Drawing a line in the sand: Effectiveness of off-highway vehicle management in California's Sonoran Desert

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ABSTRACT

Public land policies manage multiple uses while striving to protect vulnerable plant and wildlife habitats from degradation; yet the effectiveness of such policies are infrequently evaluated, particularly for remote landscapes that are difficult to monitor. We assessed the use and impacts of recreational vehicles on Mojave Desert washes (intermittent streams) in the Chemehuevi Desert Wildlife Management Area (DWMA) of southern California. Wash zones designated as open and closed to off-highway vehicle (OHV) activity were designed in part to protect Mojave desert tortoise (*Gopherus agassizii*) habitat while allowing recreation in designated areas. OHV tracks were monitored in washes located near access roads during winter and early spring holidays – when recreation is typically high – and at randomly dispersed locations away from roads. Washes near access roads had fewer vehicle tracks within closed than open zones; further away from roads, OHV tracks were infrequent and their occurrence was not different between wash designations. Washes were in better condition in closed zones following major holidays as indicated by less vegetation damage, presence of trash, and wash bank damage. Furthermore, the frequency of washes with live tortoises and their sign was marginally greater in closed than open wash zones. Collectively, these results suggest that low impacts to habitats in designated closed wash zones reflect public compliance with federal OHV policy and regulations in the Chemehuevi DWMA during our study. Future monitoring to contrast wash use and impacts during other seasons as well as in other DWMAs will elucidate spatial and temporal patterns of recreation in these important conservation areas.

Keywords: degradation, desert wash, *Gopherus agassizii*, monitoring, OHV, xeriparian habitat condition

1. Introduction

Desert washes are important landscape features in the northeastern Colorado Desert of California. These washes generally flow from hillside or mountain slopes into valleys and are often eroded during extreme rain events (Averill-Murray and Averill-Murray, 2005). They are also known as “xeririparian” (also *xeroriparian*) habitats due to their intermittently wet, but mostly dry condition. As intermittent channels for the flow of surface and subsurface water, desert washes concentrate important resources for wildlife (Schwinning et al., 2010). A larger proportion of diverse seasonal plant biomass is found within, and on the margins of, washes than on surrounding upland areas (Marshall et al., 2005). The xeririparian vegetation communities (also known as microphyll woodland) of California’s Mojave and Sonoran deserts are characterized by creosote bush scrub (*Larrea tridentata*) with component species including bursage (*Ambrosia dumosa*), rabbitbrush (*Ericameria paniculatus*), woolly brickellia (*Brickellia incana*), Mojave bridlebush (*B. oblongifolia*), desert cassia (*Cassia armata*), palo verde (*Parkinsonia microphylla*), ironwood (*Olneya tesota*), cat’s-claw acacia (*Acacia greggii*), and desert willow (*Chilopsis linearis*) (Barbour et al., 1999; Lathrop and Rowlands, 1983; Schoenherr and Burk, 2007; Turner and Brown, 1982).

Xeririparian habitats in the Sonoran Desert of southern California provide an inordinate benefit to desert wildlife (Stebbins, 1974). Vegetation is typically taller, denser, and highly productive in washes providing nesting and breeding grounds, cover, and protection from predators for resident and migrant birds (Esque et al., 2013). Such enhanced habitat structure also provides protection for the threatened Mojave desert tortoise (*Gopherus agassizii*), which uses wash channels for traveling, burrowing, and foraging (Jennings, 1997; Todd et al., 2016).

Tortoises commonly occur in wash habitats on the lower slopes of bajadas and forage on preferred food plants located exclusively in hill areas and washlet margins during the spring (Esque et al., 2014; Jennings, 1997; Luckenbach, 1982). Consequently, changes to habitat conditions by repeated anthropogenic disturbance within wash systems can have profound effects on wash structure and the wildlife that depend on these resources.

Desert washes are popular scenic byways for people that use off-highway vehicles (OHV) to access infrequently traveled desert lands and spend time in relative solitude or in social groups. Desert washes are also popular places to view wildlife, to access interesting destinations, and to challenge recreation enthusiasts as they test their equipment and skills on rugged terrain. Although desert washes are ‘disturbance prone habitats’ that support species that tolerate frequent flooding, recreational activities that remain unchecked can alter wash structure and denude vegetation, thus disrupting geomorphic and ecological processes (Schwinning et al., 2010).

