THE ECOLOGICAL IMPORTANCE OF THE WHITE WASH SAND DUNES, UT, AND THE EFFECTS OF OFF-ROAD VEHICLES ON THIS SYSTEM

Submitted to:

The Southern Utah Wilderness Alliance

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I. INTRODUCTION

To produce this literature review and report on the ecological aspects and biological significance of the White Wash Sand Dunes of Utah, I spoke to various scientists and experts with knowledge of these dunes, and dune systems in the Colorado Plateau and intermountain West in general. In addition, I visited the dunes myself, and compiled the scientific literature on general dune ecology and dune systems in other areas of the Southwest that can be extrapolated to this system. In order to ascertain the impacts that off-road vehicles (ORVs) are currently having or are likely having on the White Wash Dunes and surrounding lands I spoke with BLM officials and obtained their ORV use data, and I visited the area. I also searched many ecological and biological databases and compiled the relevant scientific studies on ORV impacts to both deserts in general and dune systems specifically, while also consulting with regional scientists and researchers who have conducted ORV impact analyses in deserts.

The Dunes

The White Wash Sand Dunes are a semi-active, longitudinal dune system located south of the town of Green River Utah and east of the Green River (above Labyrinth Canyon) on the outskirts of the San Rafael Desert in east-central Utah (Figure 1). The dunes run northeast-to-southwest, and are about ½ mile wide and 2.5 miles long. White Wash, an ephemeral tributary of the Green River, emerges from the Entrada, Summerville and Curtis formations to the East (that contain Duma Point), and skirts around the base of the dunes to the east, north, then west as it finally merges with the Green River.

Sand dunes are built principally of well-sorted grains of fine to medium sand (0.125 – 0.5 mm), which are moved across the landscape surface by either saltation or reptation[1] (Smith 1982, MacMahon 2001). These grain movements are caused by the shearing action of wind and are often restricted by sand grain size and shape, the slope of the ground surface, moisture content, and the surface roughness of the ground (especially that caused by vegetation). Dune form is controlled by a combination of the availability of sediments, the local wind regime, and vegetation (Hack 1941, MacMahon and Wagner 1985).

The White Wash Sand Dunes are the result of eolian, or wind-blown, deposits derived from wind-transported sand from the San Rafael Desert to the West. The transported sand in turn has been derived from the Entrada Formation in the San Rafael Desert. The prevailing winds in the region primarily flow from the west/southwest, and the first significant topography this wind pathway encounters in the immediate area is the Entrada, Summerville and Curtis formations near Duma Point on the east side of the Green River. This is the trigger for suspended sediments to fall out in the deposits that have, over time,

[1] Saltation refers to a "bouncing movement," and reptation to "short jumps or creeping," of sand particles (McMahon 2001).

created the semi-active White Wash Dunes. The exact age of the dunes is not known with certainty, but they were likely formed during the Pleistocene (so, anywhere from about 1.8 million years ago to about 50,000 years ago) and deposited in lakes and interior drainage basins was exposed and blown into dunes (Bowers 1984).

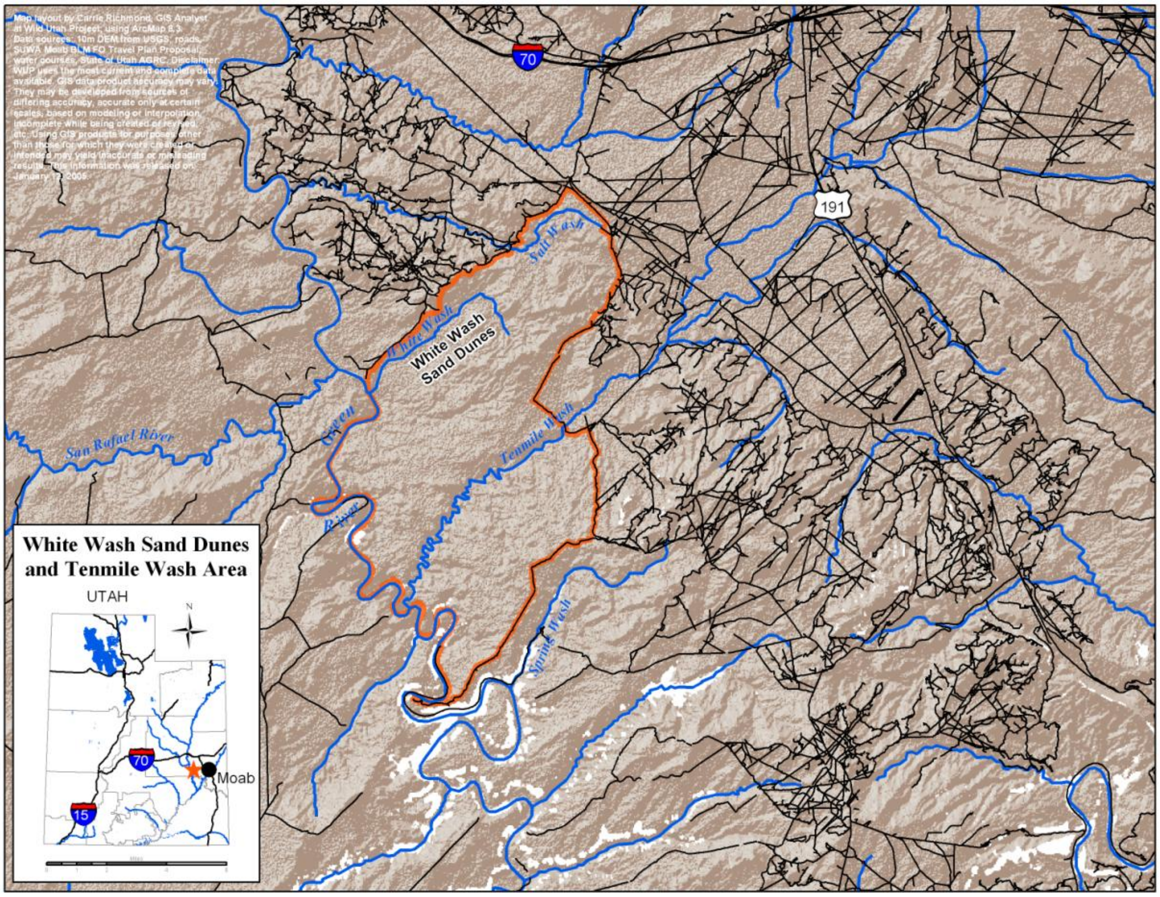

Figure 1. The White Wash Dunes/Tenmile Wash roadless area (outlined in orange) with the White Wash Dunes shown in the top part of the study area (map credit, Carrie Richmond, WUP).

The base of the dunes are well vegetated on all sides, with vegetation primarily associated with both sagebrush (multiple sp. of *Artemesia*) bunchgrass vegetation type as well as the more halophytic saltbush – bunchgrass association, with more saline soils exhibiting salt grass (*Distichlis spicata*) and pickleweed (*Allenrolfea occidentalis*). Many species of both perennial and annual forbs occur within both vegetation associations, including some that were flowering at the time of our field visit (November 17, 2004).

