

CHAPTER 9

VEGETATION, SOILS, & WATER

EFFECTS OF RECREATION ON ROCKY MOUNTAIN WILDLIFE

A Review for Montana

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ABSTRACT

Recreational activities can affect vegetation, soils, and water. These components of the environment would benefit from limiting of all off-highway vehicle (OHV) use to official routes, as well as devising timing and use standards for moderate, to high impact, non-motorized recreation areas. Additionally, all recreational activities should be carefully controlled and monitored in fragile and unique vegetation communities. Establishment of a monitoring system to determine the effect of various weed control methods on native vegetation could ultimately benefit wildlife habitat. Facilities should be developed where recreationists can wash weed seeds from sources of transportation. Limits should be established for personal watercraft and other two-stroke engines where ecological risk from toxic contaminants is to be avoided or reduced.

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The day does not seem wholly profane in which we have given heed to some natural object.
~~ Ralph Waldo Emerson ~~

INTRODUCTION

Vegetation, soil, and water, structurally arranged to meet the life-cycle necessities of wildlife, *is* wildlife habitat. The healthy function and interaction of these ecological components largely determines the well-being of wildlife populations. A brief discussion of vegetation, soils, and water is provided to initiate dialogue on this topic and to invite a more comprehensive synthesis of the extensive body of literature that exists relative to recreational impacts upon vegetation, soils, and water. The Montana Chapter of the Wildlife Society's (MCTWS) on-line bibliography that accompanies this project, currently houses over 520 references to vegetation, soil, and water that, to a large extent, focus on declining conditions resulting from recreational activities. The database will increase as additional references are located and new information becomes available, and is added to the database. Other professional societies or individuals with expertise in the arenas of botany, limnology, hydrology, soils, and fisheries are encouraged to provide updated, comprehensive chapters on these issues for inclusion on the MCTWS web site, or develop publications that may be referenced at the web site (www.montana.org).

Disturbances to landscapes induced by recreational activities were documented as early as 1935 by Bates who described mechanical damage to plants and changes in soil structure. Recreational impacts to vegetation can be extensive because recreationists disperse throughout large areas (Knight and Gutzwiller 1995), although the most visible impacts are generally near denuded trails, campsites and animal holding facilities (Cole 1987). Intensity of recreational use in some areas has resulted in water quality degradation potentially affecting human health (Christensen et al. 1979, NPS 1999). Activities in the name of leisure certainly have the ability to impact wildlife habitat, and possibly the biosphere. As Odum (1993) points out, "We need to learn a lot more about how the current real-world life-support systems of our earth function . . . so we can maintain the quality of these systems".

VEGETATION

Damage to Vegetation from Trampling

Vegetation is affected by trampling, which initially bends and weakens leaves and branches and ultimately breaks them. Trampling directly damages plants reducing photosynthetic surfaces, seed production, and carbohydrate reserves. It eventually kills some vegetation species. This changes community composition (Luckenbach and Bury 1983, Cole 1993). As soil compacts and erodes, roots are exposed and eventually killed (Liddle 1975, Hartley 1976). This level of disturbance allows the establishment of weed species (Mack 1986).

Leonard et al. (1985) determined that the greatest increase in plant mortality from trampling on simulated trails occurred at a low intensity of trampling, that is, between 100 and 300 passes on the simulated trail, with gradual increases in mortality at higher intensities. Frissel and Duncan (1965), LaPage (1967), Bell and Bliss (1973), Weaver and Dale (1978) provided data that corroborates Leonard et al. (1985) showing that loss of cover occurs most rapidly at the onset of disturbance.

Weaver and Dale (1978) compared trampling damage due to hikers, horses, and motorcycles in meadow and forest. Horses were most destructive on level ground, and going downhill, while motorcycles were most destructive on uphill slopes. There is more spinning on slopes than on level ground. Dale and Weaver (1974) showed that grass communities are more resistant to trampling than shrub communities. Bell and Bliss (1973) reported that alpine vegetation is very sensitive to trampling.

Significance of impact is related to rarity of the vegetation type, the value of the vegetation to wildlife species that depend on it, and to the potential to de-stabilize soils (Cole and Landres 1995). Trails along streams negatively affect riparian vegetation with concurrent increases in sedimentation to adjacent streams. Sediments can inhibit or kill periphyton communities, bacteria, and fungi, which are important food sources for invertebrates, amphibians, and fish (Cardone and Kelly 1961, Murphy et al. 1981).

