Cumulative and Universal: ATV Impacts on the Landscape and Wildlife

A Review of the Literature on the Subject

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Introduction

This white paper is a review of scientific literature on the effects of all-terrain vehicle (ATV) use on wildlife habitat and wildlife. For the purposes of this report, ATV's are defined as 2, 3, or 4 wheeled vehicles specifically designed for off-road travel. This definition does not include sport utility vehicles or 4-wheel drive jeeps. The white paper does not delve into the social arena or address issues arising from real or perceived user conflicts.

The paper consists of three sections: (1) Effects of ATV use on soil and water quality, and the impact of soil and water degradation on vegetation productivity and stream sediment delivery. (2)The effect of ATV use on wildlife focusing on, but not necessarily limited to, Rocky Mountain Elk in the northwestern United States. Due to the plethora of available literature covering the effect of ATV use on many wildlife species a review of the literature for all species is unfeasible. (3)The connection between ATV travel, physical disturbance of the environment, habitat degradation, and the effect those disturbances ultimately have on wildlife.

This report has two objectives. The first objective is to provide a review of scientific literature on the effects of ATV use on the physical environment, wildlife and wildlife habitat. The second objective is to give advocates of wildlife and its habitat a report that can be used to cite scientific literature when providing public comment on proposed or existing policies and legislation, or for informative or educational endeavors.

Section 1. Effects of ATV Use on the Physical Environment

Natural resources are affected by ATV use (Meadows et al. 2008). All-terrain vehicle use affects soil and hydrologic function primarily through soil compaction, increased soil strength, and removal of the forest litter layer in temperate environments (Ouren et al. 2007). Soil compaction and the removal of the forest litter layer can reduce vegetation growth (Webb et al. 1978) and is a primary factor in accelerated erosion rates (Megahan 1990). In desert environments, the reduction in desert biological soil crusts is listed as a top concern. Desert biological soil crusts contain nitrogen and carbon-fixing bacteria critical for soil nutrient cycling in arid environments (Belnap 2003). These unique features also act as soil stabilizers and are a key parameter in functioning desert ecosystems (Belnap 2002; Ouren et al. 2007). Rutting, fugitive dust migration, and changes in plant species composition are other effects on the physical environment resulting from ATV use. Rutting channels water into preferential flow paths resulting in rill erosion. Rill erosion occurs when soil particles are detached as the flow of water is concentrated into shallow troughs called rills. Rill erosion is responsible for increases in soil loss (Foltz et al. 2007) and increased stream sediment deposition (Meadows et al. 2008). Fugitive dust migration results from ATV traffic as soil crusts are disturbed, soils are abraded and pulverized and wind currents are generated. Lovich and Bainbridge (1999) suggest that wind erosion can increase debris flow once the soil surface is disturbed and fine particulates are exposed. Photosynthetic and respiration processes are disrupted as dust migrates and accumulates on vegetation, leading to reductions in plant growth, reproduction, and survival (Ouren et al. 2007). Changes in plant species composition can occur as a result of invasive species being propagated by ATV trails that act as conduits for human-caused disturbances which promote invasion by exotic species (Greenberg et al. 1997). In contrast, one of the cornerstones of conservation ecology is the fundamental belief that roadless habitats serve as refuges for native species diversity (Soule´ and Terborgh 1999).

Soil compaction affects a number of soil physical, chemical, and biological properties. Compacted soil exhibits a decrease in total porosity and a corresponding increase in bulk density, soil strength, and volumetric water content (Greacen and Sands 1980; Gomez et al. 2002). Soil bulk density is defined as the mass of a unit volume of dry soil. Soil strength is a measure of a soils capacity to resist penetration or rupture (e.g. plant root exploration). Volumetric water content is the volume of water present in a given volume of soil (Brady and Weil 2004). Although the volumetric water content in soil increases as a result of compaction, the amount of water available for uptake by plants decreases in fine and medium textured soils because the water is held tightly in micropores or as moisture films on clay surfaces (Brady and Weil 2004). Compacted soils exhibit increased soil strength which impedes penetration by plant roots, restricting access to water and nutrients (Gomez et al. 2002). Other properties affected include macroporosity, infiltration, aeration, hydraulic conductivity, and cation exchange capacity (Parker et al. 2007). Macroporosity, infiltration, and hydraulic conductivity control the rate that water enters and moves through the soil vertically and horizontally. Soil macroporosity (soil pores ≥ 0.08 mm), infiltration, aeration, and hydraulic conductivity are reduced as soil becomes compacted. This decreases the rate water flows through the soil profile, increases surface flow, concentrates water, and leads to increased erosion and decreasing gaseous exchange rates, which in turn may reduce soil microbial activity and mineralization rates which alter nutrient cycles and can reduce plant nutrient availability, decreasing plant growth. The cation exchange capacity of the soil is also reduced by compaction. Cation exchange capacity measures the total exchangeable cations (critical nutrients for plant growth) that a soil can absorb and is a useful metric for estimating soil fertility (Brady and Weil 2004). Generally speaking, as the cation exchange capacity increases so does soil fertility. Soil compaction is typically measured in terms of soil bulk density or soil strength. Soil bulk density can increase logarithmically as a result of compaction with the number of off-highway vehicle passes over the soil surface (Iverson et al. 1981). Environmental factors controlling soil susceptibility to compaction include soil texture (percentage of sand, silt, and clay in the soil profile), soil moisture content at the time of travel, soil organic matter, and the percentage of coarse fragments in the soil profile (Page-Dumroese et al. 2000). Fine textured soils (soils with a high clay content) at a greater risk for compaction will be affected more than coarse textured soils. Soils that are sandy and/or have high levels of organic matter are less susceptible to increases in bulk density due to compaction (Page-Dumroese et al. 2000). Compaction of coarse textured soils is still a concern because the soil crusts that act as soil stabilizers can be destroyed when soils are compacted, increasing water and wind erosion rates (Iverson et al. 1981; Webb 1982). Meadows et al. (2008) reported that 40 passes over the soil surface by ATV's reduced the upper portion of the mineral soil by 30%-50% on gravelly sand soil in the Beaverhead-Deerlodge National Forest in Montana. In contrast, similar reductions were achieved after 30 ATV passes on loamy sand soils in Louisiana, and 20 ATV passes on gravelly loamy sand soil in Washington (Meadows et al. 2008). Meadows et al. (2008) note that soils could be subjected to the number of ATV passes required to achieve this level of compaction in one weekend's travel by a moderate sized ATV group. Similarly, soil strength can be dramatically increased by minimal traffic. Adams et al. (1982) reported an 81% increase in soil strength relative to adjacent undisturbed areas after a single vehicle pass.