Sand dunes are classified as either stable, active, or semi-stable. Simply stated, these terms refer to whether the rate of sand deposition approximates the rate of sand deportation off the dunes due to wind. Stable dune systems are generally not increasing or decreasing in mass over time. Active dune systems can either be growing smaller or larger over time, depending on long-term rates in sand accumulation or loss (http://geochange.er.usgs.gov/sw/impacts/geology/sand, Smith 1982). The single most important factor controlling whether dunes trend towards being more active or more stable depends on the amount of vegetation anchoring the dune (http://geochange.er.usgs.gov/sw/impacts/geology/sand). This factor in turn depends on whether the balance between precipitation (P) and potential evapotranspiration (PE) is such that vegetation can grow on the dunes and stabilize them. Although the Colorado Plateau has an overall moisture deficit (where the ratio of P to PE is less than 1.0), there is still enough moisture to support plants. In the areas where dunes occur on the Plateau, most P/PE values are around 0.3 to 0.5, which is high enough to support sagebrush and other shrubs, as well as grasses at lower elevations. Therefore, the reason that dunes on the Colorado Plateau are generally stable is due to the P/PE balance and its support of stabilizing vegetation. Currently, it would appear that the White Wash Dunes are a primarily stable system, due to moderate vegetation anchoring, but could possibly be classified as semi-stable (personal observation, ALJ). This classification could change over time due to loss of vegetation because of either climate change or land use.

Located between well-known areas such as Salt Wash, Duma Point, and Tenmile Wash, it is interesting that so little research has been conducted to date on the biological resources and geomorphic and ecological processes ongoing in this very unique system. What little is known about the dunes is related below (augmented with extrapolation from other studies in desert dune environments in the Southwest).

II. ECOLOGICAL IMPORTANCE & UNIQUENESS OF THE WHITE WASH DUNES

General Uniqueness and Specialties of Arid Dune Systems

Study after study has shown that sand dune systems, by virtue of being rather unique habitat "islands" surrounded by a more comparatively homogenous desert environment, can be hotspots of endemism (Bowers 1982, Bowers 1984, Biodiversity Conservation Alliance 2003, Center for Biological Diversity 2004, and others). The percent of the biota on any given dune system that is endemic typically ranges between 5-15% (Bowers 1982). For example, Bowers (1984) reviewed all flora present on eight major sand dune systems of the desert southwest, and found that endemic species comprised 10% or more of five of the eight floras. There is a relationship between the period dune system has been in existence, and the rate of endemism in the system (personal communication Chris Knauf, desert ecologist, BLM California, November 2004). Generally, dunes that have formed since the last glaciations have lower levels of endemism, while those that date back to before the Pleistocene have higher levels. By virtue of their very narrow habitat requirements, endemic species are generally considered to be more prone to extinction than widespread species (Rabinowitz 1981, Fischer and Stocklin 1997). Moreover, dune systems often lack adjacent or nearby colonization sources (Bury and Luckenbach 1983), which makes their protection from habitat destruction and degradation even more important, since local extirpations of rare species will unlikely receive a "rescue effect" from other nearby sources.

Many dune environments host unique and endemic invertebrate species (Center for Biological Diversity 2004), often because these species become highly specialized due to dependence on a particular host plant, which is often itself a rare endemic (Griswold et al. 1997, Center for Biological Diversity 2004). In addition, many endemic beetles, will tend to harbor endemic species of parasites as well (personal communication Chris Knauf, desert ecologist, BLM California).

One reason that dune systems are hotspots of biological diversity in desert regions is because they are more mesic than the more xeric habitats typically surrounding dunes, due to their ability to store water through water holding capacity and capillary action of sand (MacMahon and Wagner 1985, MacMahon 2001, personal communication Stan Welsh, with the BYU Herbarium, November 2004). For example, sand will have much more water available than other substrates that have higher clay content, because water binds molecularly with clay (resulting in negative matrix potentials), but not with sand so even small amounts of water in sand are readily available to plants (Bowers 1984, personal communication Stan Welsh).

In addition, plants that occupy dune environments typically exhibit a suite of morphological adaptations that enable them to cope with the unique habitats that exist on dunes (Danin 1996). For example, many plants that grow in dunes exhibit vine-like lateral roots for anchorage, and rapid growth form (an adaptation to sand movement which allows them to keep flowers and leaves above the level of accumulating sand), (Bowers 1984). In particular, dune plants tend to develop increased stature, which allows them to grow large enough and quickly enough to outstrip sand accumulation (Bowers 1982), and this can take two forms. One is gigantism, a phenomenon seen in the Little Sahara sand dunes with *Atriplex canescens gigantea*, which is considered a rare endemic subspecies in Utah. The other growth form seen in dune plants is woodiness in taxa that is usually herbaceous, which can be triggered by release from seasonality, absence of large herbivores and shifts in ecological preference due to unoccupied niches (Carlquist 1974). The plants found in dune systems are generally seldom found in other habitats.

Deserts in general are among the most temporally variable and unpredictable habitats on earth and typically occur in extreme environments (MacMahon and Wagner 1985, MacMahon 2001, Center for Biological Diversity 2004). The variation in potential evapotranspiration between years in deserts is greater than any other biome, and both temperatures and precipitation levels can vary dramatically over time (MacMahon and Wagner 1985). Periodic change in a natural factor that exceeds tolerance of desert organisms is highly likely. Because the time to recovery from such perturbations can be long, deserts are especially susceptible to disturbance, and may, in fact, seldom be in "equilibrium" with the larger ecosystem (MacMahon and Wagner 1985, MacMahon 2001). It follows that the species that live in deserts, while adapted to such environments, may not be able to withstand human-caused stresses above and beyond the natural stressors expected in deserts. The same principal holds for dune ecosystems (personal communication Richard Reynolds, USGS, November 2004). As such, human use resulting in habitat degradation should be avoided in all desert systems, whether or not they contain dunes. Moreover, dune systems are worthy for protection because they are intrinsically rare in North American deserts; only about 0.5% of North American deserts include dune environments (Bowers 1984).

Deserts may be more susceptible than other systems to cumulative impacts that compound both human degradation and current and future global climate change. As Clark and Rendell (1998) point out, the anticipated impacts of climate change to southwest dune systems is unknown, but this added stressor to dunes and deserts in general should not be taken lightly. For example, in the nearby Mojave Desert, most dunes that were once stable have recently become active dunes again (Smith 1982). In fact, there are definite trends toward greater dune activity in drier regions (http://geochange.er.usgs.gov/sw/impacts/geology/sand/). When the ratio of precipitation (P) to potential evapotranspiration (PE) is low, dunes tend to be more active. The ratio of wind to the P/PE value is referred to as the *dune mobility index*, and has been tested in many regions for its ability to describe the degree of dune activity as a function of climate variables. Therefore, with a decrease in the P/PE value, as would be expected during climate change involving warming, we could expect dunes to become more active in the future….perhaps to the point of diminishing over time. In the past century, the worst drought on the Colorado Plateau, which was accompanied by higher-than-average temperatures, occurred in the years 1899-1904. If we recalculate the dune mobility index values using data from the 1899-1904 drought, the values are shifted into the category of mostly active dunes (http://geochange.er.usgs.gov/sw/impacts/geology/sand/). In any case, greater dune activity could be expected in such a drought, or in the case of global warming.

Biological Significance of the White Wash Dunes

The White Wash Sand Dunes and immediate surrounding area represent a unique ecosystem that is known or suspected to provide important habitat for a number of species that are of high management concern and priority to both the BLM and the Utah Division of Wildlife Resources. This includes watering holes for the local population of desert bighorn sheep, and High Value Habitat for pronghorn antelope (Utah GAP data 2003). In addition, the White Wash Dune area contains known or suspected habitat for a number of State Sensitive Species. This includes possible habitat for long-billed curlew, Critical Habitat for black-footed ferret, Substantial Habitat for big free-tailed bat, both Substantial and High Value Habitat for spotted bat, and High Value Habitat for burrowing owl, ferruginous hawk, peregrine falcon, and Townsend's big-eared bat (Utah GAP data 2003).