Damage to Vegetation from Snowmobiles and OHVs

Snowmobile impacts appear to be greater in forest communities than in open areas, partially because snow drifting fills in the tracks in open areas (Wanek 1971). One traverse over undisturbed snow can affect the physical environment beneath the snow and physically damage important plants. Snow compaction lowers soil temperatures and reduces the survival of plants and soil microbes. The impact of snowmobiling on the biota varies with the depth of snow accumulation, the intensity of snowmobile traffic, and the susceptibility of the organism to injury caused by cold temperatures or physical contact. Temperatures beneath snow compacted by snowmobiles are considerably colder than those under undisturbed snow cover. Thus the growth and reproductive success of early spring flowers is retarded and reduced where snowmobiles travel. Herbs with large underground storage organs are winter-killed under snowmobile tracks. Woody plants are particularly vulnerable to physical damage by snowmobiles (Wanek 1973). Bury (1978) noted that “the greater the torque applied at the machine/environment interface, the greater the potential for impact.” Boucher and Tattar (1975) reported that disruption to plants under snowmobile trails was most heavy on south-facing slopes exceeding 30 degrees incline. On steep slopes, shallow roots and rhizomes were damaged. Neumann and Merriam (1972) also showed that direct mechanical effects by snowmobiles on vegetation at and above snow surface can be severe. After only a single pass by a snowmobile, more than 78% of the saplings on the trail were damaged, and nearly 27% of them were damaged seriously enough to cause a high probability of death. Although Neumann and Merriam (1972) indicated that it is difficult to predict whether whole ecosystems will be affected by snowmobiling, they state that “management of snowmobiles as a factor in the human environment should not await this purely ecological information.”

Vegetation suffers directly and indirectly from the passage of off-road vehicles (ORVs). The effects can last decades or even centuries (Blackburn and Davis 1994). A report by White House council on Environmental Quality entitled “Off-Road Vehicles on Public Land” states, “ORVs have damaged every kind of ecosystem found in the United States: sand dunes covered with American beach grass on Cape cod; pine and Cyprus woodlands in Florida; hardwood forests in Indiana; prairie grasslands in Montana; chaparral and sagebrush hills in Arizona; alpine meadows in Colorado; conifer forests in Washington; arctic tundras in Alaska. In some cases the wound will heal naturally; in others they will not, at least for millennia” (Pica et al. 1998). Blackburn and Davis (1994) states, “There is a strong correlation between damage to soil and damage to vegetation. Compaction and erosion, for instance, influence the ability of plants to take up nutrients and carbon dioxide, experience proper root growth, and have enough stability to grow upwards.... Unless regulations exist and are strictly enforced, users will choose their own routes and hillclimb areas. Unfortunately, they select areas for their challenge, not for their soil type and stability.”

A controlled study by Leininger and Payne (1971) showed that forbs were damaged by all-terrain vehicles (ATVs) most significantly in early fall. Shrubby species were impacted most during spring and early summer. Graminoids were least affected from vehicle travel. Eight passes with a vehicle caused significant loss of shrub cover. Vegetation was completely destroyed after 32 passes with the vehicle. In a study of the impact of ORV use on valley vegetation in West Virginia, Stout (1992) indicated that valley grasses tend to replace the shrubs that have been destroyed. Blackburn and Davis (1994) stated, “Direct and indirect impacts add up to a transformation of plant communities for the worse. Communities on a site prior to human disruption are composed of a variety of species adapted to that particular habitat. They live together in a relatively stable balance. ORVs and other severe disruptions destroy the balance and make it impossible for the plants to continue to coexist. Some plants are better able to endure the presence of ORVs than others. The adaptable plants are likely to have root systems that survive compaction. These plants flourish while more sensitive species disappear.”

Recreational Activities and Weeds

Uncontrolled and largely unmanaged trail systems, spreading across public lands, provide an expeditious avenue for weed dispersal. Recreational activities may introduce and encourage weeds. Hay for pack animals and the resulting excrement are sources of weed seeds. Backpackers may import seeds on their equipment, and motorized vehicles are capable of distributing weed seeds (Kummerow 1992). Rapid dispersal of weeds is characteristic of motorized routes where a vehicle in one trip, can spread 2,000 knapweed seeds over a 10-mile course (Montana State University Extension Service Bulletin 1992). Although dispersal of weeds is a prodigious issue, disturbance of soils by vehicles has long-term effects that favor the establishment of weedy species (Blackburn and Davis 1994).

