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Off-road vehicle best management practices for forestlands: A review of scientific literature and guidance for managers

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ABSTRACT: Management of off-road vehicles (ORVs) on forestlands has become increasingly challenging as various user groups compete for a finite amount of land on which to recreate. Additionally, no uniform methods exist for managing ORVs in forests to reduce their impacts to the environment and lessen conflicts with other user groups. The objectives of this paper are to review recent research on the environmental and social effects of ORVs in forested landscapes, and based upon the best available science, propose Best Management Practices (BMPs) for forestlands to help minimize ORV impacts. We found extensive scientific literature documenting the physical and ecological effects of ORVs in forestlands, ranging from soil compaction to non-native plant dispersal. Many species of wildlife are also affected by ORV use through direct and indirect mortality, disturbance and cumulative loss of habitat. Conflict with non-motorized users has been documented as well, resulting in diminished recreational experience and displacement of quiet users. The BMPs presented here for ORV management and monitoring in forestlands should help managers provide opportunity for motorized recreation while protecting natural resources and reducing user conflicts.

Keywords: Off-road vehicle, ORV, Best Management Practices, BMPs, erosion, stream sedimentation, invasive species, wildlife disturbance, user conflicts

INTRODUCTION

Management of outdoor recreation including off-road vehicles (ORVs) use is becoming increasingly challenging as more people recreate on public and private forestlands. Technological advances have given ORVs more power and control, allowing even beginners to access remote wildlands. This has increased the popularity of riding ORVs, and the potential for impacts on natural resources and conflicts between off-roaders and non-motorized forest visitors. The environmental and social impacts of their use have been well documented in hundreds of research articles, extensive literature reviews (e.g., Joslin and Youmans 1999, Schubert and Associates 1999, Gaines et al. 2003, Davenport and Switalski 2006, Ouren et al. 2008) and books (e.g., Knight and Gutzwiller 1995, Liddle 1997, Havlick 2002). While the majority of research on this topic has focused on arid locations (e.g., Webb and Wilshire 1983) and more recently beach environments (e.g., Lucrezi and Schlacher 2010), many recent studies have also addressed ORV use in forested landscapes.

Best Management Practices (BMPs) provide science-based criteria and standards that land managers follow in making and implementing decisions about human uses and projects that affect natural resources. BMPs are usually developed for a particular land use and are based on ecological considerations, legal obligations and pragmatic experience, and should be supported by the best available scientific knowledge. Several states have adopted ORV management plans, policies or strategic plans (e.g., Michigan Department of Natural Resources 2008, California State Parks 2009, Arizona State Parks 2010) and trail design, and construction and maintenance manuals have been written (e.g., Wernex 1994, Meyer 2002, Crimmins 2006). Unfortunately, no consistent broad-based guidelines have been developed for planning, implementing and monitoring off-road vehicle use on forestlands based on ecological considerations. In addition, most of the state plans and policies, and design and construction manuals, tend to consider ORV trail and forest road design, management, maintenance and monitoring from a viewpoint centered around legal and administrative stipulations, user needs and desires, and avoiding soil erosion. It is very seldom that such state plans or design and construction manuals take a more ecological or holistic viewpoint in deciding where to site trails, or one that stresses consideration of multiple natural resources.

This paper reviews recent scientific literature on ORV effects on forestlands, and based upon the best available science, proposes Best Management Practices (BMPs) to aid land managers in travel planning or in any decision-making process related to off-road vehicle management on forested lands. Each section reviews research on a key resource impact of ORVs, and is followed by a list of BMPs for planning and decision-making, implementation and monitoring to mitigate the impact. These BMPs will help transportation managers place ORV routes in areas where they can be enjoyed by motorized recreationists while minimizing harm to the environment and reducing user conflicts.