Hydraulic conductivity is a measure of potential water flow through the soil profile and has implications for erosion and mass flow. Declining hydraulic conductivity equates to less infiltration and more runoff. Compaction resulting from ATV travel reduced hydraulic conductivity 8% at the MT site, 59% on the LA site, and 51% at the WA site (Meadows et al. 2008). The changes in soil structure and physical properties described by Meadows et al. (2008) highlight the potential for ATV use to result in significant degradation of hydrologic function over relatively short time frames.

Erosion and mass flow (landslide scale erosion) are natural processes occurring on all landscapes, but the rate and extent of erosion can be increased by both human and naturally caused disturbances (Megahan 1990). Activities such as ATV travel that reduce soil cover, i.e. vegetation and forest litter, alter natural drainage patterns and can lead to increased rates of surface and off-site erosion (erosion that moves soil particles and plant nutrients off-site) (Rice et al. 1972; Grigal 2000). Factors controlling erosion and mass flow include slope length and steepness, precipitation intensity and duration, infiltration rate, soil texture, geomorphology (i.e. convex or concave drainage patterns), and soil cover (Sidle et al. 1985; Elliott and Hall 1997; Robichaud et al. 2007). Slope length and steepness control water run-off concentration and influence its speed (Brady and Weill 2004). For instance, ATV routes situated on slopes >15% are more likely to result in increased erosion (Welch and Churchhill 1986). Precipitation intensity influences the timing and volume of water movement during periods of rain, snow, and snow melt. Soil texture interacts with rainfall duration and intensity by controlling the rate and duration of moisture inputs and the infiltration rate. Soil texture refers to the percentage of sand, silt, and clay particles ≤2 mm in diameter that make up the soil. Soil texture influences the rate that water infiltrates into the soil. Coarse textured soils have more macropore space (large diameter pores in the soil profile) than fine textured soils facilitating higher rates of infiltration. Soil compaction resulting from motorized recreation can destroy macropores effectively reducing infiltration. When the rate and duration of rain or snow exceeds the infiltration rate into the soil, erosion is increased as water moves across the soil surface instead of infiltrating into the soil profile (Troeh et al. 1980). Soils covered with dense vegetation and forest litter provide the most resistance to erosion (Troeh et al. 1980). Forest litter also promotes infiltration and protects the soil surface from impact erosion (erosion resulting from rain drop splash) when it rains or snows (Megahan 1990). When vegetation and forest litter coverage is destroyed by ATV travel, the roughness of the soil surface decreases and thus facilitates increased water flow along the soil surface (Troeh et al. 1980). Off-site erosion affects site productivity by removing topsoil used as the growth medium for vegetation (Megahan 1990). Off-site erosion decreases plant productivity by transporting nutrient rich soils through soil mass movement decreasing nutrient availability for plants (Jurgensen et al. 1997).

All-terrain vehicle travel increases erosion and sediment concentrations by removing soil cover and compacting the soil thus decreasing infiltration. Sediment delivery to streams via erosion is a result of ATV travel (Misak et al. 2002). Increased sediment loading decreases water quality, fish habitat quantity and quality, and fish reproductive success (Newcombe and MacDonald 1991).The increase in runoff and sediment transport can be substantial. Meadows et al. (2008) compared the effects of ATV traffic across seven sites on diverse landscapes ranging from the Wenatchee National Forest in Washington State to the Land Between the Lakes in Kentucky and concluded that **"ATV trails are high-runoff, high sediment producing strips on a low-runoff, low sediment producing landscape."** Runoff and sediment loads resulting from ATV trails increased by 56% and 625%, respectively, when compared to adjacent undisturbed sites. Meadows et al. (2008) reported a decline in soil cover from 70% on undisturbed sites adjacent to ATV trails to 17.6% after 40 ATV passes in Montana. The decline in soil cover at the

