails, 4 percent of non-motorized trails, and 6 percent of non-mechanized trails (Table 5).

Installation of bridges and culverts on trails is recommended to minimize degradation of water quality (Hammitt and Cole 1998). On motorized trails, 85 percent of stream crossings in our study had bridges or culverts (Table 5), but 53 percent of crossings with bridges or culverts still had sediment input to stream channels. On non-motorized trails, 30 percent of bridges and culverts had sediment additions, as did 48 percent of improved crossings on non-mechanized trails. Proper planning, installation, and maintenance of crossing structures are critical to minimizing sediment inputs and protecting water quality (Maine Forest Service 2004). A study of unpaved forest roads found that crossing structures installed without proper best management practices resulted in sediment input to the streams 44 percent of the time (Maine Forest Service 2006).

4.0 CONCLUSIONS

All trail types (motorized, non-motorized, and non-mechanized) contribute sediment to streams and degrade stream quality. The prevalence of sediment inputs from trails to streams should be a concern for recreation managers because of the direct implications for water quality and aquatic biodiversity (Allan 1995). Despite the ecological and societal importance of maintaining clean water (Postel and Carpenter 1997), we could find few other studies examining sediment inputs from trails to water bodies (Rinella and Bogon 2003). Evaluating stream crossings during trail assessments, as well as establishing guidelines and best management practices for installation, maintenance, and repair of crossing structures, would help ensure that recreation trails are not degrading water quality.

Overall, we found that motorized trails had greater soil disturbance and more frequent ruts and erosion than did non-motorized and non-mechanized trails. Most motorized trails are located on roadbeds with a recent history of human impacts and are heavily managed (e.g., gravel additions and routine grading). The location and management regime of motorized trails may be both ecologically and socially appropriate. However, this study reports on trail conditions and compares conditions across trail types but cannot make value judgments regarding the acceptability of these types of impacts (Stankey 1979, Stankey and Manning 1986). As the motorized trail network expands, recreation managers and other stakeholders need discuss the amount and types of impacts that are acceptable for motorized trails. Establishing limits of acceptable change (Stankey et al. 1985, Cole and McCool 1997) will help ensure that trails are managed and designed to reduce environmental impacts and conflicts among user groups.

5.0 CITATIONS

Allan, J.D. 2005. **Stream Ecology: Structure and function of running waters.** Dordrecht, The Netherlands: Kluwer Academic Publishers.

Bosworth, D. 2007. **Four threats to the health of the nation's forests and grasslands.** Washington, DC: U.S. Forest Service.

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

Cole, D.N.; McCool, S.F. 1997. **Limits of Acceptable Change and natural resources planning: when is LAC useful and when is it not?** In: McCool, S.F.; Cole, D.N., comps. Proceedings - Limits of Acceptable Change and related planning processes: progress and future directions; 1997 May 20-22; Missoula, MT. Gen. Tech. Rep. INT-371. Ogden, UT: US Department of Agriculture, Forest Service, Rocky Mountain Research Station. 84 p.

Conrad, R. 1997. **National survey highlights agency training need in the United States.** International Journal of Wilderness. 3(4): 9-12.

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

Demrow, C.C. 2002. **Maine trails manual: guidelines for recreation trail construction in Maine.** Augusta, ME: Maine Department of Conservation, Bureau of Parks and Lands.

Floyd, M.F.; Jang, H.; Noe, F.P. 1997. **The relationship between environmental concern and acceptability of environmental impacts among visitors to two US National Park settings.** Journal of Environmental Management. 51: 312-391.

Hammitt, W.E.; Cole, D.N. 1998. **Wildland recreation: Ecology and management (2nd ed.).** New York: John Wiley and Sons.

Hendee, J.C.; Stankey, G.H.; Lucas, R. 1990. **Wilderness management (2nd ed.).** Colorado: North American Press.

International Mountain Bike Association. (2004). **Trail solutions: IMBA's guide to building sweet singletrack.** Colorado: International Mountain Bike Association.

Jensen, C.R.; Guthrie, S.P. 2006. **Outdoor Recreation in America (6th ed.).** Illinois: Human Kinetics.

Jewell, M.C.; Hammitt, W.E. 2000. **Assessing soil erosion on trails: A comparison of techniques.** In: Cole, D.N.; McCool, S.F.; Borrie, W.T.; O'Loughlin, J., comps. Wilderness science in a time of change conference—Volume 5: Wilderness ecosystems, threats, and management; 1999 May 23-27; Missoula, MT. Proceedings RMRS-P-15-VOL-5. Ogden, UT: U. S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 133-140.

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

Leung, Y.-F.; Marion, J.L. 1996. **Trail degradation as influenced by environmental factors: a state-of-knowledge review.** Journal of Soil andWater Conservation. 51: 130-136.

Leung, Y.F.; Marion, J.L. 2000. **Recreation impacts and management in wilderness: A state-of-knowledge review.** In: Cole, D.N.; McCool, S.F.; Borrie, W.T.; O'Loughlin, J. comps. Wilderness science in a time of change conference—Volume 5: Wilderness ecosystems, threats, and management; 1999 May 23-27; Missoula, MT. Proceedings RMRS-P-15-VOL-5. Ogden, UT: U. S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 23-48.