The severity of damage in desert washes is dependent on the amount and types of OHV traffic. Heavy vehicles, such as trucks compared to all-terrain vehicles (ATV), produce a higher rate of compaction with fewer passes than lighter vehicles over the same area (Webb et al., 2013). Direct impacts include crushing of the foliage, root systems, and seedlings while shear forces related to tire action from heavy vehicles uproot small plants (Stebbins, 1974) and disrupt root systems of larger plants through soil compaction (Ryan et al., 2016; Wilshire et al., 1978). Soil compaction and flocculation, though not as persistent in wash channels due to the intermittent flow of water and higher sand content, can still be one of the most important and long-lasting effects OHV use has on soil (Webb, 1983; Webb et al., 2013). The magnitude of damage by soil compaction is dependent on the texture and moisture of any particular soil (Webb

et al., 2013). Compaction can increase soil bulk density and reduce infiltration rate and porosity that can lead to soil erosion (Iverson, 1980; Mancilla-Leytón et al., 2016) and loss of plant cover. Furthermore, bank cuts made by OHVs may increase erosion, destroy tortoise burrows, or damage vegetation thereby diminishing food and cover important for habitat. Disturbed areas where native vegetation is removed are susceptible to weed invasions and erosion. Soil disturbances caused by OHV traffic and their effects on soil, moisture characteristics, and structure can alter production of desert annual plants (Adams et al., 1982; Brown and Schoknecht, 2001) – the primary food for the Mojave desert tortoise (Esque et al., 2014; Jennings and Berry, 2015). Ultimately, increased OHV traffic can modify natural communities and reduce biomass and diversity of animals living there (Bury et al., 1977; Wilson et al., 2009).

Ecological impacts of vehicular traffic also occur in arid landscapes around the world. In the Kabd area of Kuwait, off-road traffic and overgrazing degraded vegetation cover and soil porosity, permeability, and infiltration except in protected areas (Misak et al., 2002). Motorcycle races and hill-climbing events peripheral to Mojave Desert washes compact soils and decrease abundance of native vegetation, insects, and animal populations (Lathrop, 1983; Wilson et al., 2009). In the Namib Desert in Africa, vehicle use threatened breeding grounds of the Damara Tern (*Sterna balaenarum*) by destroying ground nests of this Near Threatened species (Braby et al., 2009). Overall breeding success was improved by restricting vehicle access during nesting. Vehicle traffic likely impacts soils and terrestrial life in arid environments worldwide, but few policies exist to protect them or have been evaluated for their effectiveness.

The Northern and Eastern Colorado Desert Management (NECO) Plan was released in 2002 and provides specific guidance on land use activities and conservation of 1.6 million acres of Bureau of Land Management (BLM) desert lands in California (BLM, 2002). The plan

designates areas that are closed or open to vehicle traffic in desert washes hereafter referred to as “open and closed wash zones,” which is more feasible than placing signage that designates every wash as open or closed. Driving within open zones is restricted to washes considered navigable: if motorized travel within a wash would result in unavoidable disturbance to the wash bank, vegetation, or soil, then the wash is not considered a travel route (BLM, 2002).

We evaluated the effectiveness of the NECO plan by quantifying the differences in OHV activity among desert washes in open and closed wash zones, by identifying wash condition associated with OHV activity, and by characterizing patterns of OHV activity among four periods of “high use” during winter/spring holidays (Thanksgiving, New Year’s, President’s Day and Easter). The NECO plan requires monitoring OHV activity to evaluate the effectiveness of current management. Compliance with other national environmental laws (e.g. Endangered Species Act, Federal Lands Policy and Management Act) requires monitoring the impacts of OHV use in desert washes to protect sensitive species, such as the desert tortoise, and for the general sustainability of the environment.

We addressed several questions on OHV impacts in the northern and eastern Colorado Desert of southern California: 1) Are resource users generally complying with regulations in the open and closed wash zones?, 2) Are closed wash zones maintaining lower vehicle use than open wash zones?, and 3) Is wash condition in closed wash zones better than open wash zones, and how so?