MT site resulted in increased surface runoff and suspended sediment concentrations. Suspended sediment concentrations in the runoff increased 50% over pre-disturbance levels after 40 ATV passes. Ricker et al. (2008) reported increases in suspended stream sediments resulting from ATV trail surface runoff in a paired watershed study in Stafford County, Virginia. Suspended stream sediments rose approximately 94X downstream of an ATV trail crossing relative to sediment concentrations above the ATV trail crossing. The results of the paired watershed study led the authors to conclude that increases in suspended stream sediment were a result of a combination of highly erodible silt loam soils (common in the Inland Northwest of the United Sates) and ATV trails acting as conduits for suspended sediment (Ricker et al. 2008). Iverson et al. (1981) reported a five-fold increase in surface runoff and increased sediment yields of 10-20 times in areas affected by OHV use in the Mojave Desert.

Impacts of ATV traffic on water quality and aquatic systems are not limited to increases in suspended stream sediments. ATV trails funnel water that dislodges contaminants which end up in streams, rivers and lakes (Ouren et al. 2007). Contaminants can also be directly introduced into aquatic systems through oil and fuel spills and wind deposition of emission particulates that are transported in dust migration, settle onto vegetation, and subsequently washed off leaf surfaces by rain and snow and moved by surface water run-off. All-terrain vehicle operation in or near streams and waterways poses a serious water pollution threat (Havlick 2002). This can have detrimental impacts on populations of aquatic animals. Garrett (2001) (as cited in Taylor 2006) reported that environmentally sensitive aquatic species (including fish) were absent from OHV impacted sites on the Nueces River in Texas, while unimpacted sites hosted numerous environmentally sensitive species. The magnitude of the effect ATV use has on water quality is influenced by trail features including trail curvature and slope percentage.

Rutting and reduced soil cover are two significant effects of ATV travel that are highly correlated with trail features. Curves in ATV trails are the trail feature most susceptible to rutting, followed by hills (both up and down), and straight segments of trails. For example, Meadows et al. (2008) suggest that disturbance levels increased from "low" to "medium" in five times fewer passes on curves than on hills or straight sections of ATV trails. On ATV loops in the Beaverhead-Deerlodge National Forest in Montana, vegetative cover was reduced and bare soil increased 36% on straight sections of the ATV trails and up to 78% on curves. Rut depths varied with trail features as well. Meadows et al. (2008) reported 0.5-3 in. ruts on straight and downhill trail segments increasing to 4 in. on uphill and 7 in. on curves. Furthermore, trail widths increased to six feet on the uphill sections of the trail, increasing the spatial effect. Changes in soil structure resulting from rutting led Meadows et al. (2008) to conclude that soil erodibility increased three times on the Montana sites in the Beaverhead-Deerlodge National Forest. It is important to note that rutting deeper than 2 in. is considered to be "detrimental soil disturbance" for National Forests in the Northern Region (USDA Forest Service 1999). Similar results were reported on ATV loops in the Kisatchie National Forest in Louisiana. Vegetative cover was reduced 41%-62% on straight and downhill sections of trails, and as much as 99% on curved sections. Bare soil increased up to 73% on curved sections. Rutting depths followed similar patterns as the Montana ATV loops, increasing to 8 in. on curves, although Meadows et al. (2008) note in at least one instance that rut depths could not increase due to ground clearance limitations of the ATV's.

ATV impacts on vegetation are not limited to removal of vegetative soil cover. Reduced plant growth rates and populations of native species coupled with increases in non-native and pioneering plant species are directly related to ATV travel (Ouren et al. 2007). Destruction of biological soil crusts in desert environments reduces nitrogen fixing organisms that are the dominant source of nitrogen in arid ecosystems (Belnap 2002). This negatively affects plant performance because nitrogen is the element most limiting plant growth in desert environments other than water (Romney et al. 1978). Soil disturbance levels required to alter patterns of plant growth can be achieved in relatively short time frames depending on soil properties and moisture at the time of travel. Adams et al. (1982) reported reductions in coverage by desert annuals after one vehicle pass on a wet loamy sand soil. The same reduction in coverage required 20 passes on similar dry soils, **suggesting that ATV restrictions based on soil moisture conditions may be warranted to reduce disturbance levels resulting from ATV traffic**. Reduction in plant coverage is not necessarily the result of plant removal. It can be due to reductions in plant growth (Adams et al. 1982; Bolling and Walker 2000). For instance, Bolling and Walker (2000) report high instances of small creosote (*Larrea tridentate)* along OHV routes in Nevada relative to the larger, more robust creosote in areas adjacent to the routes. Although changes in soil properties that reduce plant growth can be achieved in relatively few passes, physical damage to plants in the form of breakage tends to increase with increased ATV traffic (Webb 1983; Ahlstrand and Racine 1993; Ouren et al. 2007). Ahlstrand and Racine (1993) define shrub injury as the sum of plant abrasion, breakage, and height compression. Their findings indicate that 25%-66% of shrub injury occurs after 10 ATV passes. In their study, Ahlstrand and Racine (1993) reported the highest shrub injury rates were incurred in the spring on ATV trails in Wrangell-St. Elias National Park, Alaska. **These results also suggest that, at a minimum, seasonal restriction on ATV travel are necessary to reduce detrimental impacts to soils and vegetation** (Ahlstrand and Racine 1993).