While known and potential habitat for sensitive wildlife species is a special feature of these dunes and surrounding lands, it is the unique spring/riparian characteristics found in the dunes, coupled with evidence or likelihood of endemism, that make even more compelling cases for the biological importance and ecological significance of the White Wash Dune system. These discussions follow.

Unique spring and riparian characteristics. Many springs emerge from the Entrada formation that surrounds the White Wash Sand Dunes, and these springs occur mostly in the shallow, narrow sandstone canyons on the east flank of the dune field, providing hydrologic input into the system. The dunes are the result of very fine eolian deposition, and as such have very high water holding capacity (personal observation, ALJ).

This high water holding capacity results in a perched water table (personal communication, Stephanie Ellingham, Moab BLM, November 2004), as evidenced by the existence of mature Freemont cottonwoods (*Populis deltoides*, Figure 2) and ongoing recruitment of both cottonwoods and willows (*Salix exigua*, Figure 3) on the tops of the dunes. It is particularly notable that the location of established cottonwoods and willows is well above the level of White Wash and emerging springs in the bottoms and along the outskirts of the dunes. Therefore, it must be concluded that the available water for these hydrophytic plants is obtained from a perched water table within the sand and drawn up by the plants through capillary action into the roots, rather than a direct connection to a water table associated chiefly with the Wash, emerging springs or other forms of surface water or runoff (personal communication Stephanie Ellingham, Moab BLM, November 2004).

Figure 2. Mature cottonwoods on the top of the White Wash Dunes

The existing scientific literature on desert and dune hydrology describes similar hydrologic situations to that present in the White Wash Dunes. Yang and Lowe (1958) point out that, for a given volume of soil, the lower, more compact substrates are capable of holding more water, yet tend to have a higher wilting coefficient, while the coarser soils above actually have more "available" moisture for plants. And Bowers (1984) reaffirms that dune systems can act like sponges, absorbing precipitation and storing it with no runoff and little evaporation. However, while the hydrologic situation that exists in the White Wash Dunes has been seen elsewhere, the fact that cottonwoods and willows have established on the tops of the dunes is a very unusual phenomenon (Bowers 1984, personal communication Stan Welsh). Unless one theorizes that the cottonwoods established long ago in swales and considerable erosion has occurred in the interim to leave these trees on the dune tops (unlikely), their placement so high above the water table can only be explained by exceptional water-holding capacity in the grain interspaces of these dunes.

Figure 3. Willows on the White Wash Dunes

In general, any riparian areas within the Moab BLM Resource Area should be of high priority for better management and protection, especially such unique riparian systems as those that occur on the top and at the base of the White Wash Dunes. Unfortunately, the riparian zones of the White Wash Sand Dunes are currently rated as "Functioning-At-Risk" by the BLM (personal communication Stephanie Ellingham, Moab BLM, November 2004).

Wetlands, including both riparian areas and springs/seeps, are key to the maintenance of biodiversity within desert regions. In fact, riparian habitats in the arid west are among the most productive in western North America. The BLM has highlighted this same point in its recent management plan for the Grand Staircase Escalante National Monument (BLM 2000), which noted that riparian areas total less than 1.0 % of the total lands within the Monument, but are used by up to 80% of all vertebrate species at some stage of their lives. In addition to supporting rich endemic floras, riparian zones are crucial for much of Utah's wildlife, including both species that are obligatory riparian dwellers and those animals that are dependent on riparian and other wetland habitats during either seasonal migrations or seasons and years when surrounding habitats are dry and unproductive. A key example in this part of the Moab Resource Area is the value of White Wash and associated springs and watering holes to desert bighorns (personal communication Stephanie Ellingham). Other than these sources, the closest watering sources for this local bighorn herd is at Tenmile Wash, which is five miles away.

One of the more critical qualities riparian zones offer in the deserts of the southwest are refuges and stopovers for migrating birds. The rigors of migration often push birds to their physiological limits, and therefore a lack of suitable stopover habitat results in death and contributes to future population declines (Moore 1990). The ecological diversity of migratory species makes an assessment of habitat requirements and the development of management strategies for migrants particularly difficult. However, the preservation and conservation of southwestern riparian habitats should be of major concern.

Because of the relative isolation of riparian sites from other areas of similar habitat (i.e. riparian zones associated with a different drainage), their recovery from disturbance is likely to be hindered by the difficulty of recolonization from other drainages. This makes it all the more crucial that small, isolated, wetlands interspersed within the landscape, such as springs, are also carefully protected because they may partially aid in limited recolonization and dispersal between disjunct riparian zones in desert lands.

Some of the rarest species in Utah and the most spectacular biotic assemblages are those associated with the springs and seeps that dot the landscape within the canyon country of southern and southeast Utah. Just as areas with distinctive soil types are inhabited by their own special floras, the uniqueness of spring and seep habitats usually translates into unusual species communities. Further, because these springs are generally isolated from other springs and seeps, their recovery from any form of disturbance is likely to be impeded markedly by the difficulty of recolonization from similar habitats that may be miles away. Isolation may also lead to genetic differentiation, in which particular subpopulations of plants and animals have adapted to local conditions in a given spring or seep. Because these communities are often one-of-a-kind and difficult or impossible to replace, they merit the strongest possible protection.[2] This is significantly underscored in the Moab BLM Resource Area, which is only known to contain s handful of bona fide, lentic wetlands.

Known and potential endemism. While the White Wash Dunes have never been systematically surveyed by a biologist, there is one rare endemic species that has been found on the Dunes. The dune scurfpea (*Psoralidium lanceolatum var. stemophyllum*), endemic to southeastern Utah, was discovered by Charlie Schelz, National Park Service Biologist for the region, on a casual excursion to the dunes (personal communication Charle Schelz, NPS, January 2005).

As described in the above section, most dunes that have been studied to any degree have been found to harbor at least a few endemic species. While, unfortunately, the White Wash Dunes have not been surveyed, researched or studied by any botanist or zoologist, there are many reasons to believe that these dunes could very well be a hotspot of endemism.

Nowhere is this a possibility more than with the bee fauna. The San Rafael Desert hosts 68 (known) endemic species of bees (Griswold et al. 1997). In fact, researchers at the Utah State University bee lab have found that one third of Utah's bee species live in an area (centered in the San Rafael desert) that covers only 2% of the State (Jones 1999). Indeed, the numbers of bee genera in the San Rafael Desert is more than in all of New England (Griswold et al. 1997). In addition to describing 48 new species previously unknown to science in the San Rafael Desert, the USU researchers have also documented extraordinarily unique bee nesting behavior, such as nests 12 feet deep, nests in honey-comb like holes in sandstone, and 20-foot long nests (Jones 1999).

The diversity of bees in the San Rafael Desert is partly the result of floral specialization; at least one third of the bee species in the San Rafael desert specialize on plants at the family or generic level (Griswold et al. 1997). Since the White Wash Dunes are just across the Green River from the San Rafael Desert, it should be expected that an impressive and diverse bee fauna awaits discovery there.