2. Methods and materials

2.1. Study area

The Chemehuevi Desert Wildlife Management Area (DWMA) covers approximately 874,843 acres (3,540 km²) of US Department of Interior, BLM, state, and private land in southern California. The DWMA contains approximately 218,711 acres (25%; 885 km²) of open wash zones and 656,132 acres (75%; 2,655 km²) of closed wash zones designated for OHV access (Fig. 1) (BLM, 2002). This DWMA lies north of highway 62 and south of Interstate 40, east of Kelbaker/Amboy Road and west of the Colorado River with US Highway 95 bisecting the area on a north-south axis. At the beginning of our study, roads within the DWMA were characterized as either open or closed in accordance with a road map layer from the Needles, California BLM Field Office (J. Weigand, California State Office and M. Margosian, BLM California Desert District, personal communication).

2.2. Potential habitat for the desert tortoise

To relate the designated OHV areas with desert tortoise habitat, we overlaid the wash zones onto a spatial model of desert tortoise habitat suitability (Nussear et al., 2009). The resolution of the model is 1 km², and the model provides habitat scores of 0 (unsuitable) to 1 (highly suitable) across the entire study area. We used ArcGIS (ver. 9.3.1) to determine habitat suitability in wash zones by calculating an average index score of the raster cells within each open or closed polygon. We then created a point in every raster within the DWMA and exported the index scores to compare mean habitat suitability between open and closed areas using a two sample t-test in R (R Core Team, 2013).

2.3. Sampling design to select NECO washes

We selected NECO washes throughout the DWMA using two approaches. First, we used

BLM spatial layers to locate washes that intersected paved or graded access roads in open and closed wash zones using ArcGIS (ver. 9.3.1). The closest wash to each randomly selected point along roadways was included for this study. Roadways occurring in areas designated as wilderness were excluded, with the exception of those located along OHV routes separating wilderness from open or closed wash zones. Additional washes that did not exist on the wash layer were selected opportunistically during field visits. During initial wash visits, we evaluated the navigability of each wash as defined in the NECO Plan: i.e., width minimally accommodates a one-track vehicle within the primary floodplain and roughly equivalent to a 102 cm (40 in) wide motorcycle handle bar (BLM Law Enforcement staff, Needles District, CA, personal communication). We then determined if the intersection of a road and a wash had recreational status signs present to designate the wash area as open or closed (though not a requirement by the NECO Plan). We initially raked 30 washes (15 each in open and closed wash zones) starting at their intersections with roads prior to Thanksgiving (November 24, 2010) and revisited them following the holiday weekend (see 2.4 Holiday and dispersed wash use in NECO wash zones for details on raking). We subsequently augmented the number of washes (49 in open and 45 in closed wash zones) that we raked and re-visited for New Year's Day (January 1), President's Day (February 21), and Easter (April 24) for a total of 312 visits. "Pre-holiday" data were collected during initial visits to the washes prior to holiday weekends. Data collected on washes immediately following all holidays were termed "post-holiday" wash data.

As a second approach, we selected washes that were distributed in a stratified-random design across the DWMA (hereafter, "dispersed") to provide a spatial analysis of OHV use of washes in open and closed wash zones. We generated 1000 random points in ArcGIS (ver. 9.3.1)

that were spaced at least 500 m apart within the open and closed wash zones. Because randomly selected points across the DWMA often fell outside of washes, we travelled upslope of these points along the fall line of the slope until a wash was encountered. If a wash was not found within 1 km of the random point, then the point was omitted and another selected. A total of 111 dispersed washes were included (56 in open and 55 in closed wash zones).

2.4. Holiday and dispersed wash use in NECO wash zones

During pre- and post-holiday visits, a 100-m transect tape was stretched from the middle of the road and down the center of the main wash channel on each side of the intersecting road. Along both 100-m transects we raked a 10-15 cm deep channel with a garden hoe that was 75-100 m from, and parallel to, the road to detect wash use during subsequent visits (Fig. 2). When crossed by an OHV, the small piles of soil cut by the hoe are disturbed indicating the unmistakable presence of tracks. Raked washes that had OHV tracks present were raked again at each post-holiday visit. In contrast to holiday wash use, we assessed OHV tracks in dispersed washes during single field visits from November 2010 through May 2011. Dispersed washes were neither raked nor revisited.