ATV trails impact plant species composition by acting as seed dispersal agents (Gelbard and Harrison 2001) by causing changes in soil and hydrologic function that promote non-native annuals and other early successional plants (Prose et al. 1987; Lovich and Bainbridge 1999), and by increasing fugitive dust migration that can limit the competitive fitness of endemic plants species (Ouren et al. 2007). Gelbard and Harrison (2003) reported the highest percent cover per m^2 (i.e. the percentage of a square meter of land covered by plants) of native species were found on sites >1000 m from roads, while the lowest cover of native species were on sites found <10m from roads on non-serpentine grasslands in California. Gelbard and Harrison (2003) assert that this "road effect" may be even more distinct in remote landscapes, citing the Colorado Plateau and Great Basin specifically. This supports the assertions of Moody and Mack (1988) who concluded that **limiting OHV access into grasslands with low road densities is warranted to stem the influx of invasive plant species and preserve native grasslands.** Significant fugitive dust migration can be manifested as dust blankets up to 10 cm. thick on short statured shrubs and mosses (Walker and Everett 1987). The effect dust loading has on plants depends on the physical characteristics of the individual plant, but dust loading can negatively affect several plant processes including photosynthesis, respiration, and transpiration, all of which may result in reduced productivity and survivorship (Ouren et al. 2007).

This review of the impact of ATV use on the physical environment suggests that the impacts are not only universal and cumulative, but that much of the damage associated with their operation can be induced by a limited number of users over short time periods. Several researchers suggest the cumulative impacts of ATV use exceed the lands ability to recover naturally, and that **recovery to pre-disturbance conditions can take generations**. Additionally, the effects of ATV traffic on-site result in environmental consequences off-site

(Ouren et al. 2007), significantly increasing the amount of land affected by localized ATV use (Brooks and Lair 2005). For example, Meadows et al. (2008) asserts that while a meadow may recover from a single pass in a relatively short time frame, multiple passes often result in damage that natural processes are unable to mitigate. This is supported by Lathrop and Rowlands (1983) who state unequivocally that **"restoration (of sites degraded by ORV's) as a management objective is for all practical purposes unattainable as long as ORV activity occurs."** It is interesting to note that Meadows et al. (2008) found no statistical difference in disturbance levels resulting from different combinations of factory and aftermarket sport and utility ATV and tire combinations. **We can infer from this finding not only that the type of motorized use is inconsequential in relation to the presence of motorized use, but that the assumptions justifying maximum width road and trail restrictions may not be sufficient to meet resource protection objectives.** Other critical points on the impacts of ATV use on the physical environment are:

- The impacts of ATV use are cumulative, universal, and can be achieved by low intensity traffic over short time periods.
- ATV use effects soil and hydrologic function primarily through soil compaction, increased soil strength, removal of the forest litter layer, and destruction of soil crusts. These changes in soil properties increase erosion and stream sediment deposition and decrease plant productivity.
- Seasonal restrictions on ATV use are necessary to limit the impact of ATV use on soils, vegetation, and watersheds.
- Restricting ATV use in areas of low road density is necessary to reduce the spread of invasive species and protect the community structure of native species.

- ATV impacts on the environment are similar regardless of the type of ATV.
- Recovery from the impacts of ATV use to pre-disturbance conditions can take generations.
- Restoring sites degraded by ATV’s is unfeasible as long as ATV use continues.

This section reviewed the effect of ATV use on the physical environment. Section two covers the impact of ATV use on wildlife.

Section 2. Effects of ATV use on Wildlife

All-terrain vehicle travel can have a profound effect on all forms of wildlife. Concerns about the effect of off-highway travel on wildlife include: direct mortality (Bury et al. 1977; Bury et al. 2002), habitat fragmentation (Ouren et al. 2007) and reductions in habitat patch size (the size of an unfragmented "patch" of land that supports at least one population of wildlife) (Reed et al. 1996; Forman et al. 2003), increases in the edge: interior habitat ratio (reductions in animal populations at the edge of forest habitats referred to as the "edge effect"), and alteration of animal behavior (Canfield et al. 1999; Rowland et al. 2000; Wisdom et al. 2004a). Although direct mortality of ungulates resulting from collisions with ATV's is low, mortality of several species of reptiles have been documented due to off-highway travel (Brooks 1999; Grant 2005).

Habitat fragmentation results from the development of barriers that divide areas of continuous habitat into smaller, disconnected parcels or "patches". **Although roads may be the largest source of habitat fragmentation in North America (Harris and Lopez 1992), ATV trails can have a greater cumulative impact due to the density of trails on previously continuous habitats (Gaines et al. 2003; Gilbert 2003)**. Habitat fragmentation can disrupt wildlife movements between and within habitats (Forman and Alexander 1998; Jackson and Griffin 1998), which can have negative consequences for endemic species and may encourage non-native and invasive species propagation (Lovallo and Anderson 1996; Jackson and Griffin 1998). When ATV use results in habitat fragmentation and the disruption of wildlife movement, subpopulations of wildlife can become isolated (Dobson et al. 1999); which promotes inbreeding within the population and results in the loss of genetic diversity (Hanski 1999). Habitat fragmentation can reduce reproductive success among nesting birds and is believed to be the main culprit in population reductions in some species of forest birds (Robinson et al. 1995).