Insect pollinators merit study and preservation efforts because 67% of extant flowering plants rely (to varying extents) on pollinators for reproduction (Tepedino 1979). Additionally, insects perform important pollinating services for Utah farmers that grow crops such as fruit, nuts, alfalfa and clover. In general, insect pollinators may be more susceptible than one might think to human-caused impacts; because pollinators are highly specialized and have co-evolved with one or two key plant hosts, they have been thought to be less adaptable to changing conditions and therefore vulnerable to extinction. The

[2] Later in this report I will discuss ORV use in areas with springs and seeps, which causes disturbances and impacts to these rare systems while also impeding recovery from other natural and human-caused disturbances

White Wash sand dunes should be surveyed to determine whether endemic bee species dwell there. This should be done as soon as possible, as the plants any undiscovered bees depend upon could be currently affected by ongoing ORV use is the dunes

III. EFFECTS OF ORVS ON THE WHITE WASH DUNES

General Effects of ORVs on Arid Lands

Physical and biological effects of ORVs range from reduction of soil stability to destruction of vegetation, wild animals, and their habitat. The capability of modern ORVs to damage the environment varies according to vehicle design and operation, but it is not possible to drive vehicles on natural terrain that has a soil cover without causing damage, no matter how careful the vehicle operator.

The least surface disturbance is caused when vehicles are driven slowly in a straight line on a dry, firm surface. Under these conditions, typical motorcycles will impact one (cumulative) acre in 20 miles of travel, and ATVs and sport utility vehicles (SUVs) will do the same in only 6 miles. Damage is incurred much more rapidly under conditions of high speed on erratic courses, and on terrain that is more susceptible to erosion (Wilshire 1977, 1992).

Physical Impacts of ORVs. Initial physical impacts of ORVs result in stripping the surface of small plants and mechanical crusts, which stabilize the soil (Wilshire 1983, Belnap 1995). At the same time that the land is denuded, soils are compacted. Maximum compaction of typical sandy loam soils of western arid lands is attained in only 10 passes of a motorcycle on a dry, level surface (Webb 1983). Soil compaction takes place in a cylinder beneath the tracks, reaching depths of 30 cm, and soil loosening (by shear) takes place in shallow zones on both sides of the cylinder of compaction. Loss of the insulating effects of plant cover and changes in the heat capacity of compacted soils causes soil temperatures to increase by as much as 10^{o} C in daytime and decrease by as much as 3^{o} C in nighttime (Webb et al.1978, Wilshire et al. 1978). Soil compaction further reduces infiltration of water, resulting in ponding in tracks and rapid evaporation, or shedding of incident precipitation by runoff. Either way, the shallow subsurface soil biota are denied their normal moisture supply. As with soil compaction, the reduction of infiltration rates quickly reaches a maximum after only 10 or so passes of a motorcycle (Webb 1983). Studies that document significant effects of ORV use on soil compaction and soil bulk density includes studies conducted by the BLM (BLM 1975).

Most southwest desert soils are susceptible to the above documented effects of ORVs. The USGS conducted an 18 month study on 200 ORV sites in California, Utah and Nevada, and found that all soil types examined were vulnerable to ORV damage, except certain dry lake deposits and clay rich soils with <10% slopes (CEQ 1979).

A name that has become synonymous with impact analysis on Utah's desert soils is Jayne Belnap of the USGS-Biological Resources Division. Most of her research takes place in the deserts near Moab. In particular, three of her recent studies (Belnap 1995, 1996; Belnap and Gillete 1997) implicate ORVs in surface soil disturbance. One of Dr. Belnap's findings is that disturbed sites (which includes ORV disturbance) have higher soil bulk densities than undisturbed sites (Belnap 1995). Increased soil bulk densities in deserts can lead to decreased soil microbial populations and decreased microbial activity levels (Torbert and Wood 1992) which is turn slows down soil nutrient cycling, thus affecting plants. Greater soil bulk densities also contribute to decreased soil infiltration rates, and thus, increased runoff (Webb and Wilshire 1980). Increased runoff in turn deprives communities of available water, causing water stress for plants (Dregne 1983). Another discovery from the Moab plots is that threshold friction velocities (the force required to detach soil particles from the surface) were significantly higher in undisturbed natural crusts than in disturbed plots (Belnap and Gillette 1997). This finding illustrates how smaller threshold friction velocities caused by ORV use or other disturbance will lead to increased erodibility of desert soils by wind.

Erosion of soil is accelerated in ORV use areas directly by the vehicles and indirectly by increased runoff of precipitation, and by creating conditions favorable to wind erosion (Wilshire 1980). Knobby and cup-shaped protrusions from ORV tires that aid the vehicles in traversing steep slopes are responsible for major direct erosional losses of soil. As the tire protrusions dig into the soil, forces far exceeding the strength of the soil are exerted to allow the vehicles to climb slopes. The result is that the soil (and any small plants) is thrown downslope in a "rooster tail" behind the vehicle. This is known as mechanical erosion, which on steep slopes (about 15° or more) with soft soils may erode as much as 40 tons of soil per mile of travel (Wilshire 1992). Erosion is also greatly accelerated by rainfall and wind action on surfaces stripped by ORVs. Common soil types in western U.S. arid lands erode readily when stripped of plant cover. ORV use of slopes with more resilient soils commonly results in gullying of adjacent unimpacted areas to which runoff from the trails is diverted, or scouring and enlargement of downstream parts of the drainage basin due to increased volume of water (Wilshire 1992). The rates of erosion measured in ORV trails on moderate slopes exceed natural rates by factors of 10 to 20 (Iverson et al. 1981, Hinckley et al. 1983), whereas ORV use of steep slopes has commonly removed the entire soil mantle, exposing bedrock. Measured erosional losses in ORV areas range from 102-614 pounds/ft^2 (Webb et al. 1978). Ultimately, increased erosion caused by ORV use can lead to increased siltation in nearby streams (Wilshire and Nakata 1976).

In his book *Deserts on the March*, Paul Sears observed that "soil in place is our friend, and soil on the move our enemy" (personal communication with Howard Wilshire). Indeed, sediment yielded by erosion of ORV use areas may be redeposited in the immediate area where it buries vegetation and the more fertile upper soil layer of undamaged soils, thus extending the damage. Smaller sediment particles can be carried long distances by running water, and subsequently pollute that same water. Wind-borne dust from ORV areas at times has produced dust plumes visible from space (Nakata et al. 1976). Dust exacerbates respiratory ailments in humans and domestic animals, and may have a deleterious effect on wildlife (Saint-Amand et al. 1986, Wilshire et al. 1981). More serious consequences may arise from spread of diseases endemic in arid land soils, such as valley fever (Medical World News 1978, Wilshire et al. 1996).

Impacts of ORVs on Desert Biota. Vehicular impacts on vegetation range from complete denudation of large staging areas to selective kill-off of the most sensitive plants. Ultimately, web-like networks of ORV trails coalesce into broad areas largely denuded of vegetation. Large shrubs and trees 15-20 feet tall have been destroyed by root exposure caused by adjacent ORV traffic, and at one locality 10-foot junipers were destroyed by direct impact (personal communication with Howard Wilshire). Seedlings, and seeds germinating within the ground, are some of the most sensitive organisms to ORVs and are easily killed outright or buried (Bury 1977, CEQ 1979). Indirect impacts on plants include the upsetting of water storage, soil infiltration rates, nutrient content and thermal structure of soils along with increased soil compaction; these are all ORV related deficiencies that that can disrupt seed germination and seedling growth and lead to exposed roots (Davidson and Fox 1974, Havlick 2000). In a study funded by the BLM, Hall (1980) documented an 80% to 90% loss in vegetal cover that is attributed to ORV activity, as well as a 20% to 80% reduction in plant diversity in the Mojave desert. Berry (1980) summarized a dozen studies of ORV effects on vegetation is various arid and semi-arid habitat types, including sand dunes, and documented reductions in densities of perennial plants, reductions in cover of perennial shrubs, reduction in diversity of perennials, reduction in plant biomass, and changes in annual plant production. And a study of the impacts on vegetation in nine locations throughout California deserts concluded that the mean percentage of perennial vegetation density and cover was seriously reduced (Lathrop 1983).