After disturbance, weedy, often exotic species, are likely to gradually crowd out native vegetation; thus biodiversity may be drastically lowered (Stout 1992).

Given establishment, the current political climate demands that we kill weeds with potent herbicides. In Montana all land management agencies are operating under state legislative mandates that weeds be “controlled.” Thus the war on weeds is being conducted by an army of personnel with backpack sprayers, tanks on ATVs, larger tanks mounted on trucks with boom-mounted applicators, as well as aerial spraying. Tons of diverse herbicides are infused into the environment.

One hypothesizes that this generalized approach will remove all forbs, and allow noxious forbs known to be especially invasive, to re-invade with greater force. Two studies support this idea. Long-term (20 year) observations of a fescue-grassland sprayed for spurge, show a good initial kill of all forbs, a strong reinvasion of spurge, but no reinvasion of native forbs (B. Maxwell and T. Weaver, professors in weed science and biology, Montana State University, personal communication). Long-term (30 year) observations of *Abies lasiocarpa/Vaccinium scoparium* habitat types sprayed to minimize understory development and encourage tree establishment, have some herbs and grasses in the understory, but no shrubs. Further testing is critically important before widespread non-directed spraying can be justified. Such testing could be made by analyzing previously sprayed sites or requiring applicator follow-up to monitor incidental effects on native plants by their treatments.

SOILS

Erosion, Compaction, and Rutting of Soils

Soil impacts caused by recreation depend on soil type, vegetation cover, topography, and intensity of use (Weaver and Dale 1978). Recreational impacts to soils are found at picnic areas and campgrounds, low-standard roads, trails, and off-road. The primary detrimental soil impacts are loss of productivity, erosion, compaction, rutting, and displacement.

Soils derived from parent materials such as granitics, coarse-grained volcanics, or gneisses are sandy and easily erode when organic layers or vegetative cover is removed. This condition is made worse by moderately steep or steeper slopes and south to west aspects (National Soil Survey Handbook 1996.) Erodibility describes a soil's susceptibility to erosion and is influenced by properties such as texture, structure, organic matter content, and chemical make-up (Lal and Elliot 1994). Erosion can be so severe that soil-surface horizons are lost, and long-term soil productivity is decreased. The process of physically detaching and transporting soil particles, can be further accelerated by a decrease in infiltration capacity associated with horse and off-highway vehicle (OHV, includes full-sized vehicles as well as ATVs) use (Satterlund and Adams 1992).

Off-road vehicles exert shear stress parallel to the soil surface, as well as compressive stress (Wilshire et al. 1978). Direct effects of sheer and compression stress include crushing of foliage, root systems, and seedlings, and uprooting and disruption of root systems of larger plants by shear stresses to the soil. 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 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. There are two basic responses in soils from OHV use (Sheridan 1979, cited in Blackburn and Davis 1994): “One, sandy and gravelly soils are susceptible to direct quarrying by ORVs, and when stripped of vegetation they are susceptible to rapid erosion processes – usually by rill and gully erosion. Two, more clay-rich soils are less sensitive to direct mechanical displacement by ORVs, but the rates of erosion of stripped clay-rich soil are much higher under ORV use than under natural conditions.” Also, pounding of the latter creates strong seal on the surface, which reduce water infiltration. This causes gullying lower in the drainage due to greater rainwater runoff (Sheridan 1979).

As with agricultural soils, conservation of soils in ORV areas requires intensive on-site management (Wilshire et al. 1978). The standards of tolerable soil loss (in tons/acre/year) set forth by the SCS (USDA 1977, cited in Wilshire et al. 1978) are predicated on retention of a long-term designated level of biological productivity of the land. Protection of public lands used by ORVs (Executive Orders 11644, 11989 – see Appendix D of this report) may be

accomplished under the same concept of loss tolerances devised from long experience and research with agricultural uses of soil. Application of such standards, of course, requires a thorough description of the soil resources of the areas of intended use and intensive management to control and monitor the levels of deterioration (Executive Order 11644, Geological Society of America 1977) so that the designated level of permissible loss is not exceeded. The problems of rapid deterioration of vegetation and soil are most severe in the upland and arid areas most commonly selected for vehicle use in the west (Wilshire et al. 1978).

