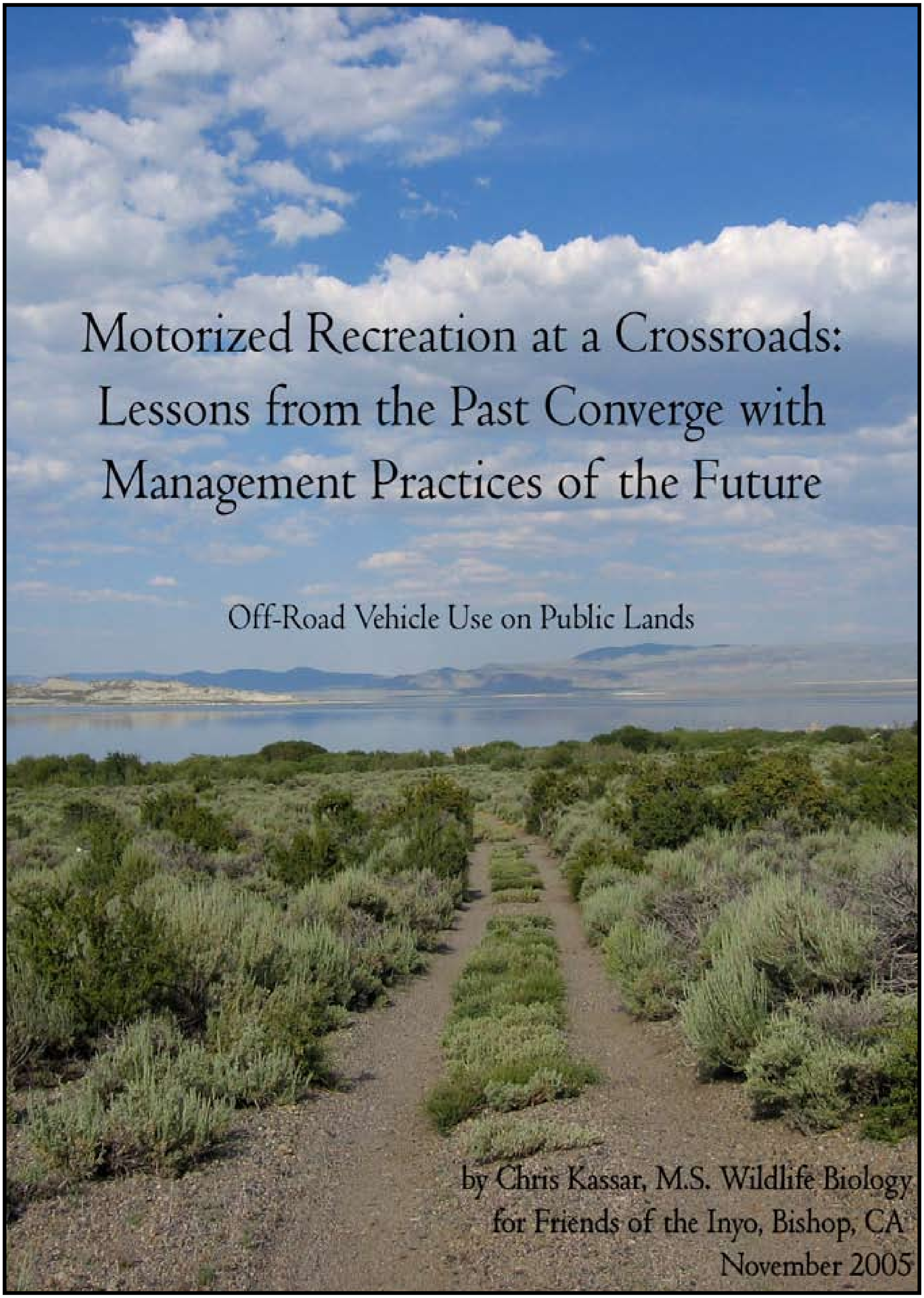
Motorized Recreation at a Crossroads: Lessons from the Past Converge with Management Practices of the Future

Off-Road Vehicle Use on Public Lands



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for Friends of the Inyo, Bishop, CA
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Examine each [land use] question in terms of what is ethically right, as well as what is economically expedient. A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise.

~Aldo Leopold 1949~

Blue-flag Iris

Acknowledgements

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Cover Photo: Route on the southeastern edge of the Mono Basin in the Inyo National Forest.

FORWARD!

Aldo Leopold - one of the founding fathers of America's robust public lands conservation movement - knew wild land. He was blessed to come of age at a time before the trip from San Francisco to Los Angeles was less than a day's drive, when "over yonder hill" actually meant something and a trip to the out of doors didn't involve loading up your car or truck; you saddled the horse or hoofed it yourself.

I often wonder what being outside was like early in Aldo's day - when the hum of a motor in the backcountry would have been as shocking as catching a blue whale in the Owens River.

Mr. Leopold's call for the adoption of a new "land ethic" - a social morality reflecting "individual responsibility for the health of the land" grew out of his experience as a hunter, angler, reformed predator killer, game manager and scientific student of the land. As much as Mr. Leopold was a scientist, he was a recreationist. More than an academic construction born of sound methodology and rigourous data - Leopold's land ethic was the product of a thinking person *being outside.*

A thoughtful hunter knows that the quality of the year's bitterbrush will affect the health of his quarry. Any angler can tell you that trophy trout don't thrive in dry streams. A farmer knows beans won't grow on rocks. Knowledge of cause and effect is gained through physical experience.

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For more and more Americans getting outside involves getting in the car. It has to. We live in larger and larger concentrations of homes tightly bound together by a web of asphalt. But get out we still do, and boy, as a nation, we are blessed with an abundance of phenomenal places to get out to: Death Valley, Grand Canyon, the High Sierra, Point Reyes National Seashore, the Black Hills and the Great Smoky Mountains.

In addition to their beauty, all of these places have one thing in common - *they are OURS!* One of the greatest products of our American democratic experiment has been the institution of Public Lands - lands owned collectively by all of us. This ownership implies responsibility. A responsibility to treasure, steward, and nurture Public Lands so we can hand them to future generations as they have been handed to us - wild, beautiful and unique refugia from an increasingly hectic, biologically barren world.

It is well known that we will only take care of what we know. It easy to dismiss what we have not touched, tasted, smelled, seen or experienced.

Our Public Lands heritage is under attack. Both from its owners - us - and from those we have elected to carry out their management. Twice in the last few months, portions of our federal government have sought to to sell off our collective heritage - our hills, mountains, deserts, forests - to the highest bidder. Today's unwritten sign hanging over all our public lands reading "Welcome and enjoy" may soon be replaced by "Private Property! No Trespassing. Violators will be Prosecuted!" Our collective wealth squandered for a few pieces of silver...

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How are we going to preserve our Public Lands heritage? By getting people out there! Out of their cars, away from the din of motors and the choke of smoke and onto the land! By providing sustainable roads, trails, picnic areas and campgrounds that create lasing memories. By ensuring people know the stories of the land, that their ears are opened to the tales of the trees and the advice of the birds, that a child can feel the joy of drinking straight from the Earth or catching their own dinner on the end of a fishing pole. We need to ensure there is still peace to be found on our Public Lands.

As Mr. Leopold reminded us decades ago, "Of what avail are the forty freedoms without a blank spot on the map."

Balancing the current abuse of Public Lands by off-road vehicles is simply the first step. In addition to saying "Enough," we need to spread a new gospel of "How, What and and Why"

-Paul McFarland
Lee Vining, California
4 February 2006

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Lourquin's Admiral

Prologue

Eventually the question will boil down to: is the use of the ORV worth losses it will cause the environment?"

~ U.S. Department of the Interior, 1971

All public land has the potential to be irreversibly and severely damaged by ORV use.

~ U.S. Bureau of Outdoor Recreation, 1974

Quad tracks through meadow, Coyote Plateau

Rutting erosion, Mono Basin

ORVs have now invaded an enormous variety of natural settings, from deserts and coastal dunes to forested mountains, and from fertile habitats for wildlife to unique refuges for relict flora and fauna. The capability of the land and its biota to sustain this impact is as varied as the invaded habitats, but damage by ORVs in even the least vulnerable areas will require periods for recovery measured in centuries or millennia. Losses of soil and changes in the land surface will be long lasting, and certain natural life systems will never recover from the intensive ORV impacts already sustained. Archaeological and historical features, relict landforms, primitive soils, and other legacies of irreplaceable cultural, aesthetic, and scientific value havealso been permanently lost.

~ Wilshire et al., 1977

OHV damage to rare desert wetlands, Furnace Creek, White Mountains

No person shall operate an off-road vehicle on public lands in a manner causing or likely to cause significant, undue damage to or disturbance of the soil, wildlife, wildlife habitat, improvements, cultural or vegetative resources…

~ U.S. Dept of Interior, 1979

Introduction

These prophetic statements on the previous page, made approximately 25 to 30 years ago, speaks of the damage already inflicted on the landscape by off-road vehicles (ORVs), and warns of the potential for damage that is yet to come. Each of the accompanying pictures suggests that today, despite warnings from governmental agencies and scientists, despite orders handed down by the President of the United States, off-road vehicles continue to wreak havoc on ecosystems of all types. Clearly, individuals, land managers and their agencies, and politicians have not heeded the messages of these cautionary voices and have, in most instances, allowed off-road vehicle recreation to remain unregulated, causing this issue to persist and grow in intensity over the last 3 or 4 decades. People may not understand how severely human use of off-road vehicles effects and damages, often permanently, the land and associated animal and plant life. Possibly, there is a misconception held by the general public and land management agencies that the severity, extent and potential for damage is not that great, or that land is resilient enough to recover rapidly. This is difficult to accept, however, because literature dating from as far back as 1970 admonished people of the fate that awaited their public lands if off-road vehicle use was allowed to remain rampant and unrestricted.

Scientists have recognized and warned of the impacts of off-road vehicles for decades (Nash et al., 1970; DeForge, 1972; Hagen and Langeland, 1973; Busack and Bury, 1974; Stebbins, 1974; Luckenbach, 1975; Luckenbach, 1978; McReynolds and Radtke, 1978; Bury et al., 1979., Griggs and Walsh, 1981). Nevertheless, today the effects of off-road vehicles continue to remain a concern to environmentalists and managers. Our public lands are being subject to unprecedented intrusion as motorized access increases in scope and popularity. The Forest Service estimates that in most areas throughout the country, the fastest growing community on public lands consists of off-road vehicle users. It is estimated that 11 million or 5 percent of all recreational visits to national forests involve off-road vehicle use. Over the past 20 years, off-road vehicle use has increased seven-fold on public lands (U.S. Department of Agriculture Forest Service, 2004b). According to recent USDA surveys, the number of ORV users in the United States has increased from 5 million in 1972 to 36 million in 2000 up to 51 million in 2004 (Cordell et al., 2000; Cordell et al., 2004). In addition to a burgeoning number of users, there is also the issue of growing and uncontrolled proliferation of trails due to repeated cross country travel by off-roaders. Unauthorized, user-created trails from motorized use are responsible for a significant amount of the natural resource damage on national forests and are a serious challenge for land managers.

In response to management challenges due to ever-growing human impacts, Forest Service Chief Bosworth identified unmanaged outdoor recreation, emphasizing off-road vehicle use, as one of the four key threats presently facing national forests (Bosworth, 2003). Clearly, there is a need for further action regarding off-road vehicle use on public lands. Educating citizens, achieving stronger environmental policies and legislation, and mandating positive movement from managers are all necessary to ensure the protection of public lands from further ORV-induced damage. This report will aid in informing the public by summarizing our current understanding of the history, background, and legalities of this issue, as well as the ecological impacts of off-road vehicle use[1].

There are a multitude of scientific studies that provide sufficient evidence and support for carefully controlled and managed motorized recreation on public lands. In this unique[2] report we will delve into these studies to illustrate the demonstrated, detrimental and interconnected effects of off-road vehicles on wildlife, habitat, vegetation, soil, air, water and other users. Although this report is organized to analyze off-road effects on individual ecosystem components (i.e., soil, vegetation, wildlife), these systems are inextricably linked, thus there is a significant amount of overlap in any complete discussion of the environmental impacts of ORVs. We will argue that these repercussions can be prevented or at least minimized within an efficient management system. Lastly, this report will beg the question: Why, despite over 35 years of research and reports of the negative direct and indirect consequences of off-road vehicle use, does motorized recreation remain largely unmanaged?

History and Background

A considerable number of off-road vehicles (ORVs) first appeared in the desert in 1968 (Steb-

Concerned users await the day when managers will live up to expectations by implementing effective practices and solutions. In the meantime, damage like this shown in the Buttermilks outside of Bishop, California persists.