Off-road vehicle BMPs can be easily used by a manager who wants to incorporate science into creating an ecologically and socially sustainable route system. For example, research has found that the risk of stream sedimentation and negative impacts on aquatic habitat are highest at stream crossings. Thus, we propose the BMP to choose route locations with the fewest number of stream crossings when planning a route. In another example, research found that ORVs cause disturbance in a number of wildlife species. Accordingly, our BMP recommends setting levels of acceptable disturbance that are compatible with maintaining species viability. Furthermore, studies have found that closing routes benefits plant and wildlife populations. We further recommend that routes be closed and restored if there is an unacceptable impact to the resource.

This paper is an abridged and updated version of our original report, *"Best Management Practices for Off-Road Vehicle Use on Forestlands,"* available online at: http://www.wildlandscpr.org/ORV-BMPs. These BMPs have already been used during environmental analyses for travel management planning on many national forests (e.g., USDA FS 2009, USDA FS 2010, USDI BLM and USDA FS 2010). For example, the Ashley National Forest found them to be useful to fill information gaps and supplement existing direction (USDA FS 2009). Additionally, the Forest Service has recently included these Best Management Practices for reference in its report, *"Comprehensive Framework for Off-Highway Vehicle Trail Management"* (Meyer 2011). This official Forest Service document will be widely used in all future efforts to manage off-road vehicle use on national forest lands.

METHODS

To identify the most current research on off-road vehicles, we searched an online bibliographic database of over 20,000 citations documenting the physical and ecological effects of roads and off-road vehicles (http://www.wildlandscpr.org/bibliographic-database-search). First completed in 1995, this database is updated every two years by Wildlands CPR by systematically searching for literature related to roads and motorized recreation. The database contains a variety of scientific and "grey" literature including journal articles, conference proceedings, books, lawsuits, and agency reports. The database was most recently updated in 2010 using an established protocol that systematically searches 13 ecological and scientific databases. Seventeen primary keywords/descriptors were used to identify research on any road, highway, or ORV effect (positive or negative) on ecosystems, wildlife, and natural resources. Each primary keyword was used alone and in Boulian combination with 89 descriptor words and phrases. Each secondary keyword was used alone and in Boulian combination with primary keywords and other descriptor words and phrases (for a list of keywords please contact lead author).

Review of the Literature and Best Management Practices

We found extensive research on the effects of off-road vehicles (ORVs) on natural resources. Several studies published in the 1970s first documented the effects of ORVs on soils in the California desert. A flurry of studies followed resulting in the first book dedicated to this topic, *Environmental Effects of Off-Road Vehicles – Impacts and Management in Arid Regions* (Webb and Wilshire 1983). As ORV popularity expanded beyond the California deserts, so did research examining its effects around the globe. Impacts on streams, vegetation, and wildlife have come to the forefront of research, as have other ecosystems such as beach environments and forestlands - the primary focus of this review.

Soil Compaction and Erosion Research

Weighing several hundred pounds, ORVs compress and compact soil, reducing the absorption of water into the soil, resulting in increased flow of water across the ground (Sack and da Luz 2003, Meadows et al. 2008). This surface flow increases erosion of soils and can also add sediment to streams (Chin et al. 2004, Ayala et al. 2005, Welsh 2008), which degrades water quality, buries fish eggs, and generally reduces the amount and quality of aquatic habitat (Newcombe and MacDonald 1991).

In ORV use areas, soil erosion is accelerated directly by the vehicles, and indirectly by increased runoff of precipitation and by creating conditions favorable to wind erosion. Knobby and cup-shaped tires that help ORVs climb steep slopes are responsible for major direct erosional losses of soil. As the tire protrusions dig into the soil, forces far exceeding the strength of the soil are exerted, resulting in a "rooster tail" of soil and small plants thrown behind the vehicle. In an Ohio forest, Sack and da Luz (2003) measured erosional losses in high-use ORV areas as high as 209 kg/m^2. Meadows et al. (2008) found that ATV trails on U.S. Forest Service lands on average produced 10 times more sediment that undisturbed soils. It has also been demonstrated experimentally that sediment loss increases with increased ORV traffic (Foltz 2006), and the greatest sediment yields occur when trails are wet (Wilson and Seney 1994).