Shallow water tables associated with riparian areas are especially susceptible to detrimental rutting, erosion, displacement, and compaction when they are crossed by low-standard roads, trails, or used for off-road travel by horses, mountain bikes, motorcycles, ATVs, and full size vehicles. Intense recreational use of these areas can lead to increased streambank erosion, bank failure, and loss of wetland function including water storage and sediment trapping (Federal Interagency Stream Restoration 1998). Soils in semi-arid and arid areas are also impacted by off-road vehicles, mountain bikes, and foot traffic. Once the soil surface and microbiotic crusts are disturbed, erosion by wind, rain and gravity increase (Johnston 1997). Soil compaction from even moderate traffic increases runoff and soil displacement, causing concentrations of water that make erosive forces more effective (Alexander and Poff 1985). Reestablishment of crusts may require hundreds of years (Blackburn and Davis 1994).

Alexander and Poff (1985) cite studies of soil compaction at campgrounds and picnic areas throughout the United States. Increases in soil-bulk density as a result of compaction ranged from 8 to more than 46%. These levels of compaction reduce water infiltration, increase runoff, limit the ability of vegetation to reestablish, and result in an overall loss of soil productivity. Vegetation recovers little 20 years after one summer of trampling in an *Abies/Vaccinium scoparium* habitat type (T. Weaver and D. Dale, professors of weed science and biology, Montana State University, personal communication). Wanek's (1971) research indicated that bacterial decomposers and litter decomposition may be significantly affected by roads. Wilshire et al. (1978) indicates that a four-wheel drive vehicle with a track 47 cm wide will impact at least a hectare of ground for every 23 km traveled. In contrast, the average motorcycle track is 13 cm wide, and impacts a hectare every 77 km.

Mass failures, such as landslides, occur naturally, but roads dramatically increase their frequency and magnitude, from several times to hundreds of times (Furniss et al. 1991). Such failures can be a major sediment source detrimental to insects and fish of nearby streams (Swanson and Dyrness 1975, Beschta 1978).

WATER

Water Quality and Quantity Issues Related to Roads

Roads have been identified as the major impact on the forest environment (Johnson 1995). Natural drainage patterns can be disrupted by roads when water is diverted and prevented from infiltrating into soils (Bagley 1998). Impacts from roads basically fall into three areas: introduced sediment into streams; snowmelt re-direction and concentration, and surface flow production (Johnson 1995). Roads can affect both the volume of water available as surface runoff and the efficiency by which water flows through a watershed (Wemple et al. 1996). Roads accelerate water flows and sediment transport, which raise flood levels and degrade aquatic ecosystems. Local hydrologic and erosional effects along roads are dispersed across the land, whereas major impacts are concentrated in the stream network and distant valleys (Forman and Alexander 1998). Bagley (1998) states, "Roads increase the volume of surface runoff in two ways. First, compacted road surfaces do not readily absorb water. And, second, road cuts intercept subsurface water flow and convert it to surface flow. Water moving through a watershed as surface runoff moves more quickly because it has less resistance to flow compared to water percolating through soil. The faster surface runoff causes accelerated soil erosion. Roads thus increase water reaching stream channels during a storm and snowmelt events, so channels must accommodate the additional volume of water and road-related sediment. More water and sediment in channels alter their physical structure, usually with negative effects on aquatic habitat."

Aquatic ecosystems are impacted by sediments from roads as well as the large water flushes just described. Road surface drainage, and the sagging of road ditches into channels and creeks, is a common Best Management Practice (BMP) violation, and the dwindling national forest road maintenance budget makes it difficult to maintain culvert crossings (Johnson 1995). Sediment originating from roads reach streams and rivers, degrading habitat and impairing fish reproduction (Harr and Nichols 1993). Fine sediments impact spawning habitat by settling into and

covering spawning gravels, and interfering with salmonid redd (nest) construction. Excessive sediments can impede intergravel water flow that provides oxygen and removes waste products, both of which are necessary for successful egg development. Roads thus increase barriers to migrating adult and juvenile salmonids and the macroinvertebrates they depend on (Furniss et al. 1991). When culverts fail during storm and runoff events, tremendous amounts of sediment can be delivered directly to the channel and from there down into lower streams, potentially affecting sensitive fish habitat (Johnson 1995). Johnson (1995) notes that “Even on roads that appear to be so thick with alder that a sediment production concern seems ludicrous, we often find that the road tracks are still actively functioning as erosion sources.”