[1] Off-road vehicle (ORV) is a term that refers to any motorized vehicle (motorcycles, ATVs, dune buggies, four-wheel drive vehicles, snowmobiles, jet skis, etc.). Note that many agencies refer to these machines as 'off-highway vehicles' or OHVs, but we have chosen to use the more common term, off-road vehicle unless citing directly from a source that uses OHV. This particular report focuses on land vehicles and does not include specific information regarding the impacts of snowmobiles because of the enormous amount of information available regarding these vehicles. In addition, "their environmental effects are qualitatively different than those of off-road vehicles which come into direct contact with the ground (Sheridan, 1979)."

[2] This analysis of existing literature is unique because it is global in scope, yet has an emphasis on California ecosystems and wildlife; when pertinent California examples were available they were included. This report is also unique because photos from my research conducted on the Inyo National Forest are included where appropriate (Kassar and Klapp, 2005).

bins, 1974). In the early 1970s, the popularity of ORV use boomed, leading to a surge in sales of off-road motorcycles, ATVs, mini-bikes, dune buggies and snowmobiles. Land management agencies were not prepared for this shift in recreational preferences and were not armed with adequate laws or policies to properly govern the use of public lands. As a result, off-road vehicle use remained unregulated, marking the beginning of severe and widespread habitat degradation on lands managed by the government; this still continues today.

In an effort to respond to increasing off-road vehicle use and the mounting concern voiced by certain citizens regarding associated damage on public land, a unified federal policy was developed to guide managers and recreaters. Executive Order 11644, signed by President Nixon in 1972 and Executive Order 11989 signed by President Carter in 1977 mandated change on federal lands and also made the public aware of the issue. Executive Order 11644 was created "to establish policies and provide for procedures that will ensure that the use of off-road vehicles on public lands will be controlled and directed so as to protect the resources of those lands, to promote the safety of all users of those lands, and minimize conflicts among the various uses of those lands (Federal Register, 1972). " The Order states that agencies must issue regulations that designate areas as either closed or open to off-road vehicle use; off-road vehicle use should be restricted or prohibited to minimize conflicts between users and damage to resources, including soil, watersheds, vegetation, wildlife and wildlife habitats. This mandate directly protects wilderness and primitive areas by closing them to off-road vehicle use.

Sign indicating restrictions in the Deadman Creek area of the Inyo National Forest per Executive Order 11644.

Executive Order 11644 provided a framework for land management agencies, but it did not provide direction for implementing these ordinances. As a result, the National Forest Management Act was passed in 1976 to provide managers with specific standards and guidelines for regulating land use on forests. Each forest was required to develop a management plan to: "1) conserve soil and water resources and not allow significant or permanent impairment of the productivity of the land; (2)

minimize serious or long-lasting hazards from flood, wind, wildfire, erosion, or other natural physical forces; 3) protect streams, streambanks, shorelines, lakes, wetlands, and other bodies of water; 4) provide for and maintain diversity of plant and animal communities to meet overall multiple-use objectives; 5) provide for adequate fish and wildlife habitat to maintain viable populations of existing native vertebrate species; 6) include measures for preventing the destruction or adverse modification of critical habitat for threatened and endangered species; 7) be consistent with maintaining air quality at a level that is adequate for the protection and use of National Forest System resources and that meets or exceeds applicable Federal, State and/or local standards or regulations (36 C.F.R.§ 219.27)[3]." Similar to Executive Order 11644, the Management Act requires the inclusion of a monitoring component in each management plan, allowing for periodic evaluations of the efficacy of management practices. The Act requires each Forest Supervisor "obtain and keep current inventory data appropriate for planning and managing the resources under his or her administrative jurisdiction (36 C.F.R.§ 219.12)."

To strengthen this act and Executive Order 11644, another order was instituted. Executive Order 11989 increased the protection given to the land by requiring agencies to identify and close areas that show evidence of damage due to off-road vehicle use. The order also allows managers to designate all lands as closed to off-road vehicle use, unless specifically designated as open to off-road vehicle use. Both Executive Orders mandate federal agencies to inform the public of designations and rules and to actively enforce regulations. Agencies are also required to monitor the use and impacts of off-road vehicles on soil, vegetation, wildlife, or other resources until "such adverse effects have been eliminated and...measures have been implemented to prevent future recurrence (36 C.F.R. § 295.5)."

Evidently, damage associated with off-road vehicle use on public lands is not a new issue. In 1979, Charles Warren, then Chairman of the Council on Environmental Quality, stated that his organization saw the problem of off-road vehicle use as "one of the most serious public land use problems

[3] The Code of Federal Regulations (C.F.R.) is the codification of the general and permanent rules published in the Federal Register by the executive departments and agencies of the Federal Government. These rules are divided into 50 broad categories; however, this report is most concerned with regulations set forth in Part 219 (Planning) and Part 295 (Use of motor vehicles off forest development roads) of Chapter 2 (U.S. Department of Agriculture, Forest Service) in Category 36 (Parks, Forests and Public Property). The C.F.R. is updated once a year and issued on a quarterly basis.

that we face (Sheridan, 1979).” This same report criticized the manner in which the Forest Service was responding to ORV use on public lands: “The two major federal land management agencies-the Bureau of Land Management and the U.S. Forest Service-have been slow to grapple with the off-road vehicle problem…Land management agencies responsible for areas of intensive off-road vehicle use will need to make new efforts to monitor impacts and enforce necessary restrictions… (Sheridan, 1979).” Sheridan (1979) urged the Forest Service to comply with Executive Order 11644 by including off-road vehicle use into their management plans. However, despite two Executive Orders, the Forest Management Act and warnings from scientists and managers, the response to this urging was neither always positive nor universal throughout government agencies. Seven years after the first Executive Order, Sheridan (1979) reported that “the Executive Orders 11644 and 11989 have been poorly implemented by the major land management agencies; hence ORV environmental damage and impairment of other recreationists’ enjoyment of the resources are still out of control.” As a whole, management agencies failed to effectively respond to these sanctions, setting the stage for degradation of our lands by off-road vehicle use; in many areas and agencies inaction persists, allowing for destruction to continue and increase in severity.

Route proliferation in the east Mono Craters of the Inyo National Forest—one of many areas validating the claim that there is little restriction of motorized use on forest lands.

The Natural Trails and Waters Coalition reports that “off-road vehicles can go almost anywhere in America’s National Forests (2005a).” Reports estimate that there are 460,000 miles of roads on National Forests and that more than 273,000 miles (~60%) of these are open to off-road vehicle use. California ranks first in the number of acres of Forest Service land and fourth in the number of acres of BLM land in the contiguous United States. This state also ranks first for the highest amount of off-road vehicle use on both BLM and Forest Service land. Off-road vehicle use is an issue in many places and many habitats in the United States, but certain areas are more prone to use and abuse by recreaters. For example, the presence of vast, variable, wide-open tracks of land (the perfect play area for ORVs) near large cities has made the

California desert and mountains extremely popular for and vulnerable to use by off-road vehicles. The dangers of ORV use in California were recognized in 1974 when the American Association for the Advancement of Science Committees on Arid Lands reported that the "almost completely uncontrolled" recreational pressure being placed on the desert in southern California was posing a "serious threat to the preservation of the environment in a desirable and stable condition." Anticipating resource damage and increased conflicts between users, the California Department of Parks and Recreation predicted that the "differences between ORV users and those who protest their intrusion and the damage they cause will be irreconcilable (1975)." In 1976, the U.S. Congress reported that the fragile resources of the California desert environment are prone to damage due to the increased pressure being exerted by recreational users. They urged managers to conserve resources for the future by adopting a multiple use, sustainable yield management plan that recommends ORV use only in appropriate areas (United States Congress, 1976).

Despite government orders and countless warnings from scientists, the use of off-road vehicles continues to be a rapidly growing threat to our public lands, especially on our National Forests. Although this has been a concern the last 30 to 50 years, the issue remains dynamic because of technological advances, a growing human population and the birth of new forms of recreation. Technological advances have changed the shape of off-roading by providing a more powerful, burly vehicle that can travel on more difficult terrain, allowing people to infiltrate even further into the backcountry than was possible in the past. These factors, combined with the lack of a universal recreation ethic, are contributing to the expansion of human activity into wildlife habitat and areas where human influences probably did not previously exist (Youmans, 1999). In 1999, Michael Dombeck, the U.S. Forest Service Chief stated, "New and less expensive technology allows people to get to areas previously unreachable to motorized vehicles…In the process, unplanned and unauthorized roads and trails may be created, sensitive wildlife habitat disrupted, erosion accelerated, and water quality degraded (Dombeck, 1999)." In a speech given on Earth Day 2003, Forest Service Chief Dale Bosworth identified unmanaged recreation and off-road vehicle use as one of the four "great threats" facing National Forests (Bosworth, 2003). He spoke about the explosion in illegal, user-created routes that has led to "erosion, water degradation, habitat destruction, damage to archeological sites and user conflicts", stating that, "We have got to improve our management so we get responsible recreational use based on sound outdoor ethics (Bosworth, 2003)."

In response to the most recent mandate set forth by Chief Bosworth and the existing, and yet unmet legal obligations cited in the Executive Orders, the Forest Service is currently revising its policy governing the use of motorized vehicles through a route inventory and designation process. At the national level, the Forest Service is seeking to develop a manageable system of roads and trails that will still allow opportunities for both motorized and non-motorized recreation, while enhancing protection of natural and cultural resources. Over 20 years after the first Executive Order was signed into law, the Forest Service is beginning a systematic response to this call to action. The rest of this report will provide a detailed analysis of the numerous documented, realized and potential impacts of human expansion and off-road vehicle use on wildlife and habitat, vegetation, soil, and water and air pollution, thus highlighting the persistence of this issue over time and the critical importance of successful implementation of new management strategies, including the process of route inventory and designation.

Wildlife and Habitat

Effects of ORVs on Wildlife and Habitat: Overview

There have been numerous studies exploring interactions between wildlife and highways, however, the impacts of off-road motorized recreation on wildlife have also been well-documented. Many scientists suggest that motorized recreation is the greatest threat to wildlife on our public lands because it can alter habitat, cause disturbance and lead to the direct death of animals (Luckenbach, 1975, 1978; Bury and Luckenbach, 1983, 2002; Sheridan, 1979; Berry, 1980; Brattstrom and Bondello, 1983; Boyle & Samson, 1985; Havlick, 1999; Joslin and Youmans, 1999; Lovich and Bainbridge, 1999; Lawler, 2000; Belnap, 2003). Lovich and Bainbridge (1999) acknowledge the significance of direct mortality but argue that the more detrimental repercussions of linear recreation corridors include

Route in the southern White Mountains of the Inyo Nanional Forest fragmenting sagebrush habitat.

habitat fragmentation, restriction of wildlife movements and gene flow, and increased human access to remote areas. They also explore other consequences of off-road vehicles, including destruction of soil stabilizers, soil compaction, reduced water infiltration rates, destruction of vegetation, and increased erosion (Lovich and Bainbridge, 1999). To the casual observer, the impacts of forest roads and motorized recreation on wildlife may not be as evident as their effects on the surrounding physical environment (i.e. loss of trees, damage to ground surface, etc.). In reality, however, wildlife are affected beginning when a route is first cut (legally or illegally) and continue to be even after the route is no longer being used. As ORVs affect soils, air, water and vegetation, they also impact wildlife species because animals depend on all of these other factors for their survival. Thus, ORV activity and associated routes has both direct and indirect effects on animals (Davenport et al, in press).[4]

Animal mortality, a significant direct effect, can occur when off-road vehicles hit ground-dwelling animals, destroy birds or small mammals by crushing ground nests or vegetation that contains nests, or cause the collapse of needed burrows. Although animal mortality is an obvious and familiar direct effect, displacement, avoidance and disturbance at specific sites, often associated with breeding and raising young, are the most commonly reported direct effects of motorized trails on wildlife (Bury et al. 1977; McReynolds and Radtke, 1978; Bury, 1980; Luckenbach and Bury, 1983; Sachet, 1988; United States General Accounting Office, 1995 Youmans, 1999).

Off-road vehicle activity and harassment can stress animals, resulting in a measured physiological stress response or increase in energy use (Schultz and Bailey, 1978; King and Workman, 1986; Canfield et al., 1999). Changes in animal behavior, (i.e., the abandonment of important activities like hunting, foraging and mating), have been attributed to the passage of off-road vehicles. These behavioral and physiological responses to motorized human disturbance may not only impact individuals, but also entire populations. It has been suggested that the impacts associated with disturbance from ORVs can increase the risk of individual mortality and decrease the productivity and viability of an entire population (Knight and Cole, 1991). For example, if the passage of an ORV causes a male yellow warbler in a canyon to change his habitat use pattern or to be displaced to the

[4] A complete discussion of these impacts must acknowledge the fact that both non-motorized and motorized recreation affects wildlife; however, motorized trails have a ‘larger magnitude of effect (Knight and Cole, 1995; Cole and Landres, 1995; Gaines et al. 2003).” Studies show that motorized trails and traffic displace wildlife for longer distances and disturb more species than similar concentrations of non-motorized recreation (Gaines et al. 2003).

next canyon, this may alter the reproductive success and survival for that entire population.

