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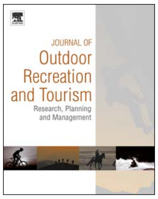

Research Note

Off-highway vehicle recreation in drylands: A literature review and recommendations for best management practices

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ABSTRACT

Around the world the rapid expansion of off-highway vehicle (OHV) recreation into arid and semi-arid lands has resulted in significant environmental and social costs. This paper reviews our current understanding on the ecological and social effects of OHVs on dryland environments. Based on research and existing management guidelines, the paper compiles a set of best management practices to minimize impacts during system design, and provides management strategies to further reduce impacts after route designation. The review found that OHVs have impacts to multiple resources that include soil compaction and erosion, trampling of vegetation, as well as wildlife habitat loss, disturbance, and direct mortality. Conflict among user groups has also been identified as occurring with non-motorized user groups being displaced. Vandalism of archaeological and cultural resources along OHV routes has also been documented. Gaps in our understanding still exist, and research needs are also presented. Knowledge of the most current research and the use of best management practices can help guide land managers to minimize conflict and resource damage.

Management implications: The paper summarizes the possible impacts by OHVs on ecological and social issues based on an extended literature review. To avoid ecological damage and user conflicts, management and planning should be based on:

- An inventory collecting baseline information on the route system as well as on the surrounding landscape covering all environmental and social issues
- An impact assessment considering the most up-to-date literature, and local resource conditions
- Design of a route network minimizing use of ecologically sensitive areas and conflicts among user groups
- Implementation of additional mitigation strategies and monitoring after designating a system of routes.

1. Introduction

Off-highway vehicle (OHV) recreation has rapidly expanded on arid and semi-arid lands (generally referred to as “drylands”) across the globe (Cordell, 2012). In southern California alone, OHV use has gone from almost none in the 1960s to more than 10 million user-days a year in the 2000s (Field, Belnap, Breshears, Neff, & Okin, 2010). Relatively slow two- and three-wheeled all-terrain vehicles (ATVs) have evolved into faster, larger, and easier to maneuver four-wheeled vehicles that can access vast areas.

Although use increased, land managers typically did not formally plan motorized route systems - rather OHVs were largely allowed to be driven cross-country or on existing multiple-use trails. In the relatively open landscape of arid and semi-arid lands, “user-created” OHV trails rapidly developed. In some areas, new routes increased in density until entire “play areas” were created and denuded of any vegetation (Matchett, Gass, Brooks, Mathie, & Vitales, 2004). Without formal planning, conflict with non-motorized uses ensued (Adams & McCool, 2010), and user-created trails in sensitive habitats or oriented directly up slopes facilitated rapid soil erosion (Brooks & Lair, 2005).

Over time it became increasingly evident to scientists, policy makers, and land managers that OHVs were causing significant social and environmental impacts (GAO, 2009; Ouren, Haas, Melcher, Stewart, & Ponds, 2007; Webb & Wilshire, 1983). In the U.S., President Nixon issued Executive Order (EO) 11644 that required all federal land management agencies to designate a system of areas and trails that are “located to *minimize* damage to soil, watershed, vegetation, or other resources of the public lands[;] … harassment of wildlife or significant disruption of wildlife habitats[; and] … conflicts between off-road vehicle use and other existing or proposed recreational uses of the same or neighboring public lands.” These “minimization criteria” provide the primary legal guidance for planning for and managing OHVs on U.S.

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public lands, and federal courts have repeatedly invalidated OHV travel plans that have not correctly applied the EOs (TWS, 2016).

Managing OHVs can be particularly challenging in arid and semi-arid environments. High temperatures and low, variable precipitation patterns result in sparse vegetation, often facilitating OHV cross-country travel and easy creation of new routes. Also, many dryland soils, such as cryptobiotic soils, are very sensitive to disturbance and can be significantly damaged after just one pass. Intense sun, high winds, limited moisture and low soil fertility make for difficult restoration and extremely long recovery times following disturbance (Lovich & Bainbridge, 1999). Closure of routes in arid lands can be difficult because of lack of obstacles such as trees.

Climate change is increasing the vulnerability of resources and ecosystems to stressors such as OHVs (CEQ, 2016). For example, in the southwestern U.S., it is predicted to become up to 5 °C warmer and up to 20% dryer by 2100 (Fleishman, Belnap, Cobb, Enquist, & Ford, 2013). Furthermore, a conversion from snowfall to rainfall may reduce soil moisture and reduce stream flows by up to 40%. Land use disturbances such as OHVs, grazing and oil/gas development add additional stress to landscapes undergoing rapid flux (Willis & MacDonald, 2011). OHVs are also an important source of gases that contribute to climate change and reduced air quality including hydrocarbon (HC) and carbon monoxide (CO) emissions (Durbin, Smith, Wilson, & Rhee, 2004).

The main purpose of this paper is to conduct a review of the literature on OHV use in dryland environments. The paper highlights the latest research, and with this information develops new management strategies and best management practices to minimize environmental damage and limit user conflicts.