Most soils are vulnerable to compaction and erosion due to several factors. An analysis of more than 500 soils at more than 200 sites found that virtually all types of soils are susceptible to ORV damage (Schubert and Associates 1999). Clay-rich soils, while less sensitive to direct mechanical displacement by ORVs, have higher rates of erosion than most other soil types, and when compacted, produce a strong surface seal that increases rainwater runoff and gullying. Sandy and gravelly soils are susceptible to direct excavation by ORVs, and when stripped of vegetation, are susceptible to rapid erosion – usually by rill and gully erosion.

ORV impacts on forest soils are compounded by the loss of vegetation following ORV use. Stable vegetation keeps soil in place; once anchoring vegetation is removed, soil erosion increases. When vehicles damage or uproot plants, exposed soils easily become wind-blown or washed away by water. Wilshire et al. (1978) first described the direct effects of ORVs on vegetation, such as crushing and uprooting of foliage and root systems, as well as the indirect effects caused by the concomitant erosion. The indirect effects include undercutting of root systems as vehicle paths are enlarged by erosion, creation of new erosion channels on land adjacent to vehicle-destabilized areas due to accelerated runoff or wind erosion, burial of plants by debris eroded from areas used by vehicles, and reduction of biological capability of the soil by physical modification and stripping of the more fertile upper soil layers. Biological soil crusts (commonly found in deserts, but also present in some forestlands) are particularly sensitive to wind erosion following ORV use and take decades to recover (Belnap 2003).

Stream Sedimentation Research

While driving on roads has long been identified as a major contributor to stream sedimentation (for review see Trombulak and Frissell 2000), recent studies have found ORV use on trails to be a significant source of fine sediment in streams (Chin et al. 2004, Ayala et al. 2005, Welsh 2008). Stream sedimentation greatly degrades aquatic habitat (Newcomb and MacDonald 1991). For example, Chin et al. (2004) found that in watersheds with ORV use streams contained higher percentages of sands and fine sediment, lower depths and lower volume – all characteristics of degraded stream quality.

While forest roads often have greater erosion potential, ORV routes often lack culverts or bridges at stream crossings, and users often simply drive across creeks. By fording creeks, sediment is released into the water by several mechanisms including: 1) concentration of surface runoff through the creation of wheel ruts, 2) exposed surfaces from the existence of tracks, 3) increased runoff from soil compaction, 4) vehicle backwash, and 5) undercutting of banks from waves (Brown 1994). A modeling exercise found that the average annual sediment yield from one ORV stream crossing in Alabama could reach 126.8 tons/ha (Ayala et al. 2005). Another study in Colorado found that ORV trails produced six times more sediment than unpaved roads and delivered 0.8 mg/km^2 of sediment to the stream network each year (Welsh 2008). Coe and Hartzell (2009) recently reported that the well-traveled Rubicon jeep trail in California's Sierra Nevada Mountains had rates of stream sedimentation 50 times higher than adjacent forest roads.