While the consequences of direct effects (i.e. a road kill) may be more evident, indirect effects on wildlife are significant and often impact habitat in areas subject to motorized recreation. For example, ORV activity that destroys vegetation by crushing it and exposing roots, also disturbs soil, thereby negatively effecting future plant growth and the potential for healthy habitat for many animals. The destruction of habitat can increase fragmentation and decrease connectivity, breaking previously suitable habitat into smaller patches which may make it less usable and can jeopardize the survival of certain species. "Edge effects" increase and are magnified in areas with small, isolated patches of habitat. Increased edge effects can impact wildlife that need interior habitat for foraging, hunting or establishing home ranges (i.e., mountain lions, martens, black bears). Research also shows that fragmentation and increased edge habitat support the invasion of non-native, noxious and weedy species that eventually displace native interior species. The destruction of native vegetation and changes in the density and diversity of plant communities as a consequence of prolonged off-road vehicle use can even further change the composition of desert reptile and small mammal communities (Bury, 1980).

Indirect effects often have such broad implications because the "road effect zone," or the outer limit of a significant ecological effect, extends much further than the actual road, route or trail (Forman 2000). Disturbance due to noise, pollution, ground impact, and speed will travel beyond the actual surface of any route. In addition, ecological effects will ripple, expanding well beyond the perimeter of a route and potentially affecting an entire ecosystem. For example, in aquatic areas, off-road vehicles can increase the amount of silt and turbidity in a stream by increasing erosion (Moyle and Leidy, 1992). If this causes degradation of habitat to the point where spawning sites are not available and food sources are destroyed, less fish will survive and so will those creatures that depend on the aquatic ecosystem for survival.

In an evaluation of threats to biodiversity, Wilcove et al. (1998) ranked habitat destruction and the spread of alien species as the two greatest threats; off-road vehicles contribute to both of these. There are a number of causes of habitat destruction, including land conversion, agriculture, development and outdoor recreation. From their study of these causes, they reported that 15 % of all endangered species are affected by roads. Twenty seven percent (27%) of all endangered species, including plants and animals, are harmed by outdoor recreation while 13% of endangered species have been specifically, negatively impacted by the use of off-road vehicles (Wilcove et al. 1998).

Route in the east White Mountains of the Inyo National Forest increasing stream turbidity and affecting quality of aquatic habitat.

Studies with similar findings regarding the impacts of off-road vehicles on wildlife and their habitat abound. Bury et al. (1977) studied the impacts of ORV use on wildlife in creosote shrub habitat in the California desert. The authors found a negative effect on desert wildlife wherever ORVs were used. In a comparison with control areas, they reported significantly less species diversity, fewer individuals present and lower biomass of mammals and reptiles in areas used by ORVs. Diversity, abundance, and biomass of avian species were also significantly greater in undisturbed areas than in those used by ORVs (Bury et al., 1977). Results also support the idea that a decrease in fauna is correlated with the level of off-road activity. The authors conclude that activity related to ORV use negatively affects desert wildlife and creosote shrub habitat, both of which they argue are irreplaceable (Bury et al., 1977). Luckenbach and Bury (1983) conducted a study to determine the ecological impacts of ORV use on biota by comparing presence and density of vegetation, rodents, arthropods and lizards on plots with and without use by off-road vehicles in sand dunes in south eastern California. They found that ORV activity in the Algodones dunes reduced the biota; in areas of ORV use, there were less herbaceous and perennial plants, arthropods, lizards and rodents. Researchers found almost no native plants or wildlife in areas of heavy ORV use and also cited negative impacts to the biota in areas with low levels of ORV activity. They argue that ORV activities very negatively affect dune biota and even low levels of use can cause a reduction in the biota of ecosystems.

Although we discuss them separately, the actual environmental effects of these factors are not individual. Rather, they are cumulative and synergistic because seemingly small, individual impacts

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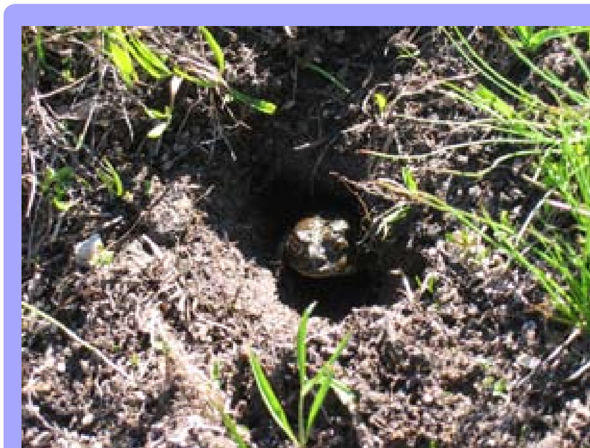
[5] This section includes groups of animals for which literature is available. When possible and appropriate, species found in California are highlighted.

may result in large scale changes in the reproductive success and survival of organisms, thereby altering the entire ecology of an area. The combination of these impacts has the potential to cause disturbance at the landscape level (McLellan and Shackleton, 1988; Eaglin and Hubert, 1993). Few species or habitats are completely immune to the effects of off-road vehicle recreation and many are threatened by similar impacts: habitat loss or fragmentation, disturbance, displacement and direct mortality. The following part will explore the literature and management options regarding the major impacts of off-road vehicles and routes on certain groups of animals.[5] This portion of the paper contains a separate section on how other ORV-related factors, including noise, pollution and fire contribute to effects on wildlife and habitat and, because of its critical role and susceptibility to injury from off-road vehicles, this part also contains a review of impacts on riparian habitat.

Effects of ORVs on Wildlife and Habitat: Specific

Herpetiles (Amphibians and Reptiles)

Herpetofauna are very important players in the food web because as a group, they are more abundant, they make-up more biomass and they contribute more significantly to the transfer of energy along the food web than mammals and birds. These creatures have an impact on communities at each stage of their development; amphibian larvae structure aquatic communities, lizards and metamorphosing amphibians provide a link between aquatic and terrestrial food webs and adults play a key role in maintaining the efficiency of terrestrial food webs. Because of these important roles and the fact that amphibians, and some reptiles, serve as indicators of the health of our environment, the impacts of routes and trails and off-road vehicle activity on herpetiles should be a management concern (Welsh and Ollivier, 1998). Off-road vehicle use can lead to the death of reptiles and amphibians due to direct kills, however, the elimination and degradation of vegetation and critical habitat by ORVs has a larger, long-term impact on these animals.



A Species of Special Concern, the Yosemite toad (Bufo canorus) breeds in Glass Creek Meadow; a currently roadless area of the Inyo National Forest.

The desert tortoise, *Gopherus agassizii,* is listed as a threatened species at both the federal and California state level. Despite this, ORV use is one of the least studied, yet most detrimental factors affecting the survival and abundance of tortoises (Bury and Luckenbach, 2002). Two studies comparing paired plots suggest that tortoises suffer most from both direct and indirect effects of ORV use in areas with low to moderate ORV use (Bury et al. 1977, Bury and Luckenbach 2002). In 1997, Jennings studied the effects of off-road vehicle use on the food preferences and habitat use of the desert tortoise. Washes and washlets are important components of tortoise habitat because they allow for easier travel, they make ideal spots for burrows, and they contain abundant and important food sources (Jennings, 1997). In terms of off-road vehicle use, preference for this habitat proved detrimental; tortoises were more susceptible to direct hits by ORVs because they preferred habitats similar to those of ORV users: hills, washes and washlets (Jennings, 1997). Compounding the impact of this direct effect, ORVs minimize food sources and suitable habitat for tortoises by destroying vegetation, disturbing the soil and changing the size and path of washes as traffic causes trails to widen over time (Jennings, 1997).

Disturbance and habitat loss from the creation of trails and off-road vehicle activity can diminish the abundance of many amphibian and lizard populations. Luckenbach and Bury (1983) compared lizard densities on plots with ORV use to those without it; on control plots there were 1.8 times the number of species, 3.5 times the number of individuals, and 5.9 times the biomass found on areas with ORV use (Bury & Luckenbach, 1983). In a study of the impacts of grazing and off-road vehicle use on lizard populations in the Mojave Desert, researchers established 3 plots in each type of area: where the vegetation had been heavily damaged, moderately damaged and slightly damaged by ORVs (Busack & Bury, 1974). Of 4 lizard species found in the area, only 2 individuals were captured in the heavily damaged site while 15 and 24 were captured in the moderately and low damaged sites respectively. Busack and Bury (1974) concluded that off-road vehicle activity and grazing decreased

Desert horned lizard (Phrynosoma platrhinos) found near a dirt route in western Nevada.

the amount (in number and biomass) of lizards present. They also found that ORV use can decrease vegetative cover, reduce invertebrate food sources, disturb social structure and cause casualties. They argue that "prolonged subjection of desert lands to intensive grazing and vehicular damage may lead to long-term, perhaps irreparable, damage to the wildlife communities (Busack and Bury, 1974)."

In addition to loss of vegetation and destruction of habitat, road traffic and the use of off-road vehicles can cause increased sedimentation and chemical contamination that can be detrimental to adjacent aquatic systems; large amounts of sediment can prove detrimental and even lethal to amphibians. Welsh and Olliver (1998) found a lower density of tailed frogs (*Ascaphus truei,* a Species of Special Concern in California*),* Pacific giant salamanders (*Dicamptodon tenebrosus*) and southern torrent salamanders (*Rhyacotriton variegatus,* a Species of Special Concern in California) in streams adjacent to road construction in Redwood National Park. Contaminated sediment and runoff from roads or campgrounds can also negatively affect amphibians and should be considered in management approaches.

Routes, trails and the use of off-road vehicles can create barriers to necessary movement (i.e., movement for migration, breeding, foraging). Studies have found a higher proportion of dead frogs and toads on roads with higher traffic volumes. Although this may result from higher direct mortality, it may also occur because traffic changes movement patterns and interrupts anuran behavior (Fahrig et al. 1995). Nicolai and Lovich (2000) found that disturbance from off-road vehicle activity decreased the rate of movement of flat-tailed horned lizards (*Phrynosoma mcalli*), a Species of Special Concern in California. Decreased movement coupled with the fact that they are often found on roads, makes this species and others disposed to road mortality. Other studies have found that ORV activity destroys large areas of habitat occupied by flat-tailed horned lizards (Lovich and Bainbridge, 1999) and may modify the way this species, and others, use habitat (Beauchamp et al. 1998).

In a literature review discussing the impacts of forest management practices on amphibians in North America, deMayndier and Hunter (1995), contend that the construction and maintenance of forest roads can lead to long-term changes in habitat because routes increase fragmentation and decrease the permeability of the landscape. Marcot et al. (1997) also reports that roads can fragment some reptile habitats. Routes and trails that serve as barriers to amphibian and reptile movements can cause populations to become isolated and therefore, more susceptible to detrimental genetic and environmental consequences. For certain reptile species, particularly burrowing species such as the long-nosed leopard lizard (*Gambelia wislizenii*), striped whipsnake (*Masticophis taeniatus*) and gopher snake (*Pituophis catenifer*), roads can severely inhibit movements (Marcot et al., 1997). Barriers also cause difficulties for herpetiles populations that migrate between aquatic breeding ranges and upland home ranges and may prevent populations from successfully breeding (i.e., red-legged frog, *Rana aurora*, California Species of Special Concern, Federally Threatened). In addition to breeding areas, amphibians and reptiles that utilize different foraging and overwintering areas are at risk during their annual migrations between sites (Reh and Seitz, 1990). For example, as gopher snakes make a seasonal migration between habitats, they are frequently killed on roads (Marcot et al., 1997).

A long-nosed leopard lizard (Gambelia wislizenii)– one of several burrowing herptiles impacted by roads on public lands of the western U.S.

Clearly, roads impact the suitability of habitat for populations of amphibians and reptiles located in the vicinity. The road itself represents a loss of habitat for many species. In addition, the edge effects, including changes in microclimate and increased predation at the border of a road or trail, may disrupt individuals and populations. Research suggests that amphibians may be highly impacted by the abrupt transition at the edge of a road and the forest; the dry, exposed substrate of roads represent a very different habitat than the shaded, moist forest covered in ground litter (DeMaynadier and Hunter, 1995). In a study comparing crossings of 2 forest roads, one 5 m in width and one 12 m in width, DeMaynadier and Hunter (2000) found that salamander crossings decreased at the wider logging road, but found no significant impacts on anurans. They cite, however, that the conversion of land to road causes the loss of significant habitat in a formerly densely roaded region (DeMaynadier and Hunter, 2000).