ORVs can have disastrous effects on cryptobiotic crusts. Cryptobiotic crusts, which were historically widespread in western U.S. arid lands, are being rapidly depleted across the West today. These crusts increase the stability of otherwise easily erodible soils, increase water infiltration in a region that receives limited precipitation, and increase fertility of soils often limited in essential nutrients such as Nitrogen and Carbon (Johansen 1993, Belnap et al. 1994). In her Moab studies, Dr. Belnap found that Nitrogenase activity levels in cryptobiotic crusts were dramatically reduced in disturbed plots relative to undisturbed plots (Belnap 1996); Nitrogenase activity decreased in disturbed plots anywhere from 30 to 100%. This has serious repercussions for plants that rely on Nitrogen fixing by these crusts for their Nitrogen supply. This occurred regardless of the type of disturbance (vehicular, or trampling). Dr. Belnap's findings are important because the cryptobiotic crusts' ability to fix nitrogen for use by desert plants is particularly helpful in desert systems where natural sources of free Nitrogen are comparatively low (Fisher et al. 1988). A single pass of an ORV through cryptobiotic crusts will increase wind and water erosion of surface soils that were previously protected by the crusts (personal communication with Howard Wilshire). This in turn can trigger rapid loss of the underlying topsoil, which can take up to 5,000 years to naturally reform in arid regions such as those that typify Utah BLM lands (Webb 1983). The destruction of cryptobiotic soils by ORVs can reduce nitrogen fixation by cyanobacteria, and set the nitrogen economy of these nitrogen-limited arid ecosystems back decades. Even small reductions in crusts can lead to diminished productivity and health of the associated plant community, with cascading effects on plant consumers (Davidson et al. 1996). In general, the deleterious effects of ORV use on cryptobiotic crusts is not easily repaired or regenerated. The recovery time for the lichen component of crusts has been estimated at about 45 years (Belnap 1993). At this time the crusts may appear to have regenerated to the untrained eye. However, careful observation will reveal that the 45 year-old crusts will not have recovered their moss component, which will take an additional 200 years to fully come back (Belnap and Gillette 1997).

Additionally, radical reduction of soil biota, including bacteria and fungi, results from compaction. Soil microorganisms in desert soils exposed to ORV use are typically reduced from about 4 to less than 1 million/g due to crushing and compaction, which in turn reduces bacterial oxidation that forms nitrates available to plants (Liddle 1997). A severe loss of nitrates to plants is significant in typically Nitrogen poor arid environments, and may even eventually lead to significant losses of vegetation, or desertification (Belnap 1995). In her Moab study sites, Dr. Belnap found that biomass of both active bacteria and soil invertebrates in undisturbed plots were two to three times greater than in disturbed plots (Belnap 1995). She also found that there were fewer species of soil invertebrates in disturbed sites compared to undisturbed areas.

Effects of ORVs on desert wildlife are extensive and well-documented (Busack and Bury 1974, Hardy and Andrews 1976, Bury et al. 1977, Bury and luckenbach 1983, Luckenback and Bury 1983, Brooks 1995, Stebbins 1995, Brooks 1999). During winter and daytime hours in hot, desert weather most animals (with the exception of birds and larger mammals) seek shelter below ground or beneath or within objects resting on the surface. Included are mice, kangaroo rats (*Dipodomys* spp.), ground squirrels, lizards, snakes, desert tortoise (*Gopherus agassizii*), amphibians, soil-nesting insects, spiders, and other arthropods. At such times, the biomass of all these sequestered animals, including eggs in developmental stages, might approach 80 to 90 percent of the total biomass of animals in an area (Stebbins 1995), and perhaps 75 percent of the biomass would be located between the surface and a depth of one foot. Their shelters and burrows are fragile. How much life expires beneath the wheels of ORVs is not known, but the figure must be staggering. A study of small mammal populations in the start area of the 1974 annual Barstow-Vegas race was made before and after the event, with a follow-up study one year later (BLM 1975, Hicks 1976). Major reduction in numbers of mammals was measured immediately after the race, and densities of small mammals in the start area one year later were found to be as much as 8 times lower than in nearby control areas (Hicks 1976). This indicated a significant reduction in habitat quality due to the ORV event. Studies that document significant effects of ORV use on desert wildlife include studies conducted by the BLM (BLM 1975, BLM 1978) including evidence that ORV use can reduce local small mammal populations by up to 90%.

ORV use can also indirectly lead to reduced abundance of invertebrates (Schultz 1988), lizards (Busack and Bury 1974, Brooks 1995, Brooks 1999) and density and diversity of small mammal populations (Bury et al. 1977, CEQ 1979, Liddle 1997, Brooks 1999). Often this effect on mammals can be attributed to a reduction in plant diversity, simplification of plant structure, and reduction in ground cover, all of which are results of ORV activity (CEQ 1979). Invertebrate larvae can be killed when host plants where the larvae are boring (within live tissue or the woody root crown) are killed by ORVs (Center for Biological Diversity

2004). Also, harassment of wildlife may place a considerable energy strain on wildlife, both due to general stress, and due to attempts to escape harassment (Bury 1977). For example, ORVs can disturb animals to the point that wildlife will change their activity patterns or foraging sites in the vicinity of "play areas," and at the times of day when recreation is at its peak (EDF 1995). A study of bird behavior in the Mojave desert showed that most birds left the area on Friday afternoons when ORVs began to arrive (personal communication, Howard Wilshire). Surprisingly they did not return as soon as the weekend fun-seekers left, but waited until the following Thursday. Thus, the 2-day presence of ORVs was sufficient to drive off much of the bird population for 5 days.

Through a contracted study, the BLM sought to quantify the impacts of ORV use on the avifauna found in the BLM-managed Afton Canyon in the Mojave desert (Weinstein 1978). The study showed significant differences between high-use and non-use ORV areas in terms of native bird abundance, variety and distribution. Specifically, high-use areas generally supported fewer species and numbers of birds than a similar nearby area that was closed to vehicles. Importantly, there was also a significant difference **within** the high-use plots between days when ORVs were being used and days when none were used (67% of bird species studied exhibited a decrease in the high-use zone during ORV activity).

Other studies have documented the deleterious effects of ORV noise on desert animals. For example, Couch's spadefoot toad (*Scaphiopus couchi*) emerges from its burrow with the first summer thunderstorms and individuals gather at pools where mating occurs. The timing of emergence during thunderstorms is of critical importance to reproductive success, because the supply of body moisture is insufficient for the animals to return to deep burrows in the absence of rainwater. The trigger that identifies approaching rain apparently is the sound of thunder, a sound simulated closely enough by dune buggies to encourage emergence and certain death (Brattstrom and Bondello 1983). In another study funded by the BLM, Bondello and Brattstrom (1979) found that both the Mojave fringe-toed lizard (*Uma scoparia*), and the desert kangaroo rat (*Dipodomys deserti*) suffered deleterious effects from moderate exposures to ORV sounds. The fringe-toad lizard experiments revealed particularly heavy hearing loss after the lizards were exposed to dune buggy sounds of comparatively moderate intensity and short duration. Desert kangaroo rats were exposed to dune buggy sounds for 8 minutes. These sounds immediately reduced hearing sensitivities, by as much as 10 dBl in one subject. Correlations with striking ranges of rattlesnakes indicated that kangaroo rats become vulnerable to nocturnal predation due to a reduction of auditory predator reduction ranges. The sensitive hearing systems of kangaroo rats can be impaired for weeks by exposure to motorcycle noise, and studies have shown that ORV noise can cause bleeding from the ears and frantic behavior in kangaroo rats ((Brattstrom and Bondello 1983).