Best Management Practices for soils

PLANNING AND DECISION-MAKING BMPS FOR FOREST SOILS

- Do not locate routes in areas with highly erodible soils.
- Locate routes only in areas with stable soils; avoid locating routes in areas with biological crusts.
- Do not locate routes to climb directly up hillslopes. Route grades should be kept to a minimum and not exceed an eight degree (15 %) grade.
- Do not locate routes above treeline or in other high elevation areas that are ecologically significant and/or especially prone to erosion.
- Locate routes a minimum distance (as listed below) from waterbodies and wetlands:
    - Fish-bearing streams and lakes – 91 m (300 ft)
    - Permanently flowing non-fish-bearing streams – 46 m (150 ft)
    - Ponds, reservoirs, and wetlands greater than one acre – 46 m (150 ft)
- Do not designate new routes requiring stream crossings and prioritize closure, re-routing or creating bridge crossings for existing routes that have stream crossings.
- Do not locate routes in areas with soils contaminated by mine tailings, or mine tailings reclamation sites, at least until they are recovered, fully stable and able to sustain safe ORV usage. If route construction is necessary, reclamation activities should be completed prior to route construction.
- Close and restore routes that cause high levels of erosion (e.g., raise sedimentation above Total Maximum Daily Loads (TMDL) and reduce native fish population potential).
- Require all motorized camping to occur in designated campsites. Reclaim undesignated motorized camping sites.

IMPLEMENTATION BMPS FOR FOREST SOILS

- Identify the type or types of soil and steepness in the area that is being affected by ORVs and use this information to prioritize mitigation efforts and create target management objectives to minimize erosion.

- Identify where waterbodies and wetlands are located, where routes cross them, and whether fish are present.
    - Prioritize stream crossing closures and route relocations, and if necessary, determine appropriate sites for upgrades and/or bridge crossings.
- Ensure adequate maintenance of bridges and culverts on routes to help prevent unauthorized stream crossings that might damage soils, streambanks, riparian vegetation, or other aquatic resources.
- Estimate the average soil loss for areas that are currently and obviously negatively affected by ORVs using the Universal Soil Loss Equation. Close and restore routes if the soils are determined to exceed standards for tolerable soil loss.
- If closing or moving a particularly damaging route is not possible, mitigate erosion with waterbars or other erosion control measures.
- Close and restore areas that have become "mud bogging areas," or are prone to "mud bogging."
- Close and restore routes where it has been determined, through analysis, that cumulative impacts of erosive activities (e.g., ORVs combined with fire, livestock grazing or other erosive stressors) are leading to a stream failing to meet erosion standards.
- Prioritize for closure renegade routes going directly up hillslopes, into wetland areas (including wet meadows), or adjacent to designated routes.
- Adaptively manage by closing or mitigating a damaging route if monitoring identifies that forest soil conditions are no longer in compliance with planning and decision-making BMPs.

MONITORING BMPS FOR FOREST SOILS

- Monitor for the amount of erosion occurring on all routes (designated and renegade). Gather data needed for the Universal Erosion Soil Loss Equation.
- Regularly survey for and identify renegade off-route spurs.
- Map stream crossings without culverts or bridges and note stream sedimentation levels and visible soil/ channel impacts in these areas.
- Identify areas of significant amounts of bare soil or route-widening along routes using photographs and route width measurements.
- Monitor closed and restored routes to ensure the measures taken are effectively mitigating impacts to forest soils.

Trampling Impacts on Vegetation and the Spread of Invasive Plants Research

Riding a several hundred pound ORV off-route or cross-country can crush, break, and ultimately reduce overall vegetative cover. Vehicular impacts on vegetation range from selective kill-off of the most sensitive plants to complete loss of vegetation in large "staging areas." Plants that do survive are weakened, malformed, and more susceptible to disease and insect predation. Trampling by ORVs can also damage germinating seeds – even those in the soil. A study that examined ORV use on several U.S. National Forests found at least a 40 percent reduction in vegetation following ORV traffic (Meadows et al. 2008). Similarly, in a desert example in southern California, Groom et al. (2007) found 4-5 times fewer plants in an ORV use area than a protected area. However, when one of the study areas was closed to motorized use (and experienced a year of high rainfall), there appeared to be a recovery of that population.