Herpetiles are susceptible to direct mortality from off-road vehicle use, especially during dispersal and migration; however, they are more greatly affected by the associated loss of vegetation that causes the degradation of critical habitat. Marcot et al. (1997) state that “off-road vehicle use has become a major threat to reptiles" while various studies suggest that ORVs are also a threat to amphibians (DeMaynadier and Hunter, 1995; Maxell and Hokit, 1999). Management plans for reptiles and amphibians that address habitat loss, as well as migration patterns and spatial use of habitat are necessary to begin mitigating the effects of off-road vehicle use. Managers should be concerned about "the potential impacts of secondary roads on sensitive species and should construct fewer and narrower roads with little or no verge clearance (DeMaynadier and Hunter, 2000)." Maxell and Hokit (1999) recommend that roads and trails avoid water bodies, wetlands and areas that are key habitat for amphibians and reptiles. They suggest that managers conduct amphibian and reptile surveys at potential road and trail sites and they urge managers to restrict ORV use to designated roads and trails.

Birds

Amphibians and reptiles have been touted as excellent indicators of overall ecosystem health because of their sensitivity to small, sometimes imperceptible changes in the environment. In terms of off-road vehicle disturbance, however, Bury (1980) argues that based on previous studies, "Birds apparently are the vertebrates most sensitive to ORV influence." Compared to areas subject to ORV use, he found 1.5 times the number of birds and twice the biomass and species of birds in control plots (Bury et al., 1977). A further analysis of the impact of ORVs on desert birds found that birds are susceptible to direct and indirect effects of off-road vehicles. By destroying nests, crushing individuals, harassing individuals and creating noise, off-road vehicles can directly impact desert birds (Luckenbach, 1978). Indirectly, off-road vehicle use can alter habitat and decrease the amount of shelter and forage available (Luckenbach, 1978; Severinghaus, 1982). Severinghaus (1982) found that "tracked vehicles disturb bird populations because of habitat alteration and reduction." A reduction in habitat can result in the replacement of sensitive and endemic species with species that are introduced who may

An endangered willow flycatcher (Epmidonax traillii), one of many species of bird found in riaprian habitats impacted by roads.

be more tolerant to habitat reduction or other consequences of the presence of off-road vehicles. Cumulatively, these effects can interfere with territorial establishment and breeding success.

Scientists suspect that motorized recreation greatly affects the breeding success of birds. Evidence shows that ORVs effect vegetation (see Vegetation section); Luckenbach (1978) stated that "minor structural changes in vegetative cover can have profound influence on an entire breeding fauna." In creosote scrub habitat, moderate ORV use caused a 50% reduction in the number of breeding species and a 24% reduction in the number of breeding pairs (Bury et al. 1977). Thus, moderate ORV use may largely affect diversity and breeding success. In a comparison of desert washes, only one species (one pair) of birds bred in the ORV use area each year while 8 to 9 species (18 to 22 pairs) bred in the wash without ORV use (Luckenbach & Bury, 1983). It is estimated that roads and motorized trails can influence the reproduction of forest birds located up to 200 meters from a route (Foppen and Reijnen, 1994).

Wilson's warblers (Wilsonia pusilla) are one of several species that indicate the health of riparian habitat.

Weinstein (1978) studied the effects of recreation on birds in a riparian community. He found that the level of use affects the abundance and diversity of birds; those areas with low use have a greater abundance and diversity of birds. When there was a significant amount of off-road vehicle activity in the high-use area, even more birds were found in low-use areas. Off-road vehicles changed the behavior of birds in riparian areas by causing them to move away from certain critical areas, to be flushed more readily and to alter their use of habitat (Weinstein, 1978). Off-road vehicles also directly affect birds by damaging riparian habitat, water caches and vital cover for wildlife. For example, wetlands and riparian habitats provide necessary resting areas, food, and water to resident and migratory birds. Because off-road vehicles have eased human access to stopover sites used by migrating birds, these critical areas are being destroyed by pollution and direct damage to plants as a result of crushing and cutting for firewood (Bury 1980).

Luckenbach (1978) evaluated management alternatives, including the rotation of ORV sites, seasonal use, restricted use and concentrated use, that account for life history and behavior (i.e., breeding and seasonal events) of avifauna. He suggests that the most effective option for limiting ORV effects on birds would include a combination of two alternatives: concentrated use in limited areas that already received high use and seasonal closures.

Small Mammals

Compared to birds, there is a paucity of scientific information regarding the effects of disturbance on mammals. This may be because there is a more involved process to estimate mammal populations and because most mammals remain inconspicuous. Similarly, there have been more studies on large mammals than small mammals because larger mammals are easier to study and count. However, limited studies have been done showing that small mammals are also prone to effects of off-road vehicle use; they are subject to direct mortality, disturbance and habitat loss and fragmentation as a result of ORV use and the creation of routes and trails.

Small mammal distribution, abundance, behavior and movements are highly influenced by the volume of vegetation present because this represents the amount of food available in a certain area. Off-road vehicles easily damage vegetation (see Vegetation section), quickly destroying critical food sources and habitat for small mammals. The destruction and conversion of habitat (i.e., the poor cover on forest roads) leaves small mammals vulnerable to predation because even routes that are small and of low use may act as barriers and may inhibit movement (Merriam et al, 1989; Burnett, 1992).

Small mammals like this young mouse, are impacted by roads through direct mortality and potentially many indirect means.

In addition to effects on habitat, ORVs also impact the abundance of small mammals by directly killing or crushing individuals or trapping one in a collapsed burrow (Luckenbach and Bury 1983). In a comparative paired-plot study in desert sand dune habitat, Luckenbach and Bury (1983) found more small mammals in areas without ORV use than in those with ORV use. On plots without ORV use, they found 1.5 times the number of species, 5.1 times the number of individuals and 2.2

times the biomass of those found on ORV use areas.

Carnivores

Unlike small mammals, carnivores are not under stress from predators (except humans). They are still sensitive to disturbance from recreationists and are directly affected by the damage that ORVs do to the soil, air, water, and other animals. Carnivores will suffer if these resources are degraded because they, and their prey animals, are dependent on all of them for survival. Carnivorous creatures, such as the black bear and the mountain lion need large amounts of space within which to live, hunt, mate and breed. Thus, they are extremely vulnerable to the impacts of habitat fragmentation and loss of connectivity due to roads, trails and off-road vehicle activity. The creation and use of routes and trails, as well as cross country travel by motorized vehicles is influential in the distribution and abundance of many carnivores (McReynolds and Radtke, 1978; Claar et al., 1999). In addition, the increased access provided by off-road vehicles and associated trails can be detrimental to the survival of carnivores because it may allow for over hunting or over trapping and illegal poaching, as well as for harassment of individuals. This section explores the effects of off-road vehicle trails and use on individual carnivorous species, with an emphasis on those that are present in California.

Coyote

Coyotes are known for their ability to adapt to disturbance and changes in their habitat. Despite extermination efforts and human development throughout most of their range, coyote populations continue to thrive in rural and urban areas. Perhaps for this reason, there have been few studies regarding the impacts of recreation, specifically ORV use, on coyotes. Possible negative influences of off-road vehicle use include direct mortality, disruption of movement and use patterns of their prey species and disruption of coyote movement and habitat use patterns. For example, coyote activity near mining roads decreased when vehicular activity increased (Douglass and Ernst, 1985). Off-road vehicles and associated trails also allow greater human access that may result in excessive hunting, trapping or harassment.

Red Fox

Red fox are adaptable and often thrive in areas near humans and their activities. Although red fox may be vulnerable to direct mortality from vehicular accidents, hunting and trapping, the red fox is more affected by the destruction of habitat caused by off-road vehicle use (Voigt, 1987). The degradation of habitat will not only affect the existence of places for shelter, for breeding and for denning, but will also reduce the amount of prey available.

Black Bears

Black bears can be displaced by roads and off-road vehicle use or they may respond to alterations and/or loss of their habitat by changing their movement patterns. Black bears in Idaho responded to increases in road densities by shifting the location of their home ranges to areas with lower road densities (Young and Beecham, 1986; Beecham and Rohlman, 1994). Similarly, Brody and Pelton (1989) found that black bears shifted their home ranges based on the density of roads in the Pisgah National Forest of North Carolina. They argue that increased access, making bears more vulnerable to hunters, is the primary effect of roads in bear habitat (Brody and Pelton, 1989). Researchers suggest that a reduction in the number of timber access roads can decrease this negative impact and the stress placed on bears (McLellan and Shackleton, 1988; Unsworth et al. 1989; Beecham and Rohlman 1994). Recreational disturbance from activities including off-road vehicle use can influence black bear den use. For example, in high-use recreation areas, bears entered winter dens 31 days earlier and more commonly abandoned dens when disturbed (Goodrich and Berger, 1994).

American black bears (Ursa americanus) are impacted by increased route densities in their home ranges.

Mustelids: Marten, Fisher, Wolverine

The primary factors influencing this group are direct mortality from trapping, habitat alteration and disturbance responses. Because of their life history and behavior, all 3 of these animals are commonly caught and overharvested (Powell, 1979; Thompson, 1994; Witmer et al. 1998). Recreational trails and roads increase access for humans, thereby increasing the susceptibility of forest carnivores to trapping (Hodgman et al., 1994; Witmer et al., 1998; Claar et al., 1999). In addition, animals crossing trails or wide open areas where ORVs travel can lead to direct mortality. The combination of over harvesting and road kill can be even more significant in small populations found in fragmented habitat because movement and dispersal is limited.

Animals respond physiologically to disturbance (MacArthur et al., 1982; Yarmoloy et al., 1988; Gutzwiller, 1995). These responses can include change in heart rate, body temperature, respiration rate, etc. Claar et al. (1998) state that it is likely that human disturbance, including off-road vehicle use, evokes similar responses and an expenditure of energy in martens, fishers and wolverines.

Forest carnivores are especially vulnerable to disturbance caused by recreational activities because they need large home ranges, have specific habitat requirements and have a low reproductive potential. Thus, the preservation of areas of undisturbed habitat without roads, off-road vehicle use, hunting or trapping is necessary for the persistence of forest carnivore populations.

The American pine marten (Martes americana) is one of several mustelids affected by roads and associated disturbance.

Felids: Bobcat and Mountain Lion

Human development and disturbance are quickly causing the disappearance and degradation of habitat necessary for the survival of mountain lions and bobcats. Murphy (1998) deemed this loss of habitat the most serious long-term threat to felid populations. Motorized recreation is one form of human disturbance that may cause felids to avoid roads and large tracts of land, further fragmenting critical habitat and altering their behavior.

A study in Arizona and Utah found that mountain lions traveled more frequently in areas with lower than average road densities and established home ranges in areas where improved dirt roads and hard surface roads were not abundant (Van Dyke et al., 1986). In this same study, lions changed their behavior to avoid human disturbance and demonstrated a preference for living in areas with low levels of disturbance. The authors suggest that even if habitat remains physically intact and shows little signs of impact by humans, the continuous presence of humans makes certain areas unusable (Van Dyke et al., 1986).

In addition to fragmentation, routes and ORVs increase hunter access. This can significantly effect lion populations by increasing their stress, changing their movement and habitat use patterns, as well as increasing hunter success. Janis and Clark (2002) explored 8 response variables to evaluate the response of Florida panthers to human activity associated with deer and hog hunting. One of the variables tested was proximity to off-road vehicle trails. During hunting season, animals moved away from trails and areas of concentrated human use; panthers did not use trails as much as before the hunt, implying that motorized recreation caused these shifts (Janis and Clark, 2002).

Human disturbance, including motorized recreation, continues to impact large predators such as the mountain lion (Puma concolor).

Difficulties with policing activity and enforcing guidelines in certain countries with low population densities (e.g. USA, Australia) compound the ecological impacts caused by off-road vehicles (Davenport et al., in press). Davenport et al. (in press) report that these difficulties persist even in nature reserves, national forests and national parks. For example, despite the fact that the endangered Florida panther (*Felis concolor coryi*) lives in the Big Cypress National Reserve, ORVs have harassed and disturbed its movements by cutting approximately 37,000 km of mainly illegal trails through the Reserve.