There is yet another way that ORVs can impact wildlife habitat, though rather indirectly. This is through the dispersal of weed seeds that can attach and ride on ORVs. Vehicles, through the tracks left behind, can also create seedbeds for weeds, thus further promoting their dispersal. This can in turn facilitate the spread of exotic weeds that often outcompete the native flora. In order to determine those factors most responsible for exotic plant invasions in the arid west, Gelbard (1999) investigated causative factors involved in exotic species presence in 674 sites in eastern Nevada, Canyonlands National Park and surrounding BLM lands, and Grand Staircase National Monument and surrounding public lands. Gelbard found that in plots where cryptobiotic soils had been disturbed, the degree of exotic invasibility was greater. This study agrees with findings reported by other researchers that have explored the relationships between cryptobiotic crusts and exotics (Rosentreter 1994, Stohlgren et al. 1997). He also found that these impacts (concentrations of exotics) tended to be concentrated within jeep tracks, and would extend out roughly two meters on either side of the trails (Gelbard 1999). He concluded that invasibility of arid rangelands was significantly correlated with disturbances caused by ***outdoor recreationists*** (emphasis added) and cattle grazing. In summary, the combination of soil disturbance, an increase in edge habitat created by ORV trails, and ready transport for seeds, makes ORVs a superb vector for invasive exotic weeds (Havlick 2000).

Studies have shown that exotic species are the second greatest cause of species extinction in the U.S., after outright persecution (Flather et al. 1994, Wilcove et al. 1998). More than 50% of the west, including Utah, is now dominated by alien weeds, and greater than 300,000 acres of habitat are irrevocably converted to alien annual grasslands each year (Belnap 1998). The grass that has been the main culprit in this virtual type conversion on western rangelands is cheatgrass (*Bromus tectorum*) which, because of its tolerance to all sorts of human-caused habitat degradation, has taken over millions of hectares of shrub steppe vegetation in the Great Basin (Billings 1990, D'Antonio and Vitousek 1992). Weeds are a major management issue on public lands throughout the west because of often profound impacts on floral and faunal diversity (Kummerow 1992). The effects of habitat conversion to exotic annual grasslands can radiate up through food chains; such adverse effects have been documented on pronghorn (*Antilocapra americana*), deer (*Odocoileus* spp.), small vertebrates, native birds and insects (Davidson et al. 1996). It is not a stretch to assume that many of Utah's state and federally listed species are negatively affected by this weed epidemic as well.

Effects of ORVs on Sand Dunes

General effects. Sand dunes are particularly fragile and are easily impacted by even light motorized use (Biodiversity Conservation Alliance 2003). Dune buggies and sand rails, whose tires can cut deeply into the sand even when accelerating on level ground (Stebbins 1995) pose significant threats to the stability of sand dunes. These specialized tires throw up large rooster tails of sand, which in the process causes loss of precious soil moisture (which most dunes hold well because of moderate to high water holding capacity of most sandy soils) (personal communication Daniel Patterson, Desert Ecologist, November 2004).

The integrity and viability of any sand dune ecosystem depends on the balance of sand deposition and sand loss, or deflation. Dunes typically have a portion of the dunes that are actively accumulating sand, a portion that are stabilized, and a portion that are actively eroding and losing sand due to wind. While some dune systems can be partially stabilized by chemical or mechanical (abiotic) soil crusts, the chief cause of stabilization is anchoring by (chiefly perennial) vegetation. It follows that any activity that destroys and decreases cover of vegetation (such as ORV use) will tend to lead to dune destabilization and eventual loss of dune area. Situations where ORVs lead to decreases in native perennial vegetation but concomitant increases in exotic annuals will not tend to remain in a stabilized state because annuals do not provide sufficient anchoring qualities as compared to perennial plants (personal communication Richard Reynolds, USGS, November 2004).

In general, the literature reports that ORV use in sand dunes can cause major destruction of dune plant communities (Bury and Luckenback 1983, Center for Biological Diversity 2004, Hess - in prep, and others). Many studies report significant impacts to diversity and richness of dune vegetation (Bury and Luckenback 1983, Kutiel et al. 2000, Center for Biological Diversity 2004). There are also multiple studies that report ORV impacts to rare, endemic plants (i.e. USFWS 1982), and negative impacts to biota even at relatively low levels of ORV use (i.e. Luckenbach and Bury 1983). Many ORV dune enthusiasts claim that they carefully avoid plants, and while they may avoid large, mature perennial grasses and shrubs, they are not even remotely aware that they are driving over many seedlings (personal communication Daniel Patterson, Desert Ecologist, November 2004).

Dune buggies and sand rails also pose significant threats to many species of animals that live in dune ecosystems. For dune-specific fauna such as sand beetles, ORVs pose a particularly significant threat. Hardy and Andrews (1980) report that most dune beetles spend the day buried at a depth of 5 to 8 cm. This depth is not sufficient to protect individuals from the shearing activity of dune buggies, sand rails and other vehicle tires (Stebbins 1995). Burrowing lizards are also directly killed by the deep digging action of paddle tires (personal communication Daniel Patterson). In general, the literature reports that ORV use in sand dunes can cause major destruction of dune plant communities, with concomitant decreases in animal populations such as invertebrates, lizards and rodents (Bury and Luckenback 1983, Knisley 1998, Center for Biological Diversity 2004).

As discussed in the previous section, dune systems are a known hotspot for invertebrates such as bees. Most bees nest in the ground. Nests are often shallow and can be crushed or exposed by ORV activity. Additional negative effects of ORVs are destruction of nest entrances and manipulation/destruction of visual landmarks bees use to locate nests when they return from foraging (personal communication Terry Griswold, USU Bee Lab). Bees produce relatively few offspring and expend considerable effort to insure their survival. This results in slightly less genetic variability than most other insects, which produce prodigious numbers of offspring (resulting in slightly higher number of mutations being expressed - etc., Tepedino 1979). This leaves bees less able to eventually develop adaptations to counter-act human-caused alterations to their habitats.

ORV impact studies on other dune systems in the Southwest. A number of studies have been conducted within the Coral Pink Sand Dunes in southwest Utah, a partly vegetated transverse and U-shaped dune system made of unusual colored quartz sand reworked from underlying sandstone (Smith 1982). The Coral Pink Dunes contain both silica and gypsum, which explains in part the high rates of endemism in this system (MacMahon and Wagner 1985, MacMahon 2001). The Coral Pink Sand Dunes tiger beetle (*Cicindela limbata albissima*), known only to the Coral Pink dunes, has one of the smallest geographic ranges of any known organism (Conserv. Committee for the CPSDTB 1997). And is currently a candidate for federal listing. In 1994 when the U.S. Fish & Wildlife Service released its findings on a petition to list the beetle as endangered, it pointed out that ORV activity "is destroying and degrading the species' habitat," and "is causing direct mortality of individual" beetles (USFWS 1994). One of the chief ways ORVs can impact the beetle's habitat is by reducing the already scarce plant cover on the dunes, which is the only food source for most of the tiger beetle's prey species (Knisley and Hill 1994). ORVs can also loosen the sand and disrupt the thermal and moisture gradient important to tiger beetle larvae (Shultz 1988). In terms of direct impacts to the beetle, any physical encounter with a vehicle that does not result in death will still cause certain injury, thereby effectively immobilizing the beetle and preventing it from avoiding predators, obtaining prey or successfully mating (Knisley and Hill 1994).