Robinson et al. (1995) concluded from their study on the effect of forest fragmentation and the nesting effect of migratory birds that **“conservation strategies should consider preservation and restoration of large, unfragmented “core” areas in each (habitat).”**

Habitat patch size has a significant influence on ecological community structure. In general, species density and diversity increase as habitat patch size increases. This relationship is simply a function of a larger landscape having the capacity to support a larger number of individuals (population density). Larger landscapes are more likely to vary in physical characteristics and localized weather patterns than smaller patches. This creates a wider spectrum of available habitats that are conducive to different species’ specific habitat needs, thus increasing species diversity on the landscape (Smith and Smith 2006). Reductions in habitat patch size resulting from fragmentation caused by roads and ATV trails may compound the effects of habitat loss, resulting in greater population declines than are experienced from habitat loss alone (Bender et al. 1998).

Reductions in animal populations at the edge of forest habitats are often referred to as the “edge effect” (Murcia 1995). Edges are created when roads or ATV trails create artificial breaks in forest cover, increasing daylight and soil temperature, and decreasing soil moisture content (Watkins et al. 2003). In turn, this has the potential to alter plant and wildlife communities (Ortega and Cappen 2002). Interestingly, Marsh (2007) found the edge effect did not significantly impact terrestrial salamander populations on gated and untraveled narrow forest roads in the Appalachian Mountains. In contrast, the edge effect significantly reduced populations of terrestrial salamanders on ungated roads, leading Marsh (2007) to conclude that **traffic is a key variable determining the magnitude of edge effects**. The conclusions of Marsh (2007) support results reported by Gruell and Roby (1976), who found that elk behavior in northwestern Wyoming was not significantly altered by the presence of off-road tracks that received minimal traffic in summer months, but were avoided by elk as traffic increased on the same tracks during the hunting season.

Alteration of animal behavior resulting from disturbance (motorized or non-motorized) ranges from immediate, short term temporary displacement to permanent abandonment of favored feeding areas (Geist 1978). According to Trombulak and Frissel (2000), animal behavior is modified through five mechanisms:

1. altered movement patterns
2. changes in home range
3. altered reproductive success
4. altered escape response
5. altered physiological state

Geist (1978) (quoted from Hershey 2011) asserts that these modifications to behavior result in three primary consequences:

1. Elevates metabolism at the cost of energy resources and reserves needed for the animal’s normal growth and reproductive potential.
2. Can cause death, illness or reduced reproduction due to secondary effects from physical exertion and temporary confusion.
3. Can lead to avoidance or abandonment of areas and to reduction in a population’s range and, ultimately, to reductions of the populations due to loss of access to resources, increased predation or increased energy cost for existence.

Geist (1978) is supported by Yarmoloy et al. (1988) who suggest that over time these consequences can result in lost productivity for a population when physiological responses to disturbance reduce an individual animal's energy budget to levels that result in death. **Similar to the effect of ATV travel on the physical environment (Meadows et al. 2008), ATV travel can have a disproportionate effect on alteration of animal behavior when compared to other forms of outdoor recreation simply because of the distances a single user can travel in a day compared to more traditional methods of travel (Hershey 2011).**

The effect of ATV travel on elk, and more generally, the effect of roads on elk, has been a focal point for researchers because of the documented aversion elk have to roads open to motorized travel (Cole et al. 1997; Rowland et al. 2000), and for their social, economic, and recreational importance (Naylor et al. 2009). Although roads in general are not the exclusive domain of ATV's, miles of road exist on public and private lands that are open only to ATV travel. Roads with "maximum width" restrictions are likely conduits for ATV travel. Similarly, roads designated as "closed" on National Forest plans, but not officially designated as such, are regularly traveled by ATV's (Rowland et al. 2004). Therefore, it is important to review current scientific knowledge on the effect roads have on elk.

There is a positive correlation between the presence of elk and the distance from open roads on the landscape (Rowland et al. 2004). This is particularly true of bull elk (Marcum and Edge 1991), although several studies indicate that the frequency of habitat utilization on areas adjacent to roads may increase when human use of road networks is limited by management practices (Basile and Lonner 1979; Gratson and Whitman 2000; Cole et al. 2004). According to Gaines et al. (2003), there are five factors associated with roads that affect elk aside from the effect roads have on habitat (e.g. conduits for noxious weeds, decline in quality and abundance of forage): hunting, poaching, collisions, displacement or avoidance, and disturbance at a specific site. Ultimately, these five factors result in elk being displaced from suitable habitat and in a decreased availability of effective habitat and in the potential for reduced populations at both the local and regional level (Forman et al. 2003). In contrast, as open road density (defined as "any road where motorized vehicles are allowed" (Rowland et al. 2004)) decreases, elk are less likely to be displaced from suitable habitat, and equally important, home range and daily movement decline. Grigg (2007) reported that relatively high levels of motorized access resulted in a 100% increase in the size of elk summer home range in southwestern Montana relative to areas with little or no motorized access. The size of home range is a key factor in elk population fitness and survival. The increase is summer home range in areas with relatively high motorized access indicate that elk must move further, and expend more energy doing so, to locate necessary food reserves while avoiding disturbance (Nicholson et al. 1997). Elk benefit from reduced movement through preferential energy budgets that are conducive to increasing fat and energy stores (Cole et al. 1997). The distance separating elk from roads open to motorized travel (i.e. "distance band" (Rowland et al. 2004)) is also a significant factor in elk vulnerability to hunting and poaching. Elk vulnerability to these activities increases as the distance to open roads decreases (Rowland et al. 2004). In contrast, closing roads to motor vehicles increases elk security, decreases hunter density (Rowland et al. 2004), and may reduce elk mortality from poaching (Cole et al. 1997). **The current body of research concluding that roads consistently influence elk patterns and behavior during all seasons is characterized by Lyon and Christensen (2002) as "overwhelming".**