In addition to trampling effects, ORVs are a major vector for non-native invasive plant species. With knobby tires and large undercarriages, ORVs can unintentionally transport invasive non-native species deep into forestlands. For example, one study found that in a single trip on a 16.1 km (10 mi) course in Montana, an ORV dispersed 2,000 spotted knapweed (*Centaurea stoebe*) seeds (Montana State University 1992). In Wisconsin, a survey of seven invasive plant species along ORV routes found at least one of these exotic plant species on 88% of segments examined (Rooney 2005). ORVs in roadless areas pose a particular risk of spreading invasive non-native species because roadless areas often have less weeds present. Gelbard and Harrison (2003) found that ORVs are the chief vector for invasive species infestation in California roadless areas, which were shown to be very important refuges for native plants. Furthermore, as a result of ORV use, the size and abundance of native plants may be reduced, which in turn permits invasive or nonnative plants to spread and dominate the plant community (GAO 2009).

Impacts to vegetation can have cascading effects throughout an ecosystem. For example, on an intensively used ORV route in Idaho, native shrubs, bunch grasses, and biological crust were greatly reduced close to the route and replaced with rabbitbrush (*Chrysothamnus* spp.) and non-native cheat grass (*Bromus tectorum.*; Munger et al. 2003). Because of these habitat changes, fewer reptiles were found alongside the route than were found 100 m away (328 ft). In another example of cascading impacts, Waddle (2006) found that three out of four species of ground-dwelling anurans in Florida were negatively influenced by ORVs due to trampling of vegetation and altered hydrology.

Best Management Practices for vegetation

PLANNING AND DECISION-MAKING BMPS FOR VEGETATION

- Locate routes in areas that do not have sensitive, threatened or endangered plant species.
- Locate routes where there are no unique plant communities such as aspen stands, bogs, wetlands, riparian areas and alpine habitat types.

IMPLEMENTATION BMPS FOR VEGETATION

- Identify sensitive, threatened, and/or endangered plants present in ORV use areas, as well as rare, fragile and/or unique plant communities (i.e., aspen stands, bogs, wetlands, riparian, alpine areas). Record the survey information into a GIS (Geographic Information System) database.
- Close areas where sensitive, threatened and/or endangered plant species are at risk.
- Remove invasive non-native plants from routes when feasible.
- Prohibit motorized camping in areas where invasive plants are a problem.
- Control invasive plants in staging areas to avoid their spread onto routes.
- Identify areas where invasive plants present a problem and require that all ORVs using such areas wash vehicles when exiting such areas.
- Close and restore routes documented as contributing to the spread of non-native invasive plants into relatively weed-free areas.
- Use native species when revegetating a closed route.
- Modify livestock grazing practices or halt grazing in newly restored areas where routes have been closed.

MONITORING BMPS FOR VEGETATION

- Monitor routes for sensitive, threatened, and/or endangered plants in ORV use areas, as well as rare, fragile and/or unique plant communities.
- Monitor for unauthorized spur routes into areas with sensitive, threatened, and endangered plant species.
- Monitor routes for presence and spread of non-native species or the decline of native species.
- Monitor closed and restored routes to ensure effective mitigation for damaged vegetation is occurring.
- Monitor the success of revegetation projects.
- Adaptively manage by closing or mitigating a route if monitoring identifies that vegetation conditions are no longer in compliance with planning and decision-making BMPs.

Wildlife Mortality, Disturbance, and Habitat Loss Research

Driving ORVs in forested environments has led to direct and indirect impacts on wildlife. When driven at high speeds, ORVs can collide with small animals and cause direct mortality. However, there are also many indirect impacts that can increase wildlife mortality. For example, in a review of research on mesocarnivores in the U.S., Weaver (1993) reported that ORV access increases the trapping vulnerability of American marten (*Martes americana*), fisher (*Martes pennanti*), and wolverine (*Gulo gulo*). Lynx (*Lynx lynx*) are also thought to be sensitive to road density due to increased trapping pressure (Singleton et al. 2002).