Spring snowmelt and runoff from frequent mid-winter melt and rain-on-snow events that would normally travel in a downhill direction, usually as shallow sub-surface flow, is intercepted by the compacted roads and their ditches and becomes surface flow (Johnson 1995). Thus the drainage efficiency of a watershed is dramatically increased (Johnson 1995). In a study of hydrologic interaction of forest roads with stream networks, it was pointed out that the contributions of the road and ditch network provides a substantial peak in water runoff flows, and may extend the stream network by as much as 40% (Wemple 1994). Carlston (1963) developed an equation to measure the mean annual flood and its variability with stream density. Using Wemple (1994) and Carlston's (1963) work, Johnson (1995) found that flows would almost double (1.96 times) where the road density was only 1.61 mi/mi². He notes that in many watersheds, particularly where attempts are being made to remove or obliterate older roads (including jammer-logging trails, major skid-trails), there are road densities that exceed 20 mi/mi². Thus drainage efficiency can be expected to be an order of magnitude or more greater than on less roaded landscapes. Hollis (1975) found dramatic increases in the size of floods related to impervious surfaces. He notes that small floods may be increased 10 times, and the 100-year flood may be doubled in size when drainage is basin-wide and 30% has been paved (left with impervious surfaces). When only 6% of the watershed was compacted, Harr (1986) notes significant peak flow increases, and emphasizes that building and locating roads so as to not intercept and re-direct water is very important.

Shallow subsurface water can be converted to surface flow when intercepted by road cuts that exceed a few feet in height (Johnson 1995). Amounts vary by soil material, but surface flow volumes are increased substantially when sub-surface flows are intercepted by roads. Wemple (1994) concluded that modifying road segments was the most effective way to approach watershed restoration.

Snowpack Issues Related to Use of Snowmobiles

Compacted snow melts rapidly and retains water less well than non-compacted snow (Neumann and Merriam 1972). Neumann and Merriam (1972) note that, after compaction by snowmobiles, snow melting times increased to as much as double, and the potential water-holding capacity of snow compacted by snowmobiles was reduced substantially throughout the profile. During spring melt, these effects could significantly reduce the ability of snow to slow runoff and to moderate the effects of thawing.

Water Quality Issues Related to Backcountry Use

The relative expanse of most remote areas is misleading. Most use of remote areas is concentrated in the most accessible portions. Even in 1968, tons of chemicals were being introduced to the Boundary Waters Canoe Area, where 75% of the visitors entered the area through only 8 of the 66 entry points (Barton 1969). National forest wilderness growth exceeds growth for many other forms of recreation taking place in the national forests (Hendee et al. 1990). As a percentage of total national forest recreation use and of national forest campground use, wilderness use has grown steadily and only recently has shown a decline (other types of recreation have also leveled off or declined since 1980) (Hendee et al. 1990). Continued population expansion and increased leisure time and affluence will require that wilderness areas absorb greater use. Barton (1969) notes that special standards must be formulated and strictly enforced in wilderness areas and tributary drainages if man's impact on these areas is to be minimized.

Water Quality Issues Related to Use of Personal Watercraft

Nearly all personal watercraft (PWC) utilize conventional two-stroke engines. As much as 30% of the fuel taken in by these engines is never used and is discharged, unburned, into water (California Environmental Protection Agency

1999). As much as 4 out of 10 gallons of gasoline that are ingested by an outboard motor, may be discharged, unused, into the water (Muratori 1968, Stewart and Howard 1968). The use of leaded gasoline may result in lead accumulations in bottom mud that interrupt decomposition cycles and the food chain. Outboard motor gasoline also contains oil that contribute specific pollution problems to water: one gram of oil requires 3.3 grams of oxygen for complete oxidation, oil slicks interfere with gas exchange on the air-water surface, and oil also contains phosphates (Muratori 1968, Stewart and Howard 1968). The combustion process discharges additional toxic compounds into water. As a result, the use of PWCs has resulted in lower water quality in the nation's lakes and reservoirs (NPS 1999).

Based on average use, a typical conventional two-stroke outboard or PWC will expel as much as 30% of the incoming fuel mixture, unburned, via the exhaust. Also known as "two-cycle" engines, these motors intake a mixture of air, gasoline, and oil into the combustion chamber while exhaust gases are being expelled from the combustion chamber. Because the intake and exhaust processes are occurring at the same time, it is unavoidable that some of the unburned fuel mixture will escape with the exhaust. This expulsion of unburned fuel is the reason for the elevated levels of hydrocarbon emissions from conventional two-stroke engines. For example, at common fuel consumption rates, an average two-hour ride on a PWC may discharge three gallons of the gas-oil mixture into the water (NPS 1999).