Carnivores generally move long distances, require large home ranges, utilize special habitats and have low rates of productivity. Because they share these characteristics, they are particularly vulnerable to the negative impacts of motorized recreation and off-road vehicles: habitat fragmentation and modification, direct mortality, and disturbance (Marcot et al., 1997). While roads act as barriers to movement for most wildlife species, forest roads now facilitate human access to areas that once served as refuges from disturbance for sensitive species. Thus, as motorized recreation increases in popularity and pressure mounts for further recreational opportunities, there is a need to continue to

[6] This includes species found in California: mule deer & black-tailed deer (*Odocoileus hemionus spp.)* and Elk *(Cervus elaphus).*

gain information on carnivores and utilize this information to implement effective management plans.

Ungulates

Bighorn Sheep *(Ovis canadensis)*

As with carnivores, camping, hiking and ORVs have been shown to negatively influence the distribution and activities of bighorn sheep (Bear and Jones, 1973). Bighorn are a particular species of concern because research suggests that, "Of the ungulate species for which relationships with humans and disturbance have been reported, the bighorn sheep appears to be most susceptible to detrimental effects (Canfield, 1999)." The largest threats to sheep are loss of habitat and harassment that results in increased stress and a destructive physiological response.

Since 1971, the California or Sierra Nevada bighorn sheep (*Ovis canadensis californiana*) has been listed as a threatened species in the state; it is also currently on the state and federal list of endangered species. The impacts of human disturbance on bighorn sheep in California have been reported since 1970. Before then there were 5 areas on the Inyo National Forest that supported bighorn sheep; in 1970, Dunaway found that those areas with the most human disturbance no longer supported sheep. He concluded that increased recreation on bighorn sheep ranges (*Ovis canadensis nelsoni or Ovis canadensis cremnobates,* also listed as federally endangered *and Ovis canadensis californiana*) in the Inyo National Forest negatively affected those populations (Dunaway, 1970). Dunaway (1971) suggested that disturbance from human recreation could be a limiting factor in the growth of California bighorn populations. In an effort to minimize these impacts, Dunaway (1971) proposed the creation of a zoological area for bighorn sheep where human use would be limited in multiple ways, including the prohibition of motorized vehicles.

Bighorn sheep are susceptible to negative impacts from motorized disturbance, which may cause them to flee or abandon an area, as well as habitat destruction and fragmentation.

Further exploring the effects of humans on bighorn sheep, DeForge (1972) directly addressed the impact of one particular road in the San Gabriel Mountains in southern California. He found that sheep utilize certain critical areas less at times of high human use, suggesting an alteration of habitat-use behavior which could jeopardize their survival. He concluded that an increased use of this road for timber cutting, fire fighting, recreational off-roading and hunting directly affected sheep's behavior and also destroyed habitat. He urged for the removal of this road and the consideration of bighorn habitat in the construction and placement of roads in the future.

In addition to a change in behavior and loss of habitat, bighorn sheep are vulnerable to harassment that can evoke damaging physiological responses (DeForge, 1976). In a study of physiological responses to human disturbance, MacArthur et al. (1982) reported that the heart rates of mountain sheep (*Ovis canadensis canadensis*) increased by a mean of 20% in conjunction with the appearance of a human. The results of a study conducted by Stemp (1983) were similar; he reported increased heart rates in bighorn sheep in response to the presence of a human in their habitat. In both studies, behavioral cues did not necessarily show these responses to disturbance, suggesting that the outward behavior of bighorn sheep is a poor indicator of response to disturbance. Research suggests that repeated disturbance leading to stress responses may have serious impacts on bighorn sheep. Such responses carry high energy costs, may be debilitating to animals that are already under stress (i.e., in winter) or may even be fatal to sheep (Berwick, 1968; Geist, 1971).

Multiple studies have corroborated these findings and recommend that regulations to control ORV use and other human activities in sheep habitat are needed (Dunaway 1971; Geist 1971; DeForge 1976; Stemp 1983; King 1985; King and Workman 1986; Krausman and Leopold 1986; and Harris et al. 1995). For example, implementing road or trail restrictions or education programs to reduce human intrusions into areas where desirable and productive bighorn sheep habitat is limited. MacArthur et al. (1982) suggest that limiting human activities to roads and established trails in places where sheep ranges and high recreational use areas overlap can also abate the impacts of disturbance.

Cervids (Deer and Elk)

Unlike research on sheep, there is significant variation in the results of studies investigating the effects of routes and off-road vehicles on deer and elk. However, many studies report changes in elk and deer behavior and/or habitat use in response to human activity. Akin to challenges faced by many other types of wildlife, research suggests that deer and elk are also threatened by habitat loss and fragmentation due to motorized recreation.

Yarmoloy et al. (1988) reported noticeable changes in behavior and reproductive success by mule deer does who were harassed by an ATV. Changes in behavior included leaving home ranges more often, using cover more frequently, feeding during darkness and increasing flight distances from the ATV (Yarmoloy et al., 1988). The harassed does suffered decreases in reproduction during the year of the study, yet had normal reproduction the year before and after the study. Ferris and Kutilek (1989) observed black-tailed deer to determine how ORVs affected the size of their home ranges, the duration of their activity periods, their habitat preferences and their reaction to disturbance. They found no significant impact on home range, activity period or habitat preferences, however, they did report that deer moved to areas with little or no traffic in response to disturbance from high levels of ORV traffic.

Wisdom et al. (2004) conducted an experiment to test the effect of various types of recreation including ATV use, horseback riding, mountain biking, and hiking on deer and elk behavior. They found that the passage of ATVs and mountain bikes elicited more pronounced reactions in elk and more consistently resulted in increased movement rates and flight responses than hiking or horseback riding. Mule deer did not show measurable responses to any of the off-road treatments (Wisdom et al., 2004).

These mule deer (Odocoileus hemionus) seen on the Coyote Plateau of the Inyo National Forest are one of several species of cervid that are impacted by ORVs.

Lyon (1983) developed a model depicting the manner in which elk use habitat in response to changes in forest road density. This model can be used to predict elk response in areas where road densities reach up to 6 miles per square mile. As road density increases, elk demonstrate an expected pattern of response; Lyon estimates that in an area with a density of five and a half miles per square mile, elk use is 18.8% of potential, whereas an area with a density of 2 to 3 miles per square mile would result in an elk use of 47.5% of potential. He concludes that "the best method for attaining full use of habitat appears to be effective road closures (Lyon, 1983)."

Evidence of the avoidance of forest roads and a decrease in the amount that elk use habitat adjacent to forest roads is abundant (Lyon 1979a, Rost and Bailey 1974, 1979, Witmer and Calesta, 1985). The magnitude of this effect is deceiving because habitat appears to remain intact. However, it can not be fully or effectively used by animals in the vicinity because of traffic, pollution, degraded habitat, and human disturbance (Lyon, 1983).

Several management techniques could minimize or mitigate these impacts. For example, redirecting trails and campsites away from preferred and/or critical habitat for certain animals (i.e., riparian and oak woodlands for deer) into adjacent areas that are not as critical or will not be as susceptible to damage. In addition, encouraging users to stay on trails may minimize the effects of human activity. Research suggests that animal responses to disturbance on established trails and roads are minimal, whereas animal responses are greater in areas with no previous disturbance (MacArthur et al., 1982; Schultz and Bailey, 1978). Wisdom et al. (2004) argue that a different measurement is needed to accurately describe disturbance; in their study, they test the concept of "off-road recreational equivalents." This is the ratio of ATV riders, mountain bikers, horseback riders and hikers that results in the same effect on a given resource if the use rate is the same. From their results, the authors suggest that "different levels of off-road activity are required to approximate the same effect on a given resource (Wisdom et al., 2004)." For example, they found that it would take 3 groups of horseback riders or hikers to every group of ATV riders and 2 groups of mountain bikers to one group of ATV riders to have the same impact on a resource.

Further study of this concept is needed because recreational equivalents could provide agencies with a more holistic management approach that would allow for the consideration of all off-road uses and their cumulative effects. The authors suggest separating ATV or mountain biking watersheds from those for hiking or horseback riding (Wisdom et al., 2004). Managers could allow more groups of users into hiking and horseback riding areas before realizing the same effects on elk, and probably other resources, as in ATV and mountain biking areas. The other management alternative that they present involves restricting each recreational use to separate, specified trails and roads (Wisdom et al., 2004). Although this might minimize user conflicts, it would spread recreational impacts out over a larger area; this may decrease the intensity of impacts, but would increase the overall extent of damage.

Effects of ORVs on Wildlife and Habitat: Contributing Factors

Although noise, fire and pollution may not have as great an impact on wildlife and their surroundings as habitat fragmentation and loss, disturbance and direct mortality, they are still important adverse impacts that can be attributed to off-road vehicle operation.

Noise

Noise from ORVs can interfere with wildlife's ability to find and capture prey, to escape from predators and to successfully mate and reproduce. Brattstrom and Bondello (1983) report significant evidence of the impacts of ORV noise in the Mojave Desert. Noise from off-road vehicles interfered with the ability of desert kangaroo rats (*Dipodomys deserti*) to hear predators (i.e., rattlesnakes) and caused permanent hearing loss in certain animals (i.e. desert kangaroo rats, fringe-toed lizards (*Uma scoparia*) and desert iguanas (*Dipsosaurus dorsalis*)). The sounds of a motorcycle passing also caused enough disturbance to initiate the premature emergence of Couch's spadefoot toads (*Scaphiophus couchi*). Due to their need for water, food and light, this species typically emerges only after summer thunderstorms have begun and temporary pools have begun to form. However, the sound of an off-road vehicle served as an environmental cue causing them to emerge from their burrows during the wrong season and in the absence of water, endangering their lives and causing deleterious effects to individuals (Brattstrom and Bondello, 1983). Further studies provide evidence of potential damaging effects of noise on herpetofauna. Northern leopard frogs (*Rana pipiens,* California Species of Special Concern) exposed to loud noises were immobilized for longer periods of time than frogs that were not exposed to noise (Nash et al., 1970). This reaction could make animals trying to cross a road or those living in

Noise and pollution from ORVs like these crossing Deadman Creek in the Inyo National Forest, have been shown to have adverse affects on survival and reproduction of wildlife.

areas used by ORVs more susceptible to mortality (Nash et al., 1970).

These findings are not surprising given that off-road vehicles emit the most common, frequent, high-intensity sound in the desert (Brattstrom and Bondello, 1983). As a result of these findings, they argue that ORV use should be limited to areas away from “undisturbed desert habitat, critical habitats, and all ranges of threatened, endangered or otherwise protected species (Brattstrom and Bondello, 1983).”

Fire

Over the past 100 years, wildfire fighting efforts have often resulted in the creation of new roads and trails. Although these roads and trails were built to facilitate access for fire fighters, they have also done the same for recreaters. Increasing motorized human access to previously inaccessible areas can negatively effect wildlife and their habitat (see above: Wildlife and Habitat), while also increasing the possibility of human-induced fire. Approximately 85% of wildfires on forest lands are caused by humans and a study of all California national forests reports that 75% of all fires occur within 10 feet of a road (Wilson, 1979).

In addition to providing access for more users, off-road vehicles can also directly ignite fires. Data collected shows that the combination of dry fuel material (i.e. grasses or debris) and an all-terrain vehicle (ATV) exhaust system can result in the ignition of a fire and the combustion of organic material (Baxter, 2004). Baxter (2002) reported that the number of ATV-caused wildfires has increased over the last 10 years. Fires may be started by ATVs due to exploding electrical switches (solenoids) on winches, the ignition of grass and fine fuels by exhaust systems and sparks from exhaust systems. While natural fires can contribute positively to ecosystem health and growth, management agencies attempt to prevent human induced fires because they are often detrimental to the environment and may put people at risk. It is possible to reduce ATV fires by requiring spark arrestors or protective shrouds to prevent debris from coming in

An increasing number of fires like this one on the western slope of the Sierra Nevada are caused by ORVs.

contact with heat produced by ATVs, prohibiting the use of ATVs in forests during times of increased fire danger and educating ATV users about what they can do to prevent fires. For example, users can install spark arrestors, clean their vehicles to prevent ignition of debris and/or carry fire-fighting tools (Baxter, 2002).

Pollution

Research suggests that off-road vehicles, including motorcycles, all-terrain vehicles (ATVs), snowmobiles, etc. contribute greatly to the pollution of water and air in the United States (Gucinski et al., 2001). They increase pollution by depositing unburned fuel into the soil, snow or water and by emitting pollutants into the air. This directly alters the composition of soil and snow while indirectly affecting vegetation and aquatic systems. Off-road vehicles also emit dangerous levels of toxins, including carbon monoxide (CO), nitrogen oxides (NO), and hydrocarbons (HC). In addition, off-road vehicles release compounds that are known human carcinogens (particulate matter (PM), benzene and polycyclic aromatic hydrocarbons, (PAHs)), and a suspected carcinogen (methyl tertiary butyl ether, MTBE). Thus, the effects of pollution generated by ORVs are pervasive as they extend well beyond any route or trail, affecting the health of humans, wildlife, vegetation and entire ecosystems.