2.5. Correlates of wash use

When OHV tracks were detected in washes during holiday and dispersed wash visits, we recorded the type of vehicle that made the tracks. For example, a two-track wheelbase width less than four feet was recorded as an ATV, greater than four feet was recorded as a truck/SUV, and single wheel tracks were recorded as a motorcycle. Washes were categorized based on four

criteria: wash width (distance between wash banks), vegetation clearance, terrain, and number of channels (i.e. a braided wash might have many individual channels) (Table 1).

At each wash, we estimated the top three perennial plant species with the greatest cover. We also collected information on factors that we consider to be correlates of wash condition including: the amount of trash; bank cuts due to OHVs; abundance of common ravens (*Corvus corax*); and vegetation damage (Nussear et al., 2007a). For example, various types of trash are known to attract or provide subsidies to predators such as ravens and coyotes (*Canis latrans*, Kristan and Boarman, 2003), and increased trash is typically correlated with more human activity. Subsidized predators are known to negatively affect tortoise populations by sustaining unnaturally high predation rates (Esque et al., 2010; Kristan and Boarman, 2003).

We estimated vehicle damage to vegetation for each wash by assigning a score from 0 to 4: 0 (no damage to canopy cover), 1 (up to 25% of the cover damaged), 2 (>25-50% of the cover damaged), 3 (>50-75% of the cover damaged), and 4 (>75% of the cover damaged or completely denuded). The presence of trash was ranked following Nussear et al. (2007a): 0 (no trash), 1 (less than a wheel barrow load), 2 (a wheel barrow load), 3 (a pickup truck load), 4 (a dump site with more than a pickup truck load, possibly resulting from many visits). OHV tracks crossing the bank of the wash were documented as bank cuts and were scored by counting the number of trails in the bank within each transect. The number of ravens observed and/or heard was also recorded as a frequency count during work at each transect. For analysis, scores were summed across these factors for each wash resulting in an index of condition for open versus closed washes.

In the absence of quantitative metrics for habitat condition (Nussear and Tuberville, 2014), we used desert tortoise sign (scat, tracks, burrows, and live tortoises) as indicators of tortoise

activity in washes (Drake et al., 2015). Other wildlife, e.g. kit fox (*Vulpes macrotis*) and burrowing owl (*Athene cunicularia*) were rarely observed and noted as ancillary. Most of the holiday periods surveyed occurred outside of the active season for desert tortoise; however, the Easter holiday is well within the desert tortoise active season (Luckenbach, 1982, Nussear et al., 2007b), especially at the low elevation of the Chemehuevi Valley.

2.6. Evaluating implementation compliance

During discussions with BLM personnel it was important to determine whether guidelines described in the CDCA and NECO were being adequately implemented. We therefore assessed our ability as “resource users” to interpret publicly available resource user information to comply with open and closed wash zone designations. In other words, we asked “Is the publicly-available brochure of open and closed areas consistent with the BLM designation of open and closed wash zones we received as GIS coverage?” We also noted the number of hours per week when we observed the presence of law enforcement on improved/unimproved roads within the DWMA.

2.7. Analyses of OHV use in NECO washes

An over-arching consideration for the use of OHVs in the NECO administrative unit is whether wash use is consistent with BLM wash designations. We first evaluated open and closed wash zone use in separate analyses for dispersed washes (tests for incidence of vehicle tracks across entire DWMA), for pre-holiday washes that intersect roads (tests for incidence of tracks associated with roads prior to holidays), and washes visited immediately after major holidays (tests for incidence of tracks related to periods of expected high visitation). Because several

frequency counts were less than 5, we report Fisher's exact test using the FREQ procedure in SAS (Cary, NC, vers. 9.2) to test for homogeneity of proportions (e.g., null hypothesis: same frequency of washes with vehicle tracks in open and closed wash zones; alternative hypothesis: frequency of washes with tracks in closed < frequency of washes with tracks in open wash zones; (Zar, 1984)). We also used a Wilcoxon Rank Sum test (NPAR1WAY procedure in SAS) for evaluating differences in the distributions of the wash degradation scores (i.e. pooled indicators of raven encounters, vegetation damage, trash, and bank cuts) where scores scaled proportionally with the level of degradation.