Liddle, M.J. 1997. **Recreation ecology: The ecological impact of outdoor recreation and ecotourism.** London: Chapman & Hall.

Maine ATV Task Force. 2003. **ATV solutions: recommendations of Gov. John Baldacci's ATV task force.** Augusta, Maine: Office of the Governor.

Maine Forest Service. 2004. **Best management practices for forestry: Protecting Maine's water quality.** Augusta, Maine: Department of Conservation, Maine Forest Service.

Maine Forest Service. 2006. **Maine forestry best management practices use and effectiveness, 2005.** Augusta, Maine: Department of Conservation, Maine Forest Service.

Manfredo, M.J.; Driver, B.L.; Brown, P.J. 1983. **A test of concepts inherent in experience based management of outdoor recreation areas.** Journal of Leisure Research. 15: 263-283.

Manning, R.; Jacobi, C.; Marion, J.L. 2006. **Recreation monitoring at Acadia National Park.** The George Wright Forum. 23(2): 59-72.

Marion, J.L. 1994. **An assessment of trail conditions in Great Smoky Mountains National Park. Research/ resources management report.** Atlanta, GA: National Park Service, Southeast Region.

Marion, J.L. 2007. **Monitoring manual for formal trails Great Falls Parks.** Unpublished field manual.

Blacksburg, VA: U.S. Geological Survey, Virginia Tech Field Station.

Marion, J.L.; Roggenbuck, J.W.; Manning, R.E. 1993. **Problems and practices in backcountry recreation management: A survey of National Park Service managers.** Natural Resources Report NPS/NRVT/NRR-93/12. Denver, CO: USDI, National Park Service.

Marion, J.L.; Leung, Y.-F. 2001. **Trail resource impacts and an examination of alternative assessment techniques.** Journal of Park and Recreation Administration. 19: 24-25.

Marion, J.L.; Olive, N. 2006. **Assessing and understanding trail degradation: Results from Big South Fork National River and Recreational Area, Final Research Report.** Reston, VA: U. S. Department of the Interior, U.S. Geological Survey.

Meyer, K.G. 2002. **Managing degraded off-highway vehicle trails in wet, unstable, and sensitive environments.** Report No. 2E22A68. Missoula, MT: USDA Forest Service, Technology and Development Program.

Noe, F.P.; Hammit, W.E.; Bixler, R.D. 1997. **Park user perceptions of resource and use impacts under varied situations in three national parks.** Journal of Environmental Management. 49(3): 323-336.

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

Postel, S.; Carpenter, S. 1997. **Freshwater ecosystem services.** In: Daily, G., ed. Nature's services: Societal dependence on natural ecosystems. Washington, DC: Island Press.

Reisinger, T.W.; Aust, M. 1990. **Specialized equipment and techniques for logging wetlands.** In: International winter meeting of American Society of Agricultural Engineers; 1990 December 18-21; Chicago, Illinois. ASAE Paper 90-7570.

Rinella, D.J.; Bogan, D.L. 2003. **Ecological impacts of Three Lower Kenai Peninsula, Alaska, ATV Stream Fords.** Anchorage, AK: Alaska Department of Environmental Conservation.

Roggenbuck, J.W.; Williams, D.R.; Watson, A.E. 1993. **Defining acceptable conditions in wilderness.** Environmental Management. 17: 187-197.

Ryder, R.; Post, T.; Welsch, D. 2006. **Best management practices implementation monitoring protocol.** Northeastern Area Association of State Foresters-Water Resources Committee.

Shafer, S.C.; Hammit, W.E. 1995. **Congruency among experience dimensions, condition indicators, and coping behaviors in wilderness.** Leisure Science. 17: 263-279.

Stangl, J.T. 1999. **Effects of recreation on vegetation.** In: Olliff, T.; Legg, K.; Kaeding, B., eds. The effects of winter recreation on wildlife: a literature review and assessment. Wyoming: National Park Service, Yellowstone National Park: 119-121.

Stankey, G.H. 1979. **A comparison of carrying capacity perceptions among visitors in two wilderness areas.** Res. Pap. INT-242. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station.

Stankey, G.H.; Cole, D.N.; Lucas, R.C.; Petersen, M.E.; Frissell, S.S. 1985. **The limits of acceptable change (LAC) system for wilderness planning.** Gen. Tech. Rep. INT-176. Ogden, UT: U. S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station.

Stankey, G.H.; Manning, R.E. 1986. **Carrying capacity of recreational settings: a literature review.** INT 4901 Publication #166. Washington, DC: The President's Commission on Americans Outdoors.

Turner, J.M. 2002. **From woodcraft to 'Leave No Trace: Wilderness, consumerism, and environmentalism in twentieth-century America.** Environmental History. 7(3): 462-484.

Vaske, J.J.; Donnelly, M.P.; Shelby, B. 1993. **Establishing management standards: Selected examples of the normative approach.** Environmental Management. 17: 629-643.

Whittaker, P.L. 1978. **Comparisons of surface impact by hiking and horseback riding in the Great Smoky Mountains National Park.** NPS-SER Res./Res. Man. Rept. No. 24. Atlanta, GA: U. S. Dept. Interior, National Park Service.

Wilson, J.P.; Seney, J.P. 1994. **Erosional impacts of hikers, horses, motorcycles and off-road bicycles on mountain trails in Montana.** Mountain Research and Development. 47: 77-88.