A significant amount of damage can be attributed to the unburned fuel that ORV engines deposit into the environment. Off-road vehicle engines may be either two-stroke or four-stroke; two-stroke engines use fuel less efficiently and emit more unburned hydrocarbons (HC) and particulate matter (PM) than four-stroke engines. The Environmental Protection Agency estimates that 25 to 30% of the fuel in a 2-stroke motor remains unburned and is released into the air and water (Natural Trails and Water Coalition, 2005b).

Because they are more powerful, lighter weight and are less expensive, two-stroke engines can be found in 60-65 % of off-highway motorcycles and 10 to 15 % of all ATVs in the United States (Unites States Environmental Protection Agency, 2001a). In 1993, the California Air Resources Board found that motorcycles with 2-stroke engines release 10 times the amount of hydrocarbon emissions as 4-stroke motorcycles. As a result of the amount of emissions released, use of 2-stroke engine motorcycles are now responsible for 90% of the emissions from ORVs that contribute to the formation of smog in California (California Air Resources Board, 2001).

In 1994, the Environmental Protection Agency (EPA) definitively announced that non road engines "are significant contributors to ozone or carbon monoxide concentrations." Durbin et al. (2004) report that off-road vehicles are "one important source of emissions that make a disproportionately high contribution to the emissions inventory." For instance, between 1989 and 1998, pollution due to off-road vehicles grew from 17 to 22 percent of the total produced by mobile sources in the U.S, while pollution from cars decreased from 62 to 56 percent despite the fact that the number of these vehicles and the miles driven increased (United States Environmental Protection Agency, 2001b). This may be due to the fact that the hydrocarbon and carbon monoxide emissions released by a new passenger car are much lower than those released by 2-stroke or 4-stroke engines.

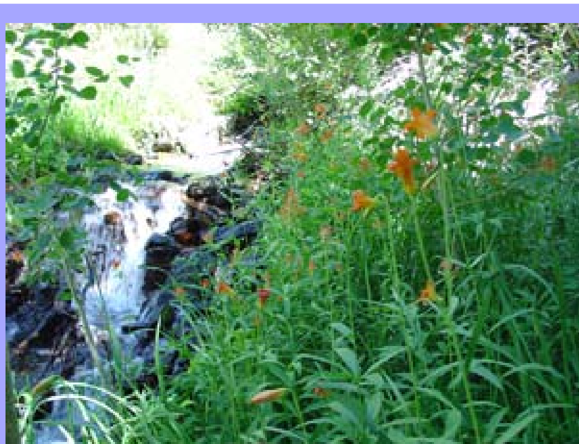
A significant proportion of the research conducted on ORV pollution relates to its impact on air quality and human health. However, pollution emitted by ORVs can have severe impacts on aquatic and terrestrial systems. The substantial amount of unburned fuel released by ORVs may be deposited into the soil where it has the potential to penetrate into underground water, adversely impact vegetation or run off into the aquatic system. A rapid pulse of these toxins into a system can quickly increase the acidity of a stream or waterway, causing the death of aquatic insects and amphibians (Hagen and Langeland, 1973). Acidification due to atmospheric deposition and pollution has been shown to effect the survival and distribution of amphibians, including tiger salamanders, boreal toads, and northern leopard frogs (Freda and Dunson, 1985; Harte and Hoffman, 1989; Corn and Vertucci, 1992). By releasing hydrocarbons and volatile organic compounds into streams and lakes, off-road vehicles can also disrupt the biological functions of fish, disrupting their ability to maintain their metabolism and immune system while also jeopardizing their reproductive success and survival (Balk et al., 1994; Juttner et al., 1995). In addition, there is evidence that low levels of PAHs released by ORVs are toxic to zooplankton, restricting the reproductive success of zooplankton and many fish (Giesy, 1997;Oris, 1998).

Off-road vehicles release detrimental pollutants, including carbon monoxide and particulate matter that work their way into the air, water, soil and snow, affecting human and environmental health. The same toxic chemicals and compounds that impact human resources and health can also affect the health and survival of wildlife and vegetation that are exposed to polluted air, water and/or food sources. Although these impacts may be silent or unnoticeable to the eye, governmental organizations and land management agencies have a legal and ethical responsibility as set out by the Clean Air Act, Clean Water Act and the Executive Orders to address the overwhelming amounts of pollution that currently threaten our public lands and the people and wildlife who use them.

Effects of ORVs on Wildlife and Habitat: Riparian Zones, Meadows and Wetlands

Sachet (1988) identified “sensitive” habitats where backcountry recreation is a concern due to 1) the ecological uniqueness of the habitat, 2) the essential habitat it provides for a key species and 3) the potential extreme sensitivity of the habitat to recreation. Two of these “sensitive” habitats are riparian zones and meadows (Sachet, 1988). The severity and extent of off-road vehicle damage can be greater in areas of uncommon habitat. Many species are dependent on riparian zones for their survival. Thus, due to a paucity of these habitats in certain areas in California, as well as their fragility and importance, damage inflicted by ORVs can have extremely detrimental, expansive and persistent effects on riparian zones and meadows and the creatures that depend on these ecosystems.

Riparian habitat areas or corridors include the vegetated areas along streams, rivers or lakes. Research shows that riparian ecosystems, as well as meadows and wetlands are vital to the health of aquatic and terrestrial ecosystems because they filter out pollutants from land runoff, prevent erosion, and provide shelter and food for many aquatic and terrestrial animals (United States Department of Agriculture, 2002). These areas are, however, sparse in certain areas (i.e., desert ecosystems in California) and fragile to disturbance from motorized recreation.



Healthy riparian systems, like this one in Lundy Canyon on the Inyo National Forest, provide critical habitat for many rare and sensitive species.

Riparian zones attract wildlife because they provide food and water, breeding and rearing areas, and hiding and resting opportunities. Riparian areas do not only provide direct sources of food to animals; they also support the needs of aquatic insects, a key food source for fish, and also provide an area for the growth of a prey base that will feed hawks, eagles, owls, falcons, bears and wolves (Brown, 1985). Riparian areas are ideal for breeding and rearing because of the diversity of resources they provide, including food, water and cover for newly born fawns and calves. In addition to providing nesting sites for raptors and their prey, riparian zones and associated vegetation help maintain the quality of spawning grounds for fish. Riparian areas are often used as corridors for movement because they provide cover and resources while connecting areas of critical habitat (i.e. deer often migrate through riparian cover to get from higher elevation areas in the summer to lower elevation areas in the winter).

Meadows are also extremely important to wildlife because they provide habitat for foraging and other necessary activities; meadow edges often have extremely high species diversity and richness. Deer and elk come to meadows to find nutritious vegetation that is not available in coniferous forests and may also use these areas for rutting and mating. Moose and bear also rely on meadows for food and even mountain goats and sheep will forage in meadows that are associated with rocky terrain and cliffs.

There are countless television and magazine advertisements depicting a motorcycle, ATV or full-size vehicle crashing through a stream, driving up and along a river bank or racing across a muddy, wet meadow. Portrayals that glorify this type of behavior are misleading and only serve to perpetuate this type of action. In actuality, the operation of vehicles in streams and pools has the potential to destroy riparian vegetation and habitat for a range of animals, including invertebrates, fish, amphibians, reptiles, mammals and birds (Manning, 1979; Bury, 1980). ORV use often causes damage to streambanks that leads to increased erosion and sedimentation in streams and rivers. Studies have found that ORV use in wetlands, meadows, bogs and swamps can create ruts which ultimately alter hydrological patterns as they change the path of water (Heede, 1983;Lodge 1994;, Duever et al. 1981; Duever et al. 1986). These impacts can alter entire ecosystem processes, affecting the ecology of an entire area.

DeMayndier and Hunter (1995) cite studies regarding the importance of riparian zones and streams to amphibians. They argue that impacts to “streamside vegetation and soils may have important effects on both stream-dwelling and upland streamside amphibian fauna (DeMayndier and Hunter, 1995)." For example, the improper construction of forest roads could lead to increased sedimentation and a degraded quality of habitat for larval and adult animals; this has been shown to lead to decreased amphibian diversity and abundance (Swanson et al., 1990). There is evidence that ORV use in riparian areas has contributed to the destruction of nesting habitat for willow flycatchers, a species that is listed as federally endangered (United States Fish and Wildlife, 1995; Saab and Rich, 1997). Damage to riparian plant communities by ORV use has also had an impact on the ranges and distribution of other western subspecies (Wildlands CPR, 1999). In addition, if the passage of off-road vehicles through riparian habitat does not directly destroy the area, it may still disrupt and restrict wildlife use. Sheridan (1979) warns that "…Any rare species inhabiting such uncommon ecosystems may be in danger of local or total extinction as a result of ORV use. "

ORVs have increased the accessibility of remote areas, thus, creating the potential for damage in places that were previously protected. For example, when campsites in riparian areas are created and become established, riparian vegetation is often cut for fuel, erosion of heavily used areas occurs and litter and water pollution become common (Bury, 1980). In addition, when riparian areas are used by ORVs, there is also a good chance for gas and oil pollution from leaks and spills.

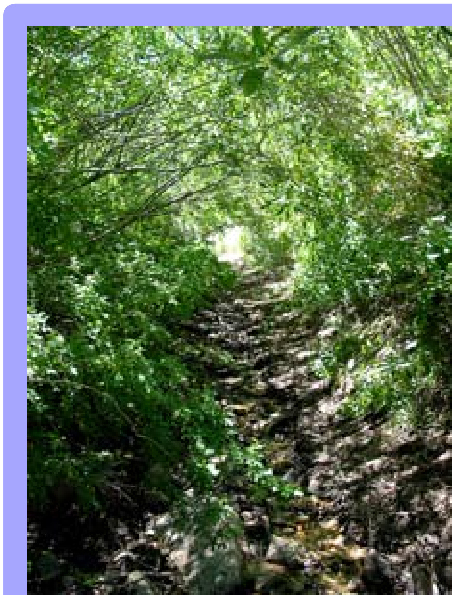
This route exists in a flowing creek up Shannon Canyon in the Inyo National Forest. Routes like this have been shown to have considerable impacts on the riparian habitat they invade.

In 1999, Wildlands CPR released a document petitioning for a change in regulations regarding off-road vehicles on national forests. This petition identified riparian zones as a habitat requiring special attention because in many instances, the government has failed to meet its own legal obligation to protect riparian areas where "no management practices causing detrimental changes in water temperature or chemical composition, blockages of water courses, or deposits of sediments shall be permitted ... which seriously and adversely affect water conditions or fish habitat (36 C.F.R. §219.28(e))."

Research suggests that impacts on riparian habitat and fishery resources may be reduced if forest managers direct more attention to the design and layout of roads (Kochenderfer 1970, Swift 1984). If management practices within riparian areas are to be effective, they will consider topography, vegetation type, soil, climatic conditions, and management objectives. Brown (1985) suggests that education is also a key component in useful management strategies; destructive behavior may be minimized if users learn that riparian areas, meadows and wetlands are extremely vulnerable to disturbance. The most valuable management strategies will prevent damage by avoiding the creation of recreation opportunities in riparian zones and will mitigate damage by closing critical riparian, wetland and meadow areas.

Vegetation

ORV use can have direct and indirect impacts on vegetation by contributing to surface damage, vegetation stripping and the spread of invasives. Direct impacts may include breaking, cutting, and crushing of foliage, root systems or seedlings and disruption of root systems due to stresses induced in the soil. These impacts can be felt by species ranging in size from grasses to trees. However, desert vegetation is more susceptible to damage at the ground surface where ORVs pass through because it grows slowly and has shallow root systems. Desertification, an imprecise term described as “the gradual reduction in the productivity of land because of excessive human use” may occur (Kockelman, 1983). Arid areas are extremely vulnerable to desertification as a result of overgrazing, de-vegetation for fuel, and ORV use. Lovich and Bainbridge (1999) estimate that it will be “probably centuries” for natural recovery to occur in California desert plant communities subjected to off-road vehicle use.



This route cuts through one of few riparian corridors on the eastern flank of the Coyote Plateau of the Inyo National Forest. Damage to vegetation in these vital areas can have significant systemic impacts.

As ORVs pass through an area they loosen soil, often causing erosion and building up piles of sediment adjacent to their path (Eckert et al., 1979). Deposition of soil on vegetation due to movement by wind or water can bury plants and destroy them (Belnap et al., 1994). Indirectly, ORVs can affect vegetation by increasing soil compaction, thereby intensifying erosion and runoff, leading to the loss of soil stabilizers that are needed to hold plants and support their growth (Tuttle and Griggs, 1987; Belnap 2002, 2003). This can be very detrimental because erosion of soil by vehicles creates large notches, gullies or channels where they did not previously exist. If vegetation is concentrated in these areas, undercutting or changes in slope due to wind and water can lead to further loss of soil and vegetation (Wilshire et al. 1978). In turn, this loss of vegetation from an area results in an increase in runoff which is often diverted to adjacent slopes. Although these slopes may not even have ORV traffic on them, added erosion, gullying and subsequent loss of vegetation may occur due to greater amounts of runoff. Thus, ORV use can contribute to beginning and perpetuating a detrimental cycle that progressively enlarges tracts of denuded land.