We also compared wash use by creating a travel distance surface by calculating a "cost" for each wash point, which describes the energy expenditure to access the point from the nearest highway exits and localized urban areas. A route shape file was first converted to a raster file in ArcGIS (ver. 9.3.1) and a point layer was created in Google Earth 6.0.2.2074 defining all highway exits and access points from urban areas. The route shape file was also converted to a KML file and opened in Google Earth to digitize routes that were not present in the BLM route layer to ensure areas that do not directly border BLM lands have visible routes connected to the route layer (i.e. near Blythe and Parker, CA).

We used the r.cost procedure (GRASS 7.0.1, 2015) to determine the cumulative distance along vehicle routes from the collective entry points to the raked points identified from the rasterized routes layer. Each cell in the raster layer has an associated cost value that represents the distance travelled on a road (i.e. cost of moving across that cell). These were also calculated for a "Main entry" point file that used fewer entries near urban areas or major access points only, and another distance surface from only paved routes. We also calculated the straight-line distance of each point from the nearest paved and open maintained road.

We analyzed route distance (cost) and straight-line distance to access washes using generalized linear mixed effect models with binary response variables to compare washes in open and closed wash zones with or without OHV tracks present. Sixteen models including an intercept-only model were ranked using the Akaike's Information Criterion (AIC) method (Burnham and Anderson, 1998) to select models best describing OHV activity in both wash zones.

3. Results

3.1. Evaluation of NECO Implementation and Compliance

3.1.1. Signage and wash usage

We found little evidence of wash route designation throughout the study area. Signage in the Chemehuevi DWMA occurred mostly on the borders of wilderness areas. The only non-wilderness 'closed route' signs bordered one open/closed wash zone and were lying on the ground or buried in the sediment. Field personnel determined that the only way to positively determine whether they were traveling in an open or closed wash zone was through a combination of maps issued by the BLM Needles Field Office or by talking with BLM officials. Four of the 100 holiday and dispersed washes sampled in closed wash zones had intact standing or damaged 'closed route' signs. We encountered fewer than ten OHV user groups during more than 500 hrs of observation during the busiest season for this region (N. Custer – personal observation) and did not encounter any BLM staff or law enforcement.

We used the brochure entitled, "Chemehuevi Valley Limited Use Area and OHV Trail Guide and Map" (available at the Needles BLM Office, Needles, CA) to navigate available routes in a

portion of the Chemehuevi DWMA, but the map in the brochure did not address wash zones. The BLM website (www.blm.gov/california; accessed 09/24/2010; no longer in circulation) directs users to a page with a link to a “Detailed Wash Zone Map 2-32” and although this map shows the DWMA with a very detailed route map it still does not address the open and closed wash zones. We then referred back to the NECO plan to a map entitled, “NECO Plan Washes Closed Zones in DWMA” indicating the DWMA with shading for the open and closed wash zones but it was poorly detailed and difficult to use for navigation. Using the resources available to the general public we found it challenging to find this information for adhering to the guidelines.

3.1.2 OHV use in desert washes of Chemehuevi DWMA

Most washes lacked vehicle tracks (S1), and we found that the frequency of washes with OHV tracks was not different between open and closed wash zones for the dispersed washes across the DWMA ($P = 0.75$, one-tailed Fisher’s exact test, Fig. 3). However, the frequency of washes with tracks was lower in the closed than open wash zones for the pre-holiday visits ($P = 0.05$, one-tailed Fisher’s exact test) and combined post-holiday visits ($P < 0.01$, one-tailed Fisher’s exact test). The washes monitored following holidays demonstrated no difference in the frequencies of wash use in closed and open wash zones for New Year’s, but use was significantly lower in closed wash zones compared with open wash zones for President’s Day and Easter holidays (Fig. 4).

We observed tracks of multiple types of OHVs including trucks, ATVs, and motorcycles (Fig. 5), and some washes had a combination of OHV tracks within them. The frequency of tracks among vehicle types (excluding washes without tracks) varied between open and closed wash zones during our visits to dispersed washes: ATV tracks were more frequent and trucks

less frequent in open than closed wash zones (Fig. 5, $P = 0.02$, Fisher's exact test). During pre-holiday visits, truck and ATV tracks were less frequent in closed than open wash zones (Fig. 5, $P = 0.03$, Fisher's exact test). The same pattern in vehicle use between open and closed wash zones occurred during post-holiday visits (Fig. 5, $P < 0.01$, Fisher's exact test).