ORV use also increases access for illegal harvest of wildlife in areas that are difficult for game wardens to patrol. For wolves (*Canis lupus*), one study found that 21 of 25 human-caused mortalities in the US Northern Rockies occurred within 200 m (656 ft) of a motorized route (Boyd and Pletscher 1999). Wolves often travel on roads and off-road vehicle routes where they risk increased poaching pressure. Studies in the US Great Lakes region have found that wolf persistence is reduced when road density exceeds approximately 0.6 km/km^2 (1 mi /mi^2; Wydeven et al. 2001). Grizzly bears (*Ursus arctos horribilis*) are also at risk from poaching and have been found to avoid open roads (e.g., Mace et al. 1996).

Elk (*Cervus canadensis*) have been the most extensively studied animal in relation to motorized access and ORVs. While recent studies have examined the effects of ORVs on elk (Vieira 2000, Wisdom et al. 2004, Naylor et al. 2009), most studies have looked more broadly at the impacts of motorized travel and roads. Research has found that increased motorized access results in decreased elk habitat and security, and increased elk mortality from hunter harvest both legal and illegal (Hayes et al. 2002, McCorquodale et al. 2003, see Rowland et al. 2005 for review).

Probably the most widespread ORV impact on wildlife is disturbance. Within individual species, a number of factors influence the degree of disturbance, including the animal's breeding status, size, and the size of the group it is with (Burger et al. 1995). Studies have shown a variety of disturbance is possible from ORVs, and while these impacts are difficult to measure, repeated harassment of wildlife can result in increased energy expenditure and reduced reproduction. Noise and disturbance from ORVs have been shown to result in a range of effects including increased stress (e.g., elk: Millspaugh et al. 2001), altered movement patterns (e.g., elk: Wisdom et al. 2004, Preisler et al. 2006, Naylor et al. 2009), avoidance of high-use areas or routes (e.g., Florida panthers: Janis and Clark 2002), and disrupted nesting activities (e.g., piping plovers: Strauss 1990).

Vieira (2000) found that elk moved twice as far from ORV disturbance than they did from pedestrian disturbance in Colorado. In studies in eastern Oregon, Wisdom et al. (2004) found that elk moved when ORVs passed within 1,640 m (5381 ft) but tolerated hikers within 500 m (1640 ft), and Naylor et al. (2009) found that elk increased their travel time and thus reduced time spent feeding or resting in response to ORV recreation. In some instances, however, low levels of disturbance do not appear to affect certain species persistence. For example, Zielinski et al. (2008) found that low levels of ORV disturbance in northern California did not change American marten occupancy or probability of detection. However, they did not measure the behavioral, physiological, or demographic responses.

Disruption of breeding and nesting birds is a particularly well documented problem (for review see Hamann et al. 1999). Several species are sensitive to human disturbance with the potential disruption of courtship activities, over-exposure of eggs or young birds to weather, and premature fledging of juveniles. Repeated disturbance can eventually lead to nest abandonment and lead to long-term bird community changes. In one example, Barton and Holmes (2007) found greater songbird nest desertion and abandonment close to ORV trails in northeastern California. While they also found less nest predation along ORV trails, some species had lower abundance than away from ORV trails.

To mitigate the impacts of disturbance, several authors have recommended spatial nest buffer zones from human disturbance for raptors (for review see Richardson and Miller 1997). Closing of ORV routes has been found to successfully restore wildlife habitat. Burger et al. (2007) found lower reproductive success of pine snakes (*Pituophus melanoleucus*) along ORV routes in the New Jersey Pinelands. However, after closing routes near nesting sites, the number of hatchlings increased to pre-disturbance levels.

Best Management Practices for wildlife

PLANNING AND DECISION-MAKING FOR WILDLIFE

- Set levels of acceptable disturbance that are compatible with maintaining species viability or recovery.
- Locate routes in areas that do not have critical habitat (formally designated or just important for survival) for sensitive, threatened and/or endangered wildlife species.
- Locate new routes where they are unlikely to significantly affect the populations of important native wildlife species specifically regarding reproduction, nesting, or rearing.
    - Do not locate routes in areas with concentrated or particularly important ungulate fawning or calving areas.