Methyl tertiary butyl ether (MTBE) and polycyclic aromatic hydrocarbons (PAHs) are commonly observed two-stroke engine contaminants and pose the most serious threats to human and ecological health. Water treatment facilities are generally ineffective in reducing MTBE concentrations. Aquatic ecological communities do not appear to be threatened by observed concentrations of MTBE; however, more research is needed to reinforce this conclusion (NPS 1999).

The concentrations of PAH in lakes and reservoirs with high motorboat activity have been found at levels dangerous to aquatic organisms (NPS 1999). The concentrations causing adverse effects can be extremely low (parts-per-trillion range) due to PAH phototoxicity, especially in oligotrophic waters where sunlight penetration is high. The concentrations of PAH in lakes and reservoirs with high motorboat activity also have been found at levels dangerous to human health where humans are drinking the water and/or consuming the fish from these waters. Although PAH concentrations have not been widely measured, there is no reason to believe that the concentrations quoted are not widespread in lakes or reservoirs with high motorboat activity.

Management strategies adopted by other agencies include outright bans on PWC and restricted use of two-stroke motors. The exclusive use of the newly introduced and less polluting, direct-injection two-stroke engines has also been examined by water management agencies. One strategy for avoiding toxins in surface waters is to draw relatively uncontaminated water from deeper intervals to supply drinking water, but the consequences of this action upon amphibians, fish, insects, and algae has not been reported.

CONCLUSIONS

Impacts to vegetation, soil, and water by recreational activities have been well documented for six decades, in many community types, in all seasons, and on all continents. Putting available information to use is the challenge. "When the 'study of the household' (ecology) and the 'management of the household' (economics) can be merged, and when ethics can be extended to include environmental as well as human values, then we can be optimistic about the future of humankind" (Odum 1993). Respect for vegetation, soils, and water, and ensuring the proper function of life-support systems, is fundamental to the health and well-being of wildlife, now, and in the future.

GUIDELINES/RECOMMENDATIONS

1. Prohibit OHV use off of officially designated routes.
2. Restrict non-motorized uses (hikers, horses, mountain bikes, etc.) to trails in heavy-use areas.
3. Restrict specific activities in fragile and unique plant communities (Bell and Bliss 1973, Dale and Weaver 1974).

4. Properly site roads and trails to minimize soil erosion, and close or relocate routes that deliver unacceptable sediment loads to streams (Wemple 1994).
5. Monitor various weed control methods and their effect on native vegetation.
6. Develop facilities for users of OHVs, horses, and other modes of transportation, to clean away weed seeds.
7. Restrictions on use in wilderness and back-country areas may be necessary to protect water quality and other resources; at the same time, monitoring systems to evaluate controls should be implemented to measure chemical, biological, bacteriological, physical, and aesthetic properties (Barton 1969).
8. Establish limits of use for PWCs and other two-stroke motors where known toxic thresholds of MTBE and PAHs are approaching ecological risk (NPS 1999) .
9. Restrict use of two-stroke motors in small or shallow bodies of water, or in identified sensitive areas in rivers, larger lakes, or reservoirs.

INFORMATION NEEDS

Recreational activities can and do impact wildlife habitat. Levels and types of recreational activity that may be allowed in sensitive areas throughout Montana can be determined by comparing areas of functional, intact habitats and other areas where detrimental changes have already occurred. Monitoring with built-in checkpoints for corrective action, could prevent institutionalization of damaging recreational activities. Specific instances may exist where pure waters, fragile soils, or rare vegetation dictate that recreational disturbance not occur at all. Prudence by natural resource managers would result in prompt decisions to protect the environment, and correct damaging activities or potentially damaging situations; managers should not delay decisions while awaiting results of definitive ecological research.

Tools are needed for resource and recreational managers to determine where, to what degree, and what types of recreational activities may be allowed across Montana landscapes, without detrimental consequences to wildlife habitat. For example, the consequences to watersheds experiencing snow compaction at varying levels as a result of snowmobile use, should be determined. An inventory of natural resource maps and sensitive species distributions should be assembled to define areas in the state that must have an order of protection over and above areas where fundamental criteria should already be in place. Management options might include seasonal avoidance areas by all recreationists, and perhaps diurnal-timing restrictions for recreationists on seasonally important wildlife areas.

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