The results of the cost analysis revealed that the travel distances for the washes with OHV tracks were not significantly different from those for washes without OHV tracks (Cost-route $P=0.42$, Cost-main $P=0.26$, Cost-paved $P=0.83$, GLM). In other words, OHV activity in washes was not due to their proximity to main roads or easy access points. The models with the lowest AIC values that best relate the evidence of tracks to wash use are ones that included wash status (open or closed) as a variable (Table 2). This is further evidence that wash status is the determining factor in wash use and that OHV riders are mostly complying with management regulations.

3.1.3. Changes in wash degradation associated with wash usage

Wash condition scores based on Wilcoxon Rank Sum test were not different between open and closed wash zones for pre-holiday washes ($z = -0.671$, $P = 0.25$) or for dispersed washes ($z = 0.20$, $P = 0.42$), but post-holiday washes had significantly lower degradation scores in closed than open wash zones ($z = -3.017$, $P < 0.01$) (i.e. lower score interpreted as more degraded). When post-holiday washes were analyzed separately, wash condition was not different between open and closed wash zones on New Year's ($z = -0.39$, $P = 0.35$), but scores were significantly lower in closed wash zones after Thanksgiving ($z = -1.75$, $P = 0.04$), President's Day ($z = -1.61$, $P = 0.05$), and Easter ($z = -2.21$, $P = 0.01$).

3.1.4. Desert tortoise habitat and activity in open and closed wash zones

The majority of open and closed wash zones have the highest habitat suitability scores for desert tortoise (Fig. 6). Open wash zones ranged in potential habitat index values from 0.30 to 1.00 (1.00 being the highest potential) and ranged in average index values from 0.73 to 0.89 ($n = 4$ polygons, Fig. 6, Table 3). Similarly, closed wash zones had a slightly broader range of index values from 0.20 to 1.00, and their averages ranged from 0.79 to 0.82 ($n = 2$ polygons, Fig. 6, Table 3). Areas with lowest potential habitat scores were mountainous or on playa margins. Differences in the average index values between open and closed wash zones were minimal, providing quantitative evidence that much of the area has high potential for supporting desert tortoise habitat.

As an indication of tortoise activity in open and closed wash zones, we analyzed the frequency of washes with and without tortoise sign (i.e. live tortoises, scat, tracks, and burrows) in dispersed and pre-holiday washes combined. Tortoise activity was marginally greater in closed wash zones (15 out of 100 washes with sign) than in open wash zones (8 out of 105 washes; $P = 0.07$, one-sided Fisher's exact test). The difference was not associated with differences in habitat suitability, as the habitat suitability index was not statistically different between open and closed wash zones ($P = 0.2196$, Two sample t-test)

4. Discussion

Although OHV use of open and closed wash zones in the NECO study area was generally low, wash use by OHV enthusiasts during peak holiday periods was lower in closed than in open wash zones for the Chemehuevi Valley, California. This finding occurred despite sparse signage and documentation of wash zone designation in the area that could confuse users as they tried to

determine the official status of a wash. This result begs the question, “how did a pattern of compliance emerge if the user group did not have sufficient information to discern whether open or closed designation was in place?” We propose that usage patterns of the landscape were partially a result of prior habits and use, as well as, the public process by which open/closed wash status was designated. For example, during public hearings for the designation of open and closed areas, BLM staff confer with the OHV community to identify areas that are mutually acceptable to all parties if possible. Thus, many or at least part of the more popular routes likely remain open. This would result in the sessions themselves providing some guidelines that were well known to the OHV user-group, and possibly the result of the land use designation process compliance.