2. Methodological approach

Over the last four decades, hundreds of research studies have documented the environmental and social impacts of OHVs in arid and semi-arid landscapes. The seminal book edited by Robert Webb and Howard Wilshire entitled "*Environmental Effects of Off-Road Vehicles: Impacts and Management in Arid Regions*," was the first to comprehensively summarize the impacts of OHVs in the Southern California desert (see Webb & Wilshire, 1983). Since then, dozens of publications have researched and reviewed the intricacies of OHV environmental and social impacts in dry environments around the world.

While many OHV impacts to drylands were documented as early as the 1970s, this paper highlights research conducted in the last 20 years to capture the most recent state of understanding. Additionally, the paper presents research primarily from peer-reviewed journals on the impacts of OHVs on dryland environments, and in some cases, includes studies on low-volume, native surface roads when no research existed on motorized trails. While most research has occurred in the western US, their findings are broadly applicable to arid and semi-arid lands across the globe. Finally, we present gaps in our understanding which would benefit from additional research.

The U.S. Geological Survey (USGS) has been instrumental in summarizing OHV impacts in drylands, especially in the western United States. Brooks and Lair (2005) reviewed the impacts of different types of vehicular routes from OHV trails to highways on the Mojave Desert landscape. They found 50 studies that specifically quantified the direct impacts of vehicular routes in the Mojave Desert. Ouren et al. (2007) drafted a more comprehensive review of impacts of OHVs on BLM lands in which they reviewed approximately 700 articles on all types of motorized recreation (summer and winter) in several ecosystem types (including forest, desert, and beach environments), as well as presented potential indicators for evaluating and monitoring OHV effects. These studies have been analyzed and their main findings are presented below.

3. Review of literature

3.1. Environmental impacts by OHVs

3.1.1. Soil compaction and erosion

In dry environments, soils can take thousands of years to develop, and are very slow to recover after disturbance (Webb, 2002). One of the first established and most important impacts of OHV use is the loss of desert soils through compaction and erosion (e.g., Wilshire & Nakata, 1976; Webb & Wilshire, 1983; Ouren et al., 2007). Compacted soils reduce water infiltration and damage soil stabilizers (such as physical and biological crusts), promoting increased rates of water and wind erosion (Iverson, Hinckley, & Webb, 1981). Simply driving an OHV in dry conditions can create a plume of dust and concurrent trail erosion (Goosens & Buck, 2009a; Padgett, Meadows, Eubanks, & Ryan, 2008). Additionally, knobby tires on OHVs can mechanically erode steep slopes when spinning wheels exceed the sheer strength of the soil (Wilshire 1983). One of the earliest studies in the western Mojave Desert found 0.3 m of soil eroded away in an OHV play area hill-climb over the course of just two years (Snyder, Frickel, Hadley, & Miller, 1976). Severely compacted soils can be very slow to recover, and in some cases, have been estimated to take more than a century for natural recovery (Webb, 2002).

While precipitation is relatively low in dryland environments, rain often comes in large episodic events. OHVs can create conditions that cause significant water erosion along trails. All soil types can be vulnerable to water erosion (Ouren et al., 2007), but some soil types such as clay-rich soils, when compacted can have a strong surface seal that can increase rainwater runoff leading to increased erosion (Sheridan, 1979). Furthermore, trails on steep slopes (15% or greater) are more likely to cause water erosion (Leung & Marion, 1996).

In dryland environments where vegetation is sparse, biological soil crusts are important soil stabilizers. Biological soil crusts are communities of living organisms composed of cyanobacteria, lichens, and moss found on the soil surface of many drylands (Belnap, 2003). They are often the dominant source of nitrogen (N), the element most limiting primary productivity in dry landscapes. OHVs traveling on these soils have been found to crush biological crusts, reduce the stability of soil, and reduce the nitrogenase activity (Belnap, 2002). This can have long-term impacts to soil erosion vulnerability and fertility, and may take decades to centuries to recover (Belnap, 2003).

Much recent attention has been given to the role of OHVs in wind-generated soil erosion and toxicity of dust emissions. In the absence of disturbance, most desert soils have very low dust emissions; this is due to a number of mechanisms protecting the soil surface including rock cover, physical crusts, biological crusts, and plants (Field et al., 2010). However, once disturbed, sediment production can dramatically increase - by up to 550 times. It has been estimated that OHV use in southern California alone may generate as much as 2.7 metric tons of dust per year (Field et al., 2010).

The type of soil surface is a key factor in determining the susceptibility to wind erosion and toxicity of dust emissions. A recent study at the Nellis Dunes Recreation Area in Nevada found that while sandy surfaces had the most natural wind-generated erosion, areas with silty surfaces were most vulnerable to OHV-generated dust (Goosens & Buck, 2009a; Goosens, Buck, & McLaurin, 2012). When protective surface crusts and surficial rock layers were traveled upon by OHVs, large amounts of dust were mobilized. More dust was emitted the faster vehicles traveled, and 4-wheelers produced more dust emissions than dune buggies or dirt bikes (Goosens & Buck, 2009b). Furthermore, when silty and clay soils were disturbed by OHVs, large amounts of arsenic (As) was emitted, potentially leading to health concerns for recreationists and the nearby Las Vegas metropolis (Soukup, Buck, Goosens, Ulery, & McLaurin, 2012). Arsenic is water soluble and there is concern for potential contamination of Lake Mead, which is downslope of the OHV area, and a major drinking water source in the region (Soukup et al., 2012).