- Locate routes a minimum distance (as listed below) from waterbodies and wetlands:
  - Fish-bearing streams and lakes – 91 m (300 ft)
  - Permanently flowing non-fish-bearing streams – 46 m (150 ft)
  - Ponds, reservoirs, and wetlands greater than one acre – 46 m (150 ft)
- Locate routes as far as possible, but a minimum of 46 m (150 ft), from natural caves, tunnels, and mines where bat nurseries are commonly found.
- Locate routes in discrete, specified areas bounded by natural features (topography and vegetative cover) to provide visual and acoustic barriers and to ensure that secure habitat is maintained for wildlife.
- Locate routes in forest cover and not in open country. Long sight lines in open country make the visual effects of machines more pronounced.
- Adaptively manage routes that affect wildlife seasonal habitat needs. Reduce route density to below 0.6 km/km^2 (1 mi/mi^2) by permanently closing, or imposing seasonal use restrictions.

IMPLEMENTATION BMPS FOR WILDLIFE

- Survey for sensitive, threatened, and endangered animals, as well as critical habitat (formally designated or just important for survival), in ORV use areas. This survey information should be catalogued and regularly updated in a GIS database.
- Prohibit ORV use in critical habitat for sensitive, threatened, and endangered species.
- Maintain large unfragmented, undisturbed blocks of forestland where no routes are designated.
- Maintain and improve habitat security by protecting whole areas rather than individual route closures.
- Reduce road/route density to below 0.6 km/km^2 (1 mi/mi^2) in important wildlife areas.
- Conduct adequate nest searches to identify raptor nest sites. Seasonally close ORV areas in raptor nesting territories during sensitive nesting phases (e.g., March through August in the Rocky Mountain West).
- If routes are already in important native wildlife habitat, seasonally close during sensitive seasons.
  - Calving/fawning period for known key ungulate calving/fawning areas (e.g., May 15 through June in the Rocky Mountain West).
  - Critical ungulate wintering habitat/winter concentration areas (e.g., December through March in the Rocky Mountain West).
  - Migration corridors during migrations.
- Do not allow the use of ORVs off designated routes for game retrieval.
- Develop public information and educational programs targeting ORV users to raise wildlife awareness, such as information about wildlife species in the focal area, key wildlife sign, and the impacts of ORVs to those species.
- Address recovering carnivores such as grizzly bears and wolves:
  - Prohibit ORV use in grizzly bear habitats that provide important food sources during spring and early summer (e.g., April 1 through July 15 in the Rocky Mountain West). These habitat components include riparian shrub types, aspen stands, wet meadows, and avalanche chutes.
  - In areas with established wolf packs where there is a desire to reduce the potential for disturbance and the risk of illegal killing, limit ORV route densities to less than 0.6 km/km^2 (1 mi/mi^2).

MONITORING BMPS FOR WILDLIFE

- Monitor routes for sensitive, threatened, and endangered animals in ORV use areas.
- Monitor routes to identify whether they are impacting the reproduction, nesting or rearing of key indicator species.
- Monitor routes to identify whether there are unauthorized spur routes, especially if they approach waterbodies, wetlands and bogs that are key habitats for amphibians and reptiles; or natural caves, tunnels and mines where bat nurseries may occur.
- Monitor use concurrently with local wildlife populations to determine their impact on wildlife species.

- Monitor closed and restored routes to ensure they are effectively mitigating impacts to wildlife.
- Manage adaptively through closure, rerouting, or mitigation if monitoring identifies that wildlife conditions are no longer in compliance with planning and decision-making BMPs. ORV use in important wildlife habitats should only be allowed after peer- reviewed studies or data from wildlife and ORV monitoring conclude that wildlife populations will not be impaired.