A significant portion of elk research has centered on "habitat effectiveness." The definition of habitat effectiveness varies from "the percentage of available habitat that is usable by elk outside the hunting season" (Lyon and Christensen 1992) to the "spatial use of potential habitats in the context of human disturbance" (Hershey 2011). Regardless of semantical differences, habitat effectiveness is used as a metric to determine if elk use of potential habitat is being limited. Benchmark values for elk habitat effectiveness related to road densities or road management criteria are a part of National Forest management plans in many western National Forests (Carter 1992; Rowland et al. 2004). Road density is used as a predictor variable in models used by management agencies to predict habitat effectiveness. Road densities as little as one mile of road per square mile of land have been reported by Lyon (1983) to **reduce habitat effectiveness by at least 25%**. Attempts to validate the assumption that road density is related to habitat effectiveness led Rowland et al. (2000) to conclude that rather than using road density alone as a modeling parameter, accurately predicting habitat effectiveness could be improved by a parameter based on the distance between roads, essentially the amount of habitat buffered from open roads. **We can infer from this research at least four important points; 1) elk (especially economically and biologically significant bull elk) preferentially use areas devoid of motorized activity, 2) elk require large blocks of non-motorized habitat for security, 3) road closures are necessary to increase habitat effectiveness, particularly in areas of high road density, and 4) road closures must be enforceable to be effective where minimum habitat effectiveness thresholds are included in management plans and objectives.**

The Starkey Experimental Forest and Range (Starkey) was developed in the late 1980's to study the effect of resource uses on mule deer and elk habitats and populations (Quigley and Wisdom 2005). This unique research facility, located near La Grande in northeast Oregon, features one of the largest ungulate-proof enclosures in the world. Researchers are able to evaluate elk and mule deer responses to disturbances on spring, summer, and fall ranges typical of those found in the western United States that are represented within the enclosure. Resource management on the Starkey unit is consistent with resource management practices on National

Forests in the western United States (Wisdom et al. 2004b). The original objective leading to the development of the Starkey project was to “fill key knowledge gaps that posed difficult impediments to effective management of ungulates, and to facilitate transfer of this knowledge in mediums most useful to managers” (Wisdom et al. 2005). Since its inception, the Starkey project has been at the forefront of research on the effect of recreational disturbances on mule deer and elk.

Wisdom et al. (2004b) published results of a landmark two year Starkey study whose objectives were four-fold: 1) “document cause-effect relations of ATV, horseback, mountain bike, and hiking activities on deer and elk, using these off-road activities as experimental treatments and periods of no human activity as experimental controls; 2) measure effects with response variables that index changes in animal or population performance, such as movement rates, flight responses, resource selection, spatial distributions, and use of foraging versus security areas; 3) use these response variables to estimate the energetic and nutritional costs associated with each activity and the resultant effects on deer and elk survival; and 4) interpret results for recreation management.” Twenty miles of off-road transects were established in a 3,950 acre enclosed study area to meet these objectives. Hikers, horseback riders, mountain bikers, and ATV riders traversed selected transects twice daily (morning and afternoon) over five day periods, from mid-April through October on a “tangential” approach, where animals are not directly targeted, rather the recreation disturbance is meant to mimic that of normal traffic patterns (both motorized and non-motorized) (Wisdom et al. 2004b).

This study resulted in several important findings. There are differences in movement rates of elk exposed to each of the four recreational disturbances. The highest morning elk movement rates were elicited by exposure to ATV travel (21 yards/ min), followed by mountain biking (17 yards/ min) > horseback riding = hiking (15 yards/ min). Afternoon elk movement rates followed a similar pattern, where elk movement rates stayed higher over a longer period when elk were exposed to ATV travel than when elk were exposed to any of the other three disturbances (Wisdom et al. 2004b). It is interesting to note that elk movement rates were above control values during periods of dawn and dusk even when no disturbance was present during the five-day periods that elk were exposed to ATV and mountain bike travel. This unusual behavior led the authors to conclude that "**elk were displaced from preferred security and foraging areas as a result of flight behavior during the daytime off-road (disturbance) activities"** (Wisdom et al. 2004b). The type of off-road disturbance and the distance between elk and disturbance causing activities are also a significant factor in the flight response of elk. The mean probability of flight response in elk declined 10%-12% when elk were exposed to horseback riders (50%) and hikers (52%) at close range (109 yards) when compared to ATV's (62%). The probability of a flight response in elk declined significantly when elk were exposed to hikers beyond 550 yards (0.31 mi.). By comparison, **the probability of elk flight when exposed to ATV travel and mountain bikers continued beyond 1640 yards (0.93 mi.)** (Wisdom et al. 2004b).