Off-road vehicles and the construction of routes and trails for their passage can have such detrimental and persistent effects because of the breadth and immediacy of their impact. For example, with one passage, a motorcycle creates an impact on the ground surface that is 13 cm wide while a 4-wheel vehicle impacts a 47 cm wide area of the ground. It is estimated that even a motorcycle driven very carefully affects 1 acre of land for every 20 miles it travels; a four-wheel drive vehicle also driven as carefully as possible affects 1 acre of land for every 6 miles it travels. Someone walking has to travel 40 miles to impact 1 acre of land (Wilshire, 1977-78). The damage done to the surface by motorized recreation is evident both in the literature and out on the landscape.

When compared to closed areas, Kay (1981) reported less vegetative species diversity in areas open to ORV use. Bury and Luckenbach (1983) reported the obliteration of vegetation in areas with heavy ORV use and further studies have concurred. In the Mojave Desert off-road vehicle use areas have significantly reduced perennial plant densities and vegetative cover amounts (Lathrop, 1983). Lathrop (1983) found that plant cover was reduced by 39 to 96 percent in areas with motorcycle, buggy and four-wheel drive use. In addition to direct crushing of foliage and germinating seeds and root systems, vegetation peripheral to routes was destroyed by parts of the vehicle that were wider than the track width (Lathrop, 1983).

In their study on the ecological impacts of ORVs on the biota in the Algodones dunes, Luckenbach and Bury (1983) reported that some percentage of the herbaceous cover was destroyed on all plots with off-road vehicle use. Compared to plots with ORV use, those plots without it (controls) had 2.4 times the number of species, ten times the density, 9.4 times the cover and 40 times the volume of shrubby perennials. Areas with heavy ORV use and damage had little to no vegetation, suggesting that the severity of damage to vegetation is positively and directly correlated with the intensity of ORV use (Bury, 1980; Luckenbach and Bury, 1983). Most of the plants were destroyed by being directly trampled or by suffering damage to their root systems (Luckenbach and Bury, 1983). Luckenbach and Bury (1983) attribute this destruction of vegetation to ORV use and suggest that vehicles similarly destroy vegetation in other ecosystems. They also suggest that changes to soil from ORV use, including compaction, reduced porosity and reduced moisture content may contribute to the death of vegetation (Luckenbach and Bury, 1983). Loss of vegetation decreases the amount of shelter and burial options for invertebrate and vertebrate species and also decreases primary production, disrupting the entire energy transfer of the ecosystem. Due to the loss of vegetation caused by ORVs, Bury and Luckenbach (1983) attribute severe habitat destruction to off-road vehicle recreation and associated routes.

Off-road vehicles can reduce diversity and density of vegetation as a result of trampling, cutting and crushing.

The synergistic impacts of the degradation of soil quality with direct crushing and killing of vegetation can be enormous. Although Bury (1980) states that the severity of damage is positively and directly correlated with the intensity of ORV use, he also suggests that even one pass by a motorcycle can disturb the soil and lead to the establishment of weedy communities. A simple change in soil can lead to changes in the species composition of a community and may allow for the invasion of exotic species that often out compete native species in disturbed areas. Combined with ORV use, overgrazing and other human activities are entirely changing vegetation communities. This can impact the entire ecology of the area by affecting birds, mammals and invertebrates that previously relied on a certain vegetative community for survival (Bury and Luckenbach, 1983).

In a very short amount of time, an off-road vehicle can spread invasive plants over a large area. The establishment of invasive and exotic plants, such as knapweed and cheat grass, is made easier by the presence of roads and the passage of ORVs as they create disturbance in the soil and suppress native vegetation (Tyser and Worley, 1992). Then, off-road vehicles transport nonnative and/or invasive plant seeds into areas where they were not present in the past (Lovich and Bainbridge, 1999; Lawler, 2000). It is estimated that one pass of an ATV can spread more than 2,000 invasive knapweed seeds over a 10 mile radius (Montana State University Extension Service, 1992).

Deep ruts like this one in Onion Valley on the Inyo National Forest disturb systems allowing for changes in species composition and degredation of ecosystem health.

Apparently, roadless areas may be integral to the conservation and preservation of native plant communities. Gelbard and Harrison (2003) tested and compared the effect of distance from roads, and its interaction with other variables, on the diversity of native and exotic plants. They found that distance from roads linked with soil type has a significant impact on the success of native plants (Gelbard and Harrison, 2003). They support the idea from conservation biology that "roadless habitats act as refuges for native plant diversity (Soule and Terborgh, 1999)." Their results indicate that habitats that are located far from roads (>1000 m) provide a haven for native grassland species on nonserpentine soils in California (Gelbard and Harrison, 2003). They suggest that distance from roads may be even more important for the survival of native species in areas that have not been invaded so heavily (i.e. remote areas of the Colorado Plateau and Great Basin), and they urge mangers to protect the remaining roadless grasslands in California and elsewhere (Gelbard and Harrison, 2003). In their list of management implications and suggestions, they mention the need to limit the access of off-road vehicles into areas with a low density of roads and to monitor the use of recreational trails and grazing allotments in roadless areas to prevent further degradation of native plant habitat (Gelbard and Harrison, 2003).

Soil

Soil is a key component of life in the natural world. Impacts to the amount and quality of soil greatly affect vegetation, wildlife, communities, and entire ecosystem functions and processes. For approximately 30 years, scientists have been providing evidence of the detrimental lasting effects that off-road vehicle use has on many types of soils (Dotzenko et al., 1967; Luckenbach, 1975). Although most of the research conducted has focused on desert ecosystems, Sheridan (1979) recognized that “No type of land in the United States can withstand sustained ORV use without some damage.” There is also data suggesting that all ecosystems and soil types are vulnerable to damage (Dotzenko et al., 1976; Webb et al., 1978; Belnap, 2002, 2003). The passage of off-road vehicles over any type of soil can degrade quality and stability by 1) increasing shear and/or compaction in the soil and 2) disturbing the surface soil directly.

Pressure on the substrate can cause instability due to shear, or the slippage of particles that are parallel to the soil surface. This can result in the collapse of the subsoil, creating a small landslide under the surface. As ORVs pass over the surface they also make it more compacted by compressing the substrate. Compaction has severe environmental impacts because compacted soil particles have less space in between them, making it more difficult for seedlings to take root and reducing the amount of water that can get into the soil. Decreased infiltration capacity results in increased erosion and runoff, alteration of hydrological flows and reduced nutrient cycling (Eckert et al., 1979; Adams et al., 1982). An increase in erosion due to off-road vehicles can have severely detrimental effects in terms of increasing sediment production. For example, 72,000 tons of sediment was attributed to concentrated off-road vehicle use after only one winter season in Hungry Valley, California (Griggs and Walsh, 1981).

This hillside has unnecessary looping tracks contributing to erosion in the fragile desert system found on Glass Mountain in the Inyo National Forest.

Off-road vehicles create disturbance at the surface of the soil because they damage the top layer, making the soil beneath it vulnerable to erosion and drying (Bury, 1980). When soil is broken down, exposed plant roots may also become crushed or dried out and vegetation may be lost (Wilshire et al., 1978). In a comparison of 2 trails, one open to ORV use and one closed to it, Kay (1981) found that the trail with off-road vehicle use had a greater loss of soil through gully erosion and had less plant litter present. Soils that have been eroded from roads enter streams and rivers degrading the quality of native fish habitat (Eaglin and Hubert, 1993).

Evidence shows that ORV use has a marked impact on soils and vegetation in desert ecosystems because deserts are fragile entities that are especially vulnerable to disturbance. Dregne (1983) estimates that desert soils suffer significant amounts of damage due to off-road vehicles and ecosystems may take 10,000 years to recover from it. The passage of off-road vehicles over desert surfaces decreases soil stabilizers, allowing for increased erosion (Lovich and Bainbridge 1983). The biotic components of soil stabilizers, referred to as crytobiotic soil or crust, hold the desert together and are especially vulnerable to damage because they are on the surface (Belnap, 2002). If subjected to a large shear stress, the crust can be destroyed by one vehicle; Belnap and Gillette (1997) repo that it may take 250 years for the crust, an integral part of desert life, to completely recover. If crus is subjected to compressive forces, it can survive in a modified form, however, over time any level off-road vehicle use can completely destroy crusts in an area (Wilshire 1983). Damage due to off-road vehicles is often difficult to revegetate because vehicle use changes the structure of the soil (increasing soil density, decreasing moisture content, etc). Wilshire et al. (1978) found that changes to the structure of the soil last for 7 years, while Power (1974) found that soil in logged areas took 40 years to rebound from compaction and to be able to once again support plant life. There is also evidence supporting the idea that the impact that ORV use has on soil loss can be especially detrimental in mountain areas that already have great potential for erosion due to the combination of sandy soil with low organic content and steep slopes (Kay, 1981).

The effects of off-road vehicle use on soils could be minimized with several management strategies. Wilshire et al. (1978) state that agencies designate areas for ORV use, but do not include management plans for land use or soil conservation. Practical management strategies to reduce the impacts of off-road vehicles on soil include reducing the steepness of slopes where people use ORVs (i.e. replacing hill climbs and steep trails with switchbacks) and decreasing the length of these slopes (i.e., by installing waterbars) to decrease erosion and the extent of its impacts. In addition to these and other site specific practical applications, like agricultural soils, “conservation of soils in ORV areas requires intensive on-site management (Wilshire et al., 1978).”

Redundant hill-climbs, like these southwest of Bishop on the Inyo National Forest ,contribute to vegetation loss and erosion.

Management Implications

It is clear that some of the differences between ORV users and those who protest their intrusion and the damage they cause will be irreconcilable. The education of all parties concerned may help restore good will, and future compromise may reduce some of the problems and conflicts, but these approaches have their limitations. Eventually, ***firm policies of land management combined with enforced regulations will be necessary.***

~California State Parks and Recreation Department,1975

This prophetic statement remains true 30 years later; public lands are still in dire need of stringent and enforceable management policies. The emotions associated with the issue of off-road vehicle use persist as land management agencies continue to struggle with developing and enforcing strict and necessary regulatory policies. Throughout this analysis, management ideas and strategies for specific ecosystem components or species (i.e., soil or bighorn sheep) have been discussed. This section will explore more general implications and will include a discussion of both current and needed management practices, as well as gaps that exist in research. We argue that effective management policies should be research-based, proactive, consistent, enforceable and focused on minimizing resource damage and user conflicts.

Past Management

In 1979, Charles Warren, then Chairman of the Council on Environmental Quality, stated that his organization saw the problem of off-road vehicle use as “one of the most serious public land use problems that we face (Sheridan, 1979).” In this same report Sheridan reported that, “The two major federal land management agencies–the Bureau of Land Management and the U.S. Forest Service–have been slow to grapple with the off-road vehicle problem…Land management agencies responsible for areas of intensive off-road vehicle use will need to make new efforts to monitor impacts and enforce necessary restrictions." He criticized the manner in which the Forest Service was responding to ORV use on public lands and urged the Forest Service to comply with Executive Order 11644 by including off-road vehicle use into their management plans (Sheridan, 1979). Other reports identifying weaknesses in the ability of agencies to implement the Executive Orders on off-road vehicles have also been written. A 1986 report on the Forest Service and a 1991 review of BLM off-road vehicle policy expose deficiencies, including incomplete inventories of routes, inadequate mapping and signing of off-road vehicle routes and insufficient monitoring of off-road vehicle effects (United States General Accounting Office, 1995). In their own study in 1995, the General Accounting Office investigated Executive Order compliance at various BLM and Forest Service cites. Although results varied, they found certain consistent problems. In areas where lands were designated as either opened or closed, there were often no clear signs or maps to help the public to know these designations (United States General Accounting Office, 1995). Off-road vehicle use was being monitored in a casual, non-systematic manner. Thus, the adverse impacts were not being documented very consistently and ways to correct these adverse impacts were not yet prioritized or being implemented (United States General Accounting Office, 1995). In many areas, enforcement was proving difficult because of confusion by officers and users about restrictions. Similar deficiencies are often found on public lands today.

This ORV user tacitly displays his disdain for management efforts to curb motorized use as he rides over an obvious barrier constructed to deter such use.

