Recreation Trails in Maine and New Hampshire: A Comparison of Motorized, Non-Motorized, and Non-Mechanized Trails

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Abstract

According to the U.S. Forest Service, public recreation is one of the four greatest threats to the health of forestland. To assess the impact of recreation trails on forestlands we sampled 112 trail segments (55 motorized, 26 non-motorized, 31 non-mechanized) in Maine and New Hampshire. We collected data at 11 random points along a trail segment (2km or 5km), continuously along the segment, and at stream crossings. On each trail 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. However, 74% of the motorized trail data points were located on seasonal, current, and historic roads and right-of-ways. We can not determine the contribution of current trail use or non-recreational uses to the physical dimensions of motorized trails. Non-motorized and non-mechanized trails were frequently located on areas specifically established for recreation. Non-motorized trails had 17% of data points on roads and non-mechanized trails had only 9%. Non-mechanized trails had the highest density of excessively muddy sections. This is likely due to the lack of current and/or historic roads on non-mechanized trails that would have compacted and hardened the trail surface. Motorized trails are routinely maintained by mechanical equipment to prevent degradation and unsafe conditions. We found that 38% of stream crossings had no sediment inputs, 29% of crossings had trace sediment inputs, and 24% had measureable inputs (formed a sediment fan). The remaining 9% of stream crossings had catastrophic sediment additions (significantly altered stream morphology) and included trails of all use types (non-mechanized, non-motorized, and motorized). The results of this study indicate that all trail types can contribute sediment to streams and degrade stream quality. The data also show significant differences in physical parameters among trail types but past land use, as well as current recreational use, may contribute to these differences.

1.0 Introduction

Public recreation is one of the four greatest threats to the health of forests in the U.S. (Bosworth 2007). In the Northeast, recreational uses on private and public forest lands are rapidly increasing, especially use of off-road vehicles (ORVs) (ME ATV Task Force 2003, Jensen and Guthrie 2006). As the demand for recreation increases, managers must balance the need for 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 (Conrad 1997, Marion et al. 1993). The large majority of motorized trails in the Northeast are located on private land (ME 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., Olive and Marion 2009, Deluca et al. 1998, Wilson and Seney 1994, Whittaker 1978). This study provides baseline information about on-the-ground trail conditions and can help managers understand the environmental impact of different recreation types and begin to identify specific management activities that can be used to protect soils and water quality.

2.0 Methods

In Maine and New Hampshire we sampled 112 trail segments totaling 335 km of recreation trails (Figure 1). These trails were grouped in 3 categories: 1) motorized trails: trails with primary use of ATV or snowmobiling (n=55, 164km), 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). Data

Figure 1. Sampling Locations

were collected along a trail segment either 2 km or 5 km in length. The beginning of the segment was determined by a random distance from the start point, usually a trailhead or road crossing. All continuous data were corrected 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 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 5 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. Even with the exclusion of sampling points with a gravel surface we retained 51% of sample sites on motorized trails, 83% on non-motorized trails, and 96% 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, Marion 2007), highly rutted and/or eroded sections (trail ≥3 m in length with tread depth exceeding 13 cm, Marion 2007) and 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).

An ANOVA (PROC GLM, SAS 1999) was used 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).

Table 1. Average tread width, cross-sectional area (CSA), and tread depth for motorized, non-motorized, and non-mechanized recreation trails. Different letters represent significant differences among groups.

	Tread Width (m)		CSA* (cm3)		Max Tread Depth* (cm)	
	Mean	SE	Mean	SE	Mean	SE
Motorized	2.03[a]	(0.10)	736.4[a]	(41.7)	7.6[a]	(0.4)
Non-motorized	1.59[b]	(0.22)	427.0[b]	(50.0)	4.5[b]	(0.3)
Non-mechanized	0.62[c]	(0.04)	164.2[c]	(19.4)	4.0[b]	(0.2)

*excludes sample locations with gravel surfaces

3.0 Results and Discussion

3.1 Tread Width

Motorized trails have an average tread width of 2.03 m (Table 1). Motorized trails were significantly wider than other trails because of the larger physical dimensions 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 are similar to guidelines for recreation trails in Maine which recommend ATV trails be 1.5 m wide and snowmobile trails be 1.8-2.4 m wide (Demrow 2002). Non-motorized trails had an average tread width of 1.59 m (Table 1). The recommended width of mountain bike trails depends on the desired difficulty of the trail. Easy trails are the widest with a recommended width of 0.91-1.8 m (IMBA 2004) and guidelines for trail construction in Maine suggest 1.2 m for easy mountain bike trails, 0.5-.6 m for more difficult trails, and 0.3 m for the most difficult mountain bike trails (Demrow 2002). Trails in this study had an average width greater than these recommendations but because most non-motorized trails are shared by mountain bikers and hikers the wider tread may improve safety and reduce user conflicts. Non-mechanized trails were significantly narrower than both non-motorized and motorized trails. The average tread width was 0.62 m (Table 1). This was consistent with recommendations for Maine hiking trails (0.3-.9 m, Demrow 2002) and with observed tread width of hiking trails in Acadia National Park (range: 0.53-0.89 m, Manning et al. 2006).