The results summarized here by Wisdom et al. (2004b) are supported by results in Naylor et al. (2009), which was also conducted at the Starkey compound. The objectives in this study were to evaluate effects of off-road recreational activities and determine if different off-road activities resulted in different responses in elk behavior patterns (Naylor et al. 2009). Using the same experimental design as that described in Wisdom et al. (2004b), Naylor et al. (2009) reported that exposure to ATV travel generated the highest travel response in elk when compared to mountain biking, horseback riding, and hiking. The increase in elk travel response post ATV exposure was followed by increased resting time and a decrease in feeding activity. In contrast, exposure to the other forms of off-road recreation, while still resulting in an increase in elk travel response, was followed by an *increase* in elk feeding activity. This finding led the authors to suggest that exposure to ATV travel resulted in elk abstaining from normal feeding patterns in favor of retreating to thick cover until the disturbance causing activities were over (Naylor et al. 2009). The energy that is expended by elk retreating from disturbance causing activities can have significant, detrimental impacts on elk populations (Rowland et al. 2004). This is particularly true on summer range for lactating cow elk, whose energy requirements are 2-3 times greater than during gestation periods (Robbins 1993). The energy requirements of lactating cow elk led Wisdom and Cook (2000) to suggest that the ability of lactating cow elk to effectively utilize summer forage is a controlling factor of elk population productivity. By comparison, less disruptive forms of off-road recreation (i.e. mountain biking, horseback riding, and hiking) did not result in alterations to elk feeding patterns once the elk had moved away from the route and were able recoup energy spent traveling by resuming feeding activity (Naylor et al. 2009). Concerns over the potential decline of long-term body condition as elk populations shift away from disturbance causing activities to areas of less productive forage led Naylor et al. (2009) to suggest that a **“comprehensive approach for managing human activities to meet elk objectives should include careful management of off-road recreational activities, particularly ATV riding and mountain biking, which caused the largest reductions in feeding time and increases in travel time.”**

Human induced disturbance has also been shown to reduce cow to calf ratios (cow:calf) through reduced calf survival (Phillips and Alldredge 2000). In this Colorado study, disturbance “treatments” were applied to cow elk during May and June two consecutive years on experimental units while no disturbance treatments were applied on control units. Cow to calf ratios remained stable in the control units but declined in the areas subjected to disturbance treatments. Calf production in the experimental units was significantly lower (0.225 calves/cow) than on the control units (Phillips and Alldredge 2000). In a spin-off of the Phillips and Alldredge (2000) work, Shively et al. (2005) reported findings from a second Colorado study that examined the reproductive response of elk resulting from the removal of calving ground disturbance. Using the same experimental approach, results showed stabilized cow to calf ratios and recovery of calf production rates equal to that of the control group by the second year after disturbance treatments were suspended (Shively et al. 2005). Phillips and Alldredge (2000) speculated that predation was the primary factor reducing cow to calf ratios and calf production on the experimental units. They based this assumption on the work of others reporting predation as the primary cause of elk calf mortality (Schlegel 1976; Bear 1989; Singer et al. 1997). However, Phillips and Alldredge (2000) suggest that disturbance may have been the root cause of calf mortality, increasing calf vulnerability to predation through increased movement and/or social and nutritional stressors. The results of this multi-year study led Phillips and Alldredge (2000) to several important conclusions:

1. “To ignore potential effects of human-induced disturbance of elk during calving season is to risk declining reproductive success in elk populations.”
2. “If elk are left inadequate calving-season habitat and can no longer escape disturbance, either from over development of backcountry access corridors or from high levels of off-trail activity, then populations may decline.”
3. “It is difficult to predict…..even more difficult to curtail human activities once they become traditional, or to recover wildlife habitats once they are lost.”

Phillips and Alldredge (2000) and Shively et al. (2005) considered elk calving season specifically for the studies reviewed here. However, similar conclusions can be drawn during seasons when elk face stressors related to breeding, hunting season, or winter. It is impossible to overstate the importance of areas that provide year round security for elk if healthy, productive elk herds are an objective of public land management (Penninger, M.A. personal correspondence).

It is prudent at this point to consider the work of Phillips and Alldredge (2000) and Shively et al. (2005) along with the results of studies completed at the Starkey compound to extrapolate effects of human access and disturbance to elk productivity. Equally important is the question of the effect of human disturbance on elk vulnerability to predators and the impact this vulnerability has on meeting elk management objectives. Perhaps the current trend toward elimination of predators should be reconsidered in this context, and more attention given to the factors controlling vulnerability to predation.

The preceding section reviewed the scientific literature on the effect of motorized access generally, and the effects of ATV travel specifically, on wildlife, with a particular emphasis on elk. Critical points from this review are:

- Although roads may be the largest source of habitat fragmentation in North America, ATV trails can have a greater cumulative impact due to the density of trails on previously continuous habitats.
- Conservation strategies should consider preservation and restoration of large, unfragmented "core" habitat areas.
- ATV travel can have a disproportionate effect on alteration of animal behavior when compared to other forms of outdoor recreation simply because of the

distances a single user can travel in a day compared to more traditional methods of travel.