The Conservation Agreement and Strategy for the Coral Pink Sand Dunes tiger beetle (Conserv. Committee for the CPSDTB 1997) cites recent surveys (Knisley, multiple years) that indicate an overall pattern of absence from dunes with moderate to heavy ORV use. Knisley (1998) illustrated that this trend has not been reversed. Knisley found densities of tiger beetle larvae to be much lower on the ORV trails than non-trail areas. He also found that overall numbers, and numbers of taxa of all invertebrates were greater in low-use ORV areas than in high-use ORV areas. The greater abundance and diversity of invertebrates in the low-use areas is an indicator of preferable tiger beetle habitat, because these areas clearly contain a more suitable and stable prey base.

Another particularly well-studied dune system in the southwest is the Algodones Dunes in southern California. Surveys comparing areas used by ORVs with unused areas at Algodones indicate that ORVs cause drastic reductions in the abundance of several beetle species (Hardy and Andrews 1976), as well as significant impacts to vegetation and other wildlife (Bury and Luckenbach 1983, Luckenbach and Bury, 1983). Specifically, control plots contained 2.5 the number of plant species as areas with heavy ORV use, with 10 times the cover, and 4-times the volume of shrubby perennials compared with ORV-impacted plots. In addition, control plots had 1.8 times the number of vertebrate species, than ORV-used plots, 3.6 times the number of individuals and 5.8 times more biomass of reptiles than ORV areas, 24 times the amount of invertebrate tracks than ORV areas, and 1.3 times more species, 2.3 times more individuals and 2.2 times the amount of biomass of rodents than ORV–used plots (Bury and Luckenbach 1983). Studies at the dunes have indicated that even moderate ORV use results in significant redulctions in plant cover (Luckenbach and Bury 1983, Hess in prep). The BLM states that "the major management issue in the Algodones Dunes concerns the effects of ORV use on…six rare dune plants, five of which are BLM special status plants [including federally threatened and State endangered plants]" (BLM 2001). Additionally, particular attention has been paid to the Andrew's scarab beetle (*Pseudocotalpa andrewsi*), a rare and endemic species that has recently been petitioned for federal listing under the E.S.A. Petitioners believe that the beetle is endangered due to the historic, ongoing, and imminent destruction of its habitat by extensive ORV use of the Algodones Dunes. The USFWS would seem to agree with this assessment, as it conceded that "the continued disruption of dune troughs by ORVs prevents the accumulation of dead organic matter upon which the immature stages of this beetle feed" (USFWS, 1978 proposed rule for listing of the species, 43 FR 35636-43).

Many other dune systems in the desert southwest bear examples of ecological uniqueness, endemism, and ORV impacts to these qualities, which can be extrapolated to the situation at the White Wash Sand Dunes. This includes the example of the rare variety of the four-wing saltbush (*Atriplex canescens gigantea*) in the Little Sahara Sand Dunes in central Utah (a transverse dune system 40 km northeast of Delta), the example of ORV impacts on the fringe-toed lizard in the Dumant Dunes in southern California (this rare species has been petitioned for federal listing), and other similar examples in the Great Sand Dunes National Monument in Colorado.

Effects of ORVs in the White Wash Dunes

The amount of ORV use that the White Wash Sand Dunes is currently experiencing is extensive. The dunes themselves and the immediate surrounding lands are classified as Open Travel Areas by the BLM. The only vehicle counter on the only road accessing the dunes reports that an average of over 16,600 vehicles have entered the dunes each year for the past 3 years.[3] The Moab BLM Field Staff report that ORV use in the dunes "has risen dramatically in the past 4-5 years" and is comparable to the accelerated levels of use in nearby Tenmile Wash (personal communication Stephanie Ellingham, Moab BLM, November 2004). The White Wash Dunes generally receive year round use from ORV enthusiasts, although use is at its peak in the spring which is problematic for many species of plants and animals.

The effects of this overuse are obvious to the casual observer. All dune systems are constantly in a state of flux between the forces of deposition and continued erosion and transport of additional particles off and away from the dunes. Signs of wind action (uprooting of willows on the tops of the dunes, for example) today in the White Wash dunes show that these forces are currently in effect. Historically, parts of the White Wash dunes were held in place by a thin, chemical crust, comprised inorganically (i.e. weather and rainfall),[4] but perhaps with some further stabilization by cyanobacteria. Traces of

[3] While it is assumed that a large majority of these vehicles are recreational vehicles, it is unknown what percentage of vehicles are ORVs and what percentage of vehicles are using the road for ranch access, river access, non-ORV recreation, or oil facility work.
[4] Since precipitation can help create these physical crusts (Jayne Belnap, unpublished manuscript), areas such as the White Wash Dunes that receive very little precipitation are less likely to often harbor these helpful physical crusts.

this mechanical crust are observable on the White Wash dunes today. However, most locations where this crust still exists is torn up and crossed by ORV tracks (personal observation, ALJ). This destruction of natural crusts on sandy soils impedes the germination of cottonwoods, among other species (personal communication Chris Knauf, ecologist, BLM California, November 2004). Crusts can assist germination by providing good “holding areas” for seeds to stay put in otherwise wind-blown surfaces, and can provide could microclimates for germination through their textures (USDI 2001).

Currently, the base of the dunes is relatively well vegetated, with a mix of desert shrubs, grasses and forbs (Figure 4). Above this zone of vegetation (which varies but typically extends anywhere from 35 to 75 m above the base of the dunes) is an intermediate zone of sparse vegetation that marks the transition zone between the stabilized slopes of the lower dunes and the destabilized upper dunes. It is clear that the extensive ORV use on the dunes is contributing to the enlargement of this transition zone (Figure 5), with unknown repercussions for the further development, stability and long-term evolution and condition of the entire dune system.

Figure 4. Band of stabilizing vegetation at base of dunes

Mature cottonwoods observed on our field visit showed many signs of stress and reduced levels of recruitment. The cottonwoods appear to have suffered stunted growth patterns, as evidenced by trees that are 10-15 feet high yet with trunk diameters that indicate the trees are 10-15 years in age (personal observation, ALJ). Cottonwoods that are experiencing more typical and healthy growing conditions would experience growth rates of anywhere from 2 to 8 feet a year (personal communication Bob Ohmart ASU, personal communication Peter Stacey, U. of New Mexico, both riparian experts). Also, much of the bark on the trees is white and desiccated (personal observation, ALJ). Moreover, many if not most of the trees observed had multiple exposed roots, clearly the result of accelerated erosion (Figure 6). While some of the signs of stress (stunted growth and desiccated limbs) are difficult to causally link to ORV use, the erosion around the bases

Figure 5. ORV tracks through stabilizing vegetation at dunes' base

of the cottonwoods is probably appropriate to tie to ORV use on the dunes (the tracks around the base of the trees support this conclusion). In fact, it is popular for ORV users to use the older cottonwoods as a "slalom course" (Figure 7, personal communication Stephanie Ellingham, Moab BLM, November 2004).