Recreational Use Conflicts Research

Conflict is defined as an emotional state of annoyance with another group or person that can result in dissatisfaction with a specific experience (Yankoviak 2005). For example, a hiker seeking quiet in nature could experience conflict after encountering an ORV user on the same trail because the ORV use could be perceived as preventing the hiker from attaining his or her goal of a quiet, natural experience. Feelings of conflict often occur among quiet users when they hear motor vehicle noise, witness acts of great speed and/or reckless behavior, smell exhaust, and see visible environmental damage. This all leads to reduced opportunity and displacement of non-motorized recreationists from places they would normally frequent (Moore 1994, Stokowski and LaPointe 2000).

Both motorized and quiet recreationists prefer that trails be managed for multiple uses but with motorized and non-motorized activities separated (Andereck et al. 2001). Where trails are designated as multiple-use, heavy motorized use tends to cause other trail users to pursue opportunities at other locations in order to realize the desired experiences. There are numerous examples of non-motorized recreationists being displaced or leaving an area altogether where motorized use is common (e.g., Moore 1994, Stokowski and LaPointe 2000, Manning and Valliere 2002).

Best Management Practices for use conflicts

PLANNING AND DECISION-MAKING BMPS FOR USE CONFLICTS

- Designate motor-free Quiet Use Zones in both backcountry and front-country settings that emphasize wildlife needs and relatively low-impact recreational activities.
- Prioritize motorized route designations to protect public land resources and the safety of all public land users, and to minimize conflicts with other recreational uses and nearby residences.
- Ensure that ORV use does not preclude meeting the demand for hiking, equestrian and other non-motorized recreational uses.
- Do not locate ORV routes on trails, areas, or watersheds primarily used by hikers, horseback riders, mountain bikers, hunters, birdwatchers or other quiet recreationists and sportsmen, particularly those routes where unmanaged use has lead to motorized encroachment on non-motorized trails.

IMPLEMENTATION BMPS FOR USE CONFLICTS

- Undertake proactive and systematic outreach to motorized and non-motorized visitors in order to facilitate mutual understanding of the preferences and desired experiences of public land visitors.
- Establish trails or recreational working groups with both motorized and non-motorized stakeholders that meet regularly with land managers. These groups should work cooperatively to identify and resolve use conflict in a manner consistent with agency policy.
- Work with agency and local law enforcement to implement penalties and consequences for violating ORV regulations that will dissuade ORV users from such violations.
- Conduct surveys to establish the demand and opportunities for non-motorized recreation.
- Document use conflicts in a database that is shared with the public.
- Match ORV use to the available management and enforcement capacity (funding and staffing). This will assure that resources exist to guarantee adequate legal enforcement along all routes.

MONITORING BMPS FOR USE CONFLICTS

- Use monitoring to identify use conflicts on trails, areas, or watersheds traditionally used by hikers, horseback riders, mountain bikers, hunters or other quiet recreationists and sportsmen.

- Monitor closed and restored routes to ensure that motorized use is not occurring.
- Use monitoring data to limit or prohibit ORV access on routes where its use is leading to trespass onto other non-motorized trails, areas or watersheds.
- Require that motorized users have identification on vehicles equal in visibility to that found on highway vehicles.
- Monitor and enforce ORV noise violations by equipping law enforcement personnel with sound meters that can be easily calibrated and used in the field to test noise levels of ORVs at established trailheads and staging areas.

CONCLUSION

Scientific literature has firmly established ORV use as a significant perturbation to natural forest systems and ecology as well as creating conflicts among user groups. This underscores the need for widely adopted off-road vehicle Best Management Practices that are grounded in science. However, the effective implementation of these BMPs must be accompanied by adequate funding and staff levels in order to ensure that necessary monitoring and legal enforcement are carried out. With adequate funding and application of these BMPs, forest managers can designate routes that will provide for motorized recreation opportunities while managing ORVs with minimal harm to natural forests systems and the wildlife they support.

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