- Elk (especially economically and biologically significant bull elk) preferentially use areas devoid of motorized activity.
- Elk require large blocks of non-motorized habitat for security.
- Road closures are necessary to increase habitat effectiveness, particularly in areas of high road density.
- Road closures must be enforceable to be effective where minimum habitat effectiveness thresholds are included in management plans and objectives.
- Elk are removed from preferential foraging areas by exposure to ATV travel resulting in unfavorable energy budgets that can have significant and detrimental effects on long-term individual and population body condition and reproductive success.
- Managing human activities to meet elk management objectives should include careful management of off-road recreational activities, particularly ATV riding and mountain biking, which were found to cause the largest reductions in elk feeding time and increases in elk travel time as part of the Starkey Project studies.
- Ignoring the potential effects of human-induced disturbance of elk during calving season is to risk declining reproductive success in elk populations.

Section 3. Summary

Off-road recreation, and especially ATV travel, on public land in the United States has continued to increase significantly since the 1970's (Havlick 2002). Citing Knight and Gutzwiller (1995) and Havlick (2002), Naylor et al. (2009) mince no words, stating: "off-road recreation, especially ATV riding, can negatively impact wildlife." Similarly, in a 2003 speech, Forest Service Chief Dale Bosworth opined that unmanaged off-road vehicle recreation "affects more imperiled species than logging and logging roads combined" (Bosworth 2003). Review of the scientific literature on the subject is revealing on the scope of the problem.

In terms of the effect of ATV use on the physical environment on which both humans and wildlife depend, the impacts of ATV use are cumulative, universal, and can be achieved by low intensity traffic over short time periods. Roughly five percent of all recreational visits to National Forest System land involve ATV use (Meadows 2008). However, this five percent of recreationists can have a disproportionately high impact on land and wildlife resources because of their ability to impact a far greater number of acres over shorter time periods than more traditional forms of recreation. Repeated ATV use on "user created" routes (i.e. cross-country travel) can exceed the lands ability to heal itself (Meadows et al. 2008). Direct impacts to the land from ATV use will have indirect effects on a much larger spatial scale (Ouren et al. 2007). The increase in scale impacts not only land and water quality, but also wildlife populations, by impacting habitat, reducing habitat effectiveness, the productivity of preferential foraging areas, and species fecundity and survival.

All-terrain vehicle use affects soil and hydrologic function primarily through soil compaction, increased soil strength, removal of the forest litter layer, and destruction of soil crusts. These changes in soil properties increase erosion and stream sediment deposition, invasive and noxious weed proliferation, and decrease plant productivity. The ultimate result of these impacts is the degradation of habitat on which wildlife populations depend. It is important at this juncture to recall that Meadows et al. (2008) found no difference in impacts to the environment resulting from different ATV models and tire configurations. Disturbance levels are not dependent on vehicle width, or the utilization of aggressive tire tread; rather, disturbance levels are dependent on the presence or absence of motorized vehicle use.

The impacts of ATV use on wildlife cannot be overstated. Similar to the effect of ATV travel on the physical environment (Meadows et al. 2008), ATV travel can disproportionately alter animal behavior relative to more traditional forms of off-road recreation due to the distances motorized vehicles can travel in a single day (Hershey 2011). Alterations in animal behavior may result in displacement from preferential habitat, increases in home range and daily movement patterns (Nicholson et al. 1997), reductions in the time spent feeding, and increases in daily travel time (Naylor et al. 2009). Increases in the size of summer home range and increasing daily movement can detrimentally impact energy budgets that are critical for building fat and energy reserves (Cole et al. 1997). Efficient utilization of summer home range by lactating cow elk is critical for the productivity of elk populations by providing quality forage for lactating cow elk (Wisdom and Cook 2000). This suggests that off-road travel restrictions limited to the calving season may be insufficient to maximize calf recruitment and limit unnecessary stressors to lactating females. Declines in the productivity of elk populations due to altered behavior in response to ATV travel are exacerbated by reduced site productivity from ATV impacts to soils and hydrologic function.

High densities of ATV trails in previously continuous habitats can have a greater cumulative impact than traditional roads in terms of habitat fragmentation (Gaines et al. 2003;

Gilbert 2003). Managing human impact on wildlife habitat is critical for maintaining healthy and diverse populations of wildlife that depend on continuous habitat. Peer-reviewed research has shown conclusively that habitat effectiveness and security is dependent upon large blocks of non-motorized areas (Nicholson et al. 1997; Cole et al. 1997; Rowland et al. 2004). Ultimately, the success or failure of management practices seeking to enhance survival and security of diverse wildlife populations by managing motorized recreation depends on the development of regulations that are enforceable and supported by funding for enforcement and implementation.

This review of the scientific literature on the effect of ATV use on the physical environment and wildlife is meant to provide a reference base for individuals who are concerned about the impacts of motorized recreation in general, and ATV use in particular, on public lands. The references cited here can be used to support arguments relating to current and proposed legislation that threaten the quality of our air, soil, and water, the viability of wildlife populations, and the security of our wild lands. The bulleted points following sections one and two are excellent references from which to draw. These references can be used to support important points when corresponding with policy makers and as talking points for educational presentations.

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