Most of the managers at these sites attributed difficulties in implementing the Executive Orders to the fact that other activities are assigned higher priority, thus funding and staffing are limited (United States General Accounting Office, 1995).The United States Department of Agriculture reports that, "at current funding levels, the Forest service will continue to restrict mapping, signing, and monitoring of adverse effects to areas that receive highest OHV use and are most ecologically sensitive (United States General Accounting Office, 1995)." The Department of Agriculture also stated that their ability to fully implement the Executive Orders is dependent on the availability of funding which generally falls below what is needed or requested (United States General Accounting Office, 1995). In 1980, Bury wrote, "This is where we stand today: a fragmented, under funded effort to assess the effects of one of our more serious land-use problems." Apparently and unfortunately, 25 years later, this is still a fairly accurate assessment of off-road vehicle research and management policies; lack of funding, foresight, dedication, collaboration and governmental support have inhibited the development of sound off-road vehicle policy. As a result, land management agencies have failed to effectively fulfill their legal and ethical obligations to control off-road vehicle use and the problem has continued to worsen.

Current Management

Over the last 55 years (1946 to 2000), the number of visitors to the National Forest System has increased by 18 times its previous figure; in 2002, the number of visitors reached 214 million. It is predicted that the U.S. population will double by the year 2100, leading to an even further increase in the number of visitors to national forests and other public lands. Growth in population and number of visitors will undoubtedly be accompanied by pressure to develop pristine natural land for recreational purposes. Traditionally, the two largest federal landowners in the United States, the Forest Service and the Bureau of Land Management have managed public lands for multiple–resource–use, including timber, grazing, mineral collection and wilderness protection. Taylor and Knight (2003) report that managers are now being faced with the additional challenge of accommodating a variety of off-road recreational uses (i.e., hiking, horsepacking, biking and ORV riding) that are gaining in popularity.

Examples of poor off-road vehicle managment practices on National Forests abound. This ineffective barrier in Bohler Canyon on the Inyo National Forest fails to completely prohibit access beyond this barrier.

Up to now, the manner in which agencies have managed public lands for off-road vehicle use has been inconsistent and unimpressive. However, due to increasing public pressure and environmental degradation, a shift seems to be occurring. In 1999, Chief Dombeck quoted T.H. Watkins' admonition that "in natural regions, as in public libraries, we should not be allowed to do everything we can merely because we can do it (Dombeck, 1999)." He made it clear that the Forest Service must fulfill its responsibility protect our resources and "ensure that no single use compromises the basic integrity of the public's soil, water, and biological resources." Even more recently, Chief Bosworth acknowledged the need for a change in Forest Service policy and action by saying that "rising use may trigger the need for increased management to protect natural resources (Bosworth, 2003)." As agencies struggle to balance the increasing demands of off-road recreationists with their mandate to protect our public lands and the species that inhabit them, new planning approaches are being developed (U.S. Department of Agriculture Forest Service, 2004c).

A draft of regulations to govern the use of off-road vehicles on national forests and grasslands was released by the Forest Service on July 15, 2004. After revising the document in response to public comments, the new regulations which will require the designation of roads, trails and areas open to motor vehicles by each individual forest were released on November 1, 2005. At the national level, the Forest Service is seeking to develop a manageable system of roads and trails that will still allow opportunities for motorized and non-motorized recreation while enhancing protection of natural and cultural resources. To achieve a balance between off-road vehicle use and resource protection, these designations will be decided through local collaboration by including forest and district rangers, local, state and tribal governments and the public. Once these areas are identified and designated, motor vehicle use off of the designated system will be prohibited (United States Department of Agriculture, Forest Service, 2005). The state of California has already begun its inventory, making it the leader in this process. Over the next four years, national forests in California will attempt to maintain recreation opportunities and protect resources by designating a system of roads, trails and areas specifically defined for ORV use. This effort includes a standardized, uniform 5-step process (outlined in the Route Designation Guidebook) for designating off-road vehicle routes on the 19 National Forests in California (United States Department of Agriculture, Forest Service, 2004a). This process includes developing an inventory of routes and trails used by ORVs, proposing a system of routes from the inventory, and finally, designating routes for ORV use.

Future Management

A revision of ORV regulations and the implementation of the Route Inventory and Designation process is a step down the right path, nevertheless, much more is possible. Learning from the past is critical to restore resources and improve management. In 1975, Luckenbach argued that the BLM Desert Management plan "creates an unmanageable situation by permitting ORVs on established roads and trails in many areas." He argues further by asking, "When the passage of one dirt-bike can make a "trail," where is the protection of the roadless areas (Luckenbach, 1975)?" Agencies can not ignore this example, nor the last 30 or more years of literature; management strategies that incorporate knowledge not only from past studies, but also from previous management failures and successes will be most effective to create change in ORV policy. This can be achieved by utilizing an adaptive management approach that continually implements improved management policies and practices by evaluating past outcomes (Walters, 1997). Adaptive management is guided by the idea that "policies are experiments and we must learn from them (Gaines et al., 2003)." This type of approach may ensure that agencies consistently and fairly evaluate their own practices and efficacy.

Consistency in management philosophies and policies is also imperative to their success. With the exception of the current attempt by California forests, there is still no uniform inventory or monitoring policy between different districts on the same forest, different forests in the same region or different regions within the entire National Forest system (Wildlands CPR, 1999). In addition, travel plans and width restrictions vary from forest to forest. This amount of inconsistency and variation makes educating citizens and enforcing regulations very difficult.

Cohesiveness and enforceability are integral in aiding agencies in actualizing their organizational goals. For example, the management of National Forest lands must ensure that recreational opportunities are compatible with ecosystem processes and functions (U.S. Department of Agriculture Forest Service, 2000). A uniform designated trail system (as suggested in the new proposed regulations) will move agencies closer to attaining this balance. Using evaluations based on the National Environmental Policy Act (NEPA), agencies can identify and designate areas that are appropriate for sustainable off-road vehicle use. A NEPA-based process will ensure that areas chosen for ORV use will not cause further environmental impacts and will maintain the integrity of integral ecosystem components.

Bury and Luckenbach (1983) argue that "…ORV recreation and biological resources are mutually exclusive and that they should be separated from one another through distinct management units." They propose a "biological option" that considers the requirements needed to protect resources and natural values while also allowing ORV activities to take place in defined areas; such a plan includes protection of core areas and corridors that connect these areas and contain unique species as well. They argue that this alternative can be monitored and enforced and will most greatly protect resources (Bury and Luckenbach, 1983). If the route designation process proposed by the Forest Service is successfully implemented, it will incorporate these ideas and will serve as a proactive way to protect core areas and corridors for many species.

Management that is consistent and based on scientific research often results in positive solutions. This hardened creek crossing on the Coyote Plateau on the Inyo NF is an excellent example of a solution that maintains recreational opportunities while still protecting nattural resources.

While restoration and recovery efforts are important, many authors suggest that focusing on increased forethought and planning to prevent damage is imperative to successful management. For this reason, Wildlands CPR (1999) supports the idea of managing in the manner of "closed to motorized use unless signed open"; this approach allows managers to take a proactive course of action in designating trails. Instead of retroactively closing areas that are damaged, mangers can evaluate, identify and designate areas that will not suffer irreversible environmental damage (Wildlands CPR, 1999). Lovich and Bainbridge (1999) state that the recovery and restoration of areas damaged by off-road vehicle use in California would cost billions of dollars. They report that projects to restore ORV use areas in the California desert are especially challenging because deserts are sensitive spaces that may suffer severe impacts from ORVs. Also, the impacts in California from ORVs are widespread and use areas are often located in or near environmentally sensitive and critical habitats (Lovich and Bainbridge, 1999). The authors suggest that in many instances, it would be a better investment to put money and effort into proactive projects, including fences, signs and enforcement to prevent future damage, rather than investing in intensive restoration (Lovich and Bainbridge, 1999). They do agree, however, that the successful restoration of areas damaged by ORV use can be made possible only if these areas are closed to motorized traffic before beginning procedures to mitigate destruction (Lovich and Bainbridge, 1999). Successful revegetation and restoration require careful attention to ecological relationships, including those above and below ground, as well as soil characteristics, microclimate, patterns of moisture availability and the effects of herbivory (Bainbridge1990, Bainbridge and others 1995). Lovich and Bainbridge (1999) also suggest that efforts that seek to recreate or mimic natural conditions are most likely to speed recovery of the entire ecosystem. We agree that the most successful strategy for the recovery of ORV areas involves a combination of work toward the prevention of further damage and a restoration of already impacted areas.

In addition to environmental issues, organizational strategies and policies can also address user conflicts and damaging behaviors. Berry (1980) reported that management problems include unauthorized user-created proliferation of trails, illegal encroachment onto areas where ORVs are prohibited, trail widening, increased vandalism and access to areas with resources that were previously protected and/or inaccessible (i.e., archeological sites, critical habitat). In his speech, Chief Bosworth (2003) spoke about the explosion in illegal, user-created routes that lead to “erosion, water degradation, habitat destruction, damage to archeological sites and user conflicts.” He stated that, “We have got to improve our management so we get responsible recreational use based on sound outdoor ethics.” Part of helping people to develop an “outdoor ethic” involves education; teaching people about how their behaviors affect wildlife, vegetation and other users may not directly change their behavior, but it will help them to make more informed decisions. Education combined with enforceable regulations are steps toward improving management.

Not all areas are appropriate for motorized use. This section of the east Mono Craters on the Inyo National Forest has been closed to prevent future route proliferation and habitat degradation.

Management policies are often developed according to the best available science. Thus, research can be very influential in guiding the implementation of effective management policies and procedures. Lovich and Bainbridge (1999) report that "research conducted in the Mojave and Colorado desert ecosystem has important applications for the American Southwest and throughout the world's arid zones. These areas have deteriorated rapidly under pressure from overgrazing, poor farming, and removal of trees and shrubs for fuelwood. The lessons learned in the desert ecosystem of southern California may help people living in these areas to protect or restore the productivity of their lands, and improve their lives." Clearly, managers must analyze research that is available and carefully consider recommendations, as well as methods and biases.

Further research is also necessary; however, this need should not be used as an excuse to prevent action. The burden should lie on scientists to provide evidence that there is little potential for damage before an area is opened to off-road vehicle use, instead of requiring such evidence before closing an area. An area in question can be closed to prevent further damage, in compliance with the Executive Orders, while studies are being completed.

Certain gaps in the literature exist because much of the literature that is available was published at the beginning of the off-road vehicle explosion in the 1970s. There is a need for more current literature and research that assesses the complete impacts of ORV use on all aspects of ecosystems in which they are used. Many studies have focused only on arid lands; research does exist regarding coastal dunes, forest, grassland and marshland, but plenary assessment of these impacts and ecosystems is needed. While a plethora of research exists on the effects of disturbance on wildlife, many of these studies explore the impacts of non-ORV disturbance. Thus, further investigation of how off-road vehicles directly and indirectly disturb wildlife would provide necessary insight. In addition, scientific studies and experiments to assess how topography, soil type, habitat type, vehicle type, seasonality, and amount of use and route density affect the impact that ORVs can have on public land would be very helpful to developing effective policy and management approaches. We also argue that effective, standard and consistent monitoring methods must be developed to promote consistency of results across public lands.

Conclusion

Over twenty years ago in a report for the White House Council on Environmental Quality, David Sheridan (1979) wrote:

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 tundra in Alaska. In some cases the wounds will heal naturally; in others they will not, at least not for millennia.

From this quote and the research provided in the body of this report it is clear that the concomitant effects of individual off-road vehicle impacts can completely alter and damage the ecological composition of an area. In addition, it is clear that managers and politicians have known of these effects for decades and have not responded strongly or effectively enough, even when required to do so by law. What is not clear, however, is this: How could we and why have we generally ignored 35 years of research, policy and Executive Orders? Why have we still not done anything substantial or proactive to protect our public lands and resources from damage? There are many possible excuses that may be offered: political pressure, lack of funding, lack of knowledge, managing for multiple use, a desire for immediate gratification, inability to enforce policies, etc. Regardless of the validity or truth behind these reasons, there is no question that inaction has fostered the growth of unmanageable and unsustainable off-road vehicle use and associated environmental damage. Recently, however, due to Chief Bosworth's call to action, this issue is gaining more attention in the Forest Service and it seems that management may be making a move toward positive action. With the development of strict regulatory policies and standards, there is the potential for managers, scientists, advocates and citizens to be instrumental in creating an off-road vehicle route system that is both manageable and sustainable. In conjunction with sufficient funding, an adaptive management approach and well-designed research, monitoring and enforcement efforts may increase effectiveness. Although this action will not negate the extensive damage that has been inflicted on the land, it may at least be a start to minimizing further destruction and beginning the healing process.

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