3.2 Cross-sectional Area (CSA) and Tread Depth

CSA and tread depth are commonly used as 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 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 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 limits the disturbance of soils by snowmobiles (Liddle 1997). However, snowmobiles can cause soil disturbance and erosion when snow cover is reduced due to weather conditions, topography, or on steep slopes (Stangl 1999). However, a large percentage (74%, Table 3) of motorized trail data points were located on seasonal, current, and historic roads and right-of-ways. Past use likely altered soil properties and we cannot determine the contribution of recreational use or non-recreational uses to the physical dimensions of trails.

Non-motorized trails (427.0 cm^2) had significantly greater CSA 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 be

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). Different letters represent significant differences among groups.								
	CSA* (cm3)		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 function of greater tread width and not the impact of mountain bikes on soil compaction and erosion. 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 smaller than non-motorized trails in this study but the CSA of ATV trails was 2-fold greater (Olive and Marion 2009).

3.3 Excessively Muddy and Rutted/Eroded Trail Segments

Non-mechanized trails had the greatest frequency of trail sections with excessively muddy soils (6.6 sections/km, Table 4); 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% of sampling points, Table 3) and the majority of trail miles (92% of sampling points, Table 3) located on trails exclusively used for recreation (not forestry, fire protection, or transportation). The geographic location and management practices 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 management, 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 et al. 1990, Marion 1994). Muddy sections on motorized trails can degrade quickly due to the weight of machinery, particularly ATVs. On motorized trails, 48% of point samples were taken on a gravel surface and 73% were located 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), locating trails on existing road beds 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 more serious concern to managers. They indicate areas with high levels of soil disturbance or loss, (Roggenbuck et al. 1993, Vaske et al. 1993) which creates safety hazards (Leung and Marion 1996; Marion and Leung 2001) and often requires costly management actions or trail improvements (Olive and Marion 2009). Motorized trails (1.6 sections/km, Table 4) had significantly greater frequency of rutted and eroded segments than non-mechanized trails (0.8 sections/km, Table 4). This occurred even though non-mechanized trails had the highest frequency of excessively muddy trail segments that are vulnerable to rutting and erosion. Motorized trails, particularly ATV trails, are thought to be 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 could be a result of the high proportion of motorized trails on historic, seasonal, or existing roads (74%) 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

Table 3. The percentage of sample points located on trails with a gravel surface, a historic, seasonal, or current roadway, or on a trail specifically designed for recreational purposes on motorized, non-motorized, and non-mechanized trails.						
	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, occurrence of litter on motorized, non-motorized, and non-mechanized recreation trails. Different letters represent significant differences among groups.						
	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)

frequencies on mountain bike (0.7 sections/km, Marion and Olive 2006) and hiking (1.31 sections/km, Marion and Olive 2006; 0.9-.8 sections/km, Manning et al. 2006) trails.

3.4 Presence of Trash

Motorized trails had significantly greater frequency of trash visible from the trail than other trail types. Motorized trails had an average of 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 shows that recreation users view trash to be highly undesirable in natural areas (Floyd et al. 1997; Shafer and Hammit 1995; Roggenbuck et al. 1993). The authors attribute the low frequency of trash on non-mechanized trails to success of the leave-no-trace program. These 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" principles within motorized user groups and investigate specific reasons (lack of trash facilities at parking areas, user behavior, social norms, etc.) why littering is so prevalent on motorized trails.

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% 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% of motorized crossings, 8% of non-motorized crossings, and 32% of non-mechanized stream crossings (Table 5). The most severe category of sediment inputs, catastrophic, occurred on 13% of motorized trails, 4% of non-motorized trails, and 6% on non-mechanized trails (Table 5).

Table 5. The percentage of stream crossing structures with different volumes of sediment inputs by trail type (motorized, non-motorized, and non-mechanized).

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

Bridges and culverts are recommended on trails to minimize degradation of water quality (Hammitt and Cole 1998). On motorized trails, 85% of crossings had bridges or culverts (Table 5), but 53% of crossings with bridges or culverts resulted in sediment addition to stream channels. On non-motorized trails, 30% of bridges and culverts had sediment additions, as did 48% of improved crossings on non-mechanized trails. Proper planning, installation, and maintenance of crossing structures is critical to minimize sediment inputs and protect water quality (MFS 2004). A study of unpaved forest roads found that crossing structures installed without proper best management practices (BMPs) resulted in sediment inputs to the stream 44% of the time (MFS 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 recreation trails are not degrading water quality.

Overall, we found that motorized trails had greater soil disturbance and more frequent ruts and erosion than non-motorized and non-mechanized trails. The majority of motorized trails are concentrated on road beds with a recent history of human impacts and are heavily managed (gravel additions and routine grading). The location and management regime of motorized trails may be both ecologically and socially appropriate. However, this study can only quantify trail conditions and compare 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 need to initiate a social conversation about the amount and types of impacts that are acceptable for motorized trails. Establishing limits of acceptable change (Stankey et al. 1985, Cole and McCool 1998) will ensure trails are managed and designed to reduce environmental impacts and conflicts among user groups.

5.0 References

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