Figure 6. Exposed roots and other signs of erosion at base of cottonwoods

We also witnessed only a few examples of cottonwood recruitment on the dunes, with only a small handful of seedlings documented. Figure 8 illustrates both cottonwood seedlings and saplings in the path of ORVs. The literature is replete with evidence that ORVs limit seedling germination and success (i.e. Bury 1977, CEQ 1979, Havlick 2000 and others). This is likely the stressor that explains the very low rates of cottonwood recruitment on the White Wash Dunes (personal observation, ALJ).

Figure 7. ORV users winding in and out of cottonwoods

Figure 8. Cottonwood seedlings and saplings in the path of ORVs.

These impacts to the unique riparian systems of the dunes have not gone unnoticed by the BLM Moab Field Office. White Wash and cottonwood forests associated with the dunes have been rated as “Functioning At Risk” by the BLM, and this rating was given because of the ORV pressure on this resource (personal communication, Stephanie Ellingham, Moab BLM, November 2004). The Field Staff reports that the impacts to the riparian zones chiefly consist of both direct impacts to vegetation by the machines, and indirect impacts (cutting down cottonwoods for fire wood for camping for ORV enthusiasts). Figure 9 depicts ORV impacts to White Wash and its riparian vegetation.

Figure 9. ORV impacts in riparian vegetation and main channel of White Wash

The paucity of sign of animal life on the White Wash dunes is striking. During an extensive, all-day tour of the dunes, only one set of rodent tracks and two rodent burrows were documented (personal observation, ALJ). The affinity of desert rodents such as kangaroo rats (*Dipodomys sp*.) for both sandy systems, and dune environments in particular (BCA 2003) is well known, and there is very little explanation for the near absence of these rodents from this system other than the extensive ORV use.[5] There was similarly no sign of lizards or other herpetofauna (though colder temperatures might have precluded their activity at the time of our site visit), and nearly no sign of invertebrates, such as scarab beetles and tiger beetles.

While the BLM does not do any regular monitoring of conditions in the White Wash Dunes, they have monitored fairly extensively both before and after the most recent (2001) "Book Cliffs Rattlers" motorcycle race through the dunes and adjacent areas. The 2001 monitoring survey reports that the average trail width before the race was approximately 9 feet across, and after the race the average trail width was about 13.7 feet across (Moab Field Office 2001). Similarly, the average depth of these routes increased from 3.9 inches before the race to 5.4 inches after the race. Water quality data was also collected before and after the event (at nearby Tenmile Wash), and surveyors found that

[5] While many desert rodents do aestivate (a form of "hibernation") during the winter months, the timing of our field visit in mid Novemember should precede aestivation for most of the heteromyid rodents, especially the larger-bodied ones. In addition, the larger bodied species such as kangaroo rats frequently interrupt aestivatation during periods of warm weather to forage. Thus, some rodent sign certainly should have been evident during our field visit, which was warm for November with temperatures near 60^{o}.

Turbidity increased from 93 NTUs[6] to 860 NTUs during the race (but levels returned to 91 NTUs after the event). Increased turbidity is known to impact both aquatic species and oxygen levels in streams. In terms of conductivity[7] within the stream, surveyors found that levels increased from 522 Microhms before the race to 583 Microhms during the race. Levels remained at 595 Microhms after the race (Moab Field Office 2001). No indications of upstream disturbance or storm run-off were observed during the race day to influence these turbidity and conductivity levels. Other impacts that were observed and noted in the monitoring report include mudholes that developed in channels with saturated soils, braided ORV trails, sedimentation in washes due to ORVs causing bank erosion (Figures 10 and 11), morphological damage to wash banks due to shortcutting of point bar meanders, (Moab Field Office 2001, personal communication with Stephanie Ellingham, Moab Field Office, December 2004). Many of these impacts, especially in ephemeral channels, floodplains and across point bar meanders did not naturally rehabilitate after the race. The field survey report made several recommendations, including relocating race routes away from drainages with saturated soils and urging the agency to re-evaluate widespread theories that the best location for ORV activity is within a wash or drainage due to previous disturbance from flooding (Moab Field Office 2001).

Figure 10. Eroding cutbanks undergoing ORV impacts

While this report chiefly focuses on the White Wash Dunes and ORV effects on this system, it should be noted that there are very serious ORV impacts occurring in areas adjacent to and nearby the dunes as well. Many areas adjacent to and nearby the White Wash Dunes are dominated by soils derived from the Mancos shale. These particular soils are highly vulnerable to erosion (Jayne Belnap, unpublished manuscript)

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[6] NTU's, or Nephelometric Turbidity Units, is the standard unit of measure to record sediments and other solids within streams.

[7] Conductivity reflects the presence of conductive chemicals within the water sample, including salinity. The unit of measure is Microhms. High levels of salinity and other chemicals can adversely affect aquatic organisms.

Another adjacent area to White Wash is the ecologically critical Tenmile Wash. Tenmile Wash is a perennial waterway that drains the second largest watershed in the Moab BLM Resource Area. As one of the extremely few perennial sources of water in the most arid part of the Resource Area, it functions as "an oasis" for many species of wildlife, including the resident bighorn sheep herd (personal communication Stephanie Ellingham, Moab BLM, January 2005). Tenmile Wash is somewhat unique in that about 5 miles of the 20 miles of wetland vegetation is classified as lentic, rather than lotic (or true riparian) vegetation.[8]

Figure 11. Changes in channel morphology due to ORV use

Unfortunately, Tenmile Wash is also being subjected to various ORV impacts (Figure 12). The BLM Field Staff are well aware that ORV use in the Wash, along with a few trespassing cattle, is the chief impact to this system. Presumably because of ORV use, the riparian health assessment rating on Tenmile Wash has recently declined from Functioning-at-Risk to "nearly Non-Functioning" (personal communication Stephanie Ellingham, Moab BLM, January 2005). In addition, the patches of lentic vegetation are being lost and are reverting to lotic systems, due to channelization caused by ORV use, which in one case has led to a ¼ mile collapse of the channel.

[8] Of the 1.8 million acres of land managed by the BLM in the Moab Field Office, only 1.6% of that is considered riparian habitat, and of that 1.6% only 0.6% of that is lentic (personal communication, Stephanie Ellingham, Moab BLM, January 2005).

FIGURE 12. Tenmile Wash.

IV. SUMMARY AND CONCLUSIONS

The findings of this survey, literature review and report of the ecological aspects and biological importance of the White Wash Sand Dunes (and immediate surrounding lands) of southeast Utah illustrate a truly unique environment that may be in peril, due to existing land use that is heavily weighted towards open ORV-based recreation.

Amazingly, this special dune and desert system has virtually never been studied. I could locate no biological data of any sort that had ever been collected by botanists or zoologists. It is not apparent that any dune specialists, hydrologists, or geomorphologists have collected data or reported on the nature of these dunes. In fact, the White Wash Dunes were not even included as a special element in The Nature Conservancy's recently completed Ecoregional Plan for the Colorado Plateau, for no other reason than the fact that TNC knows so little about it's ecological uniqueness (personal communication, Joel Tuhy of TNC, December 2004). The picture this paints is one that calls for much more critically needed research and inventory of the biological attributes of these sand dunes. This need was echoed by many experts and scientists that I interviewed while writing this report (i.e. Stephanie Ellingham, Stan Welsh, Joel Tuhy, Terry Griswold, Rich Reynolds, and Jayne Belnap). It would be most unfortunate if yet undiscovered rare varieties of species endemic to the White Wash dunes were extirpated by ORV use before anyone has documented these resources.

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