The amount of OHV activity we observed was dwarfed by that observed in concentrated OHV areas of the west Mojave in Fremont Valley, Kern County, California approximately 200 mi west of Chemehuevi Valley. Observers documented up to 65 vehicles at a monitoring site in only 4 hrs: 38% of those vehicles were on open routes, 20% were on closed routes, and 42% of them were traveling cross country (Goodlett and Goodlett, 1992). Despite the infrequent wash use by OHVs in our study, greater wash degradation (as characterized by wash bank cuts, vegetation damage, abundance of trash, and incidence of ravens) was associated with washes in the open wash zones near access roads. This pattern is of concern as low levels of OHV activity can have negative impacts to native plants and animals (Luckenbach and Bury, 1983). In addition, the low activity of this area should not be considered an indication of a static pattern. Relative to other OHV open areas, the Chemehuevi DWMA is remote, more than 120 mi from major metropolitan areas of Las Vegas, Los Angeles, San Diego and Phoenix. Should management be changed at other OHV sites where use is heavier (e.g. partial closures to allow

recovery of over-used areas), managers could anticipate a shift in use patterns, with OHV recreationists using the Chemehuevi DWMA with greater frequency. Such an increase in OHV use would likely result in similar impacts to those reported for high use locations (Adams et al., 1982; Goodlett and Goodlett, 1992; Luckenbach and Bury, 1983; Matchett et al., 2004; Sampson, 2009; Stebbins, 1974).

OHV activity in washes was typically concentrated near access roads (in our pre- and post-holiday assessments), yet washes associated with roads within closed wash zones had a lower incidence of use than those within open wash zones. Higher use near roads and other linear features was also documented in the Fremont Valley and Rand Mountains OHV areas (Goodlett and Goodlett, 1992) and the Dove Springs Canyon OHV areas (Matchett et al., 2004), both in Kern County, California. In desert environments, linear features that provide vehicle access influence the proliferation of OHV routes (Matchett et al., 2004). Consequently, the area influenced by vehicles in open or closed wash zones is likely greater than the access road footprint, and this pattern is consistent with previous studies on OHV activity in open and closed recreation areas (Goodlett and Goodlett, 1992). In regard to natural resources, the effect of these linear features may far exceed the apparent effect of the roads themselves.

The BLM previously developed and supported a protocol for identifying change in areas of heavily used OHV open zones bordering protected areas (Matchett et al., 2004). Heavily concentrated OHV activity was conducive to monitoring landscape scale land use change with remote sensing. In contrast, the type of activity that we monitored in the Chemehuevi DWMA was diffuse, and the detection of tracks of a single to few OHVs at any one place using available remotely sensed data is unlikely. Furthermore, tracks in washes are inherently ephemeral because heavy rainfall and overland flow can easily erase the tracks within the floodplains. For detecting

scattered OHV activity in closed wash zones and for comparison with open wash zones, we found that the most effective and efficient way to monitor OHV activity is the raking technique that we adapted from Goodlett and Goodlett (1992).

Some OHV activity observed in closed wash zones reflected disregard for the policy set forth in the NECO plan, as evidenced by vandalized signs that designated route closures. Such attrition of signage is costly to public resources and confuses law-abiding recreationists differentiating open and closed wash zone designations. In the Chemehuevi DWMA, even our field teams had difficulty distinguishing wash zones based on available information signage, maps, and information kiosks in this vast, remote management area. Goodlett and Goodlett (1992) reached a similar conclusion from observations in the heavily used Fremont Valley and Rand Mountains OHV areas in California nearly 20 years ago. It may be possible that the first user to a closed wash may use this route due to this confusion, and then others simply follow previously laid tracks. Despite the ambiguity in zone delineation, the lower use of washes in closed wash zones associated with roads suggests that the traditional means of informing the public have been somewhat successful. However, we recognize that lower incidence of vehicle activity in closed wash zones may also reflect social factors such as cultural memory of OHV users leading to compliance maintained and communicated from one generation to the next.

New forms of information dissemination may facilitate education for new users of the DWMAs, especially as recreation continues to increase from urban centers such as Los Angeles and Las Vegas. With today's technologically savvy culture, open and closed wash zones for OHVs could be incorporated into free mapping software that can be readily downloaded to a mobile device or provided in a geospatial "app" that can integrate with smart phone technology, and be disseminated through a variety of forms of social media. Such geospatial applications

could provide information about points of interest concerning geological, biological, historical, archaeological, and social interests to enthusiasts while providing messages about protecting vulnerable resources in the area. In addition, the public highway radio channel could broadcast information about the availability of these mapping tools for recreation as public service announcements on stations that target that demographic. All such spatial information might also be compatible with, and available on, traditional paper maps for those who do not have access to such technologies – perhaps as a welcoming package provided with permits for use of the area.

Holiday weekends provide OHV riders an extended period of time to escape heavily populated metropolitan areas and travel to OHV areas to drive their vehicles on public lands. Capturing the frequency of this activity can enlighten managers on the spatial and temporal patterns of wash use, the associated environmental damage, and provide guidance on where and when to focus public education and law enforcement. The frequencies of washes with and without vehicle tracks were not different between open and closed wash zones during the New Year's holiday due to low visitor use. Weather may be a factor influencing the lack of detection of OHV activity in desert washes through longer time periods. For instance, rain fell consistently for three days providing some washes enough water to flow during the week of December 20-24, 2010. This surface flow of water was evident in some of the raked washes we visited following the New Year's holiday. In contrast, the lower frequency of wash use in closed versus open wash zones was pronounced during the early spring President's Day and Easter holidays. This pattern reveals an increase in the frequency of washes with tracks in open wash zones from President's Day to Easter while closed wash zones maintained a constantly low frequency of use during the same time period. This lower frequency of OHV activity is similar to that of pre-holiday visits, suggesting little change in wash use through time for these closed wash zones.

Our survey of dispersed washes – those that were randomly distributed without regard to their proximity to access roads – revealed low incidence of use and negligible difference in the frequency of OHV activity between open and closed wash zones. OHVs in the Chemehuevi DWMA do not appear to be straying far from road access, as many of our dispersed wash surveys occurred on average 0.99 km from road access (range = 0.03 km to 2.95 km). Trucks were the heaviest and largest of OHVs driven in desert washes and potentially cause the most damage to these ecosystems. Even though their weight is dispersed over four tires, the large mass of trucks has been shown to cause greater soil compaction than the same number of passes with a motorcycle (Adams et al., 1982; Webb et al., 2013). Washes with a high proportion of trucks in closed wash zones may be of concern, and methods of their deterrence should be considered. The closed wash zones are areas designated by BLM with input from the US Fish and Wildlife Service as critical habitat for the recovery of the desert tortoise, and the indirect effect of trucks, more so than ATVs and motorcycles, can cause the most damage to the tortoise and its habitat. However, any vehicle is capable of damaging tortoise burrows and especially injuring small tortoises.

The Chemehuevi DWMA is a large contiguous area that has a large proportion of high potential desert tortoise habitat (Nussear et al., 2009). Given our results, it is apparent that wash habitats near access roads in open wash zones are susceptible to greater incidence of visitation and greater wash degradation compared with washes farther from roads and therefore should be a high priority for monitoring and preventing the potential negative impacts of OHV activity. We developed a protocol that can be implemented by land managers to monitor wash use and wash condition based on ocular estimators and is available as supplementary online data (S1). Marginally greater tortoise activity for washes in closed wash zones (presence of burrows,

tracks, scat, live animals) indicates that OHV use in washes may negatively impact tortoise activity. Most studies involving desert tortoise surveys are of long duration (e.g. multiple years), are more intensive, or more extensive (e.g. kilometer-long transects) than our study. Therefore, our results should be considered carefully in this context. We suggest that a synthesis of the data generated from this study and from the US Fish and Wildlife Service Distance Sampling Program would provide results of a proper scale to answer questions at the level of the tortoise population (Swann et al., 2002). In the future, it will be worthwhile to consider a greater emphasis on the OHV aspect of this work and collaborations with tortoise-centric projects to make the most of both types of studies – individually and in collaboration.

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Tables

Table 1. The classification of washes monitored for OHV use in the Chemehuevi DWMA.

Width (m) ^a	Vegetation Clearance ^b	Terrain ^c	Channels ^d
Small (1-20)	Open (no to little vegetation)	Sandy-cobble (easy travel)	1
Medium (>20-39)	Partially obstructed (travel without vegetation damage)	Cobble-rocky (slow travel)	2-3
Large (>39)	Fully obstructed (travel with vegetation damage)	Rocky-boulder (difficult travel)	>3
		Impassable (unable to travel)	

^aRefers to the average distance between wash banks.

^bDescribes the amount of vegetation in the wash channel.

^dNumber of water flow channels within the wash system.

Table 2. Best models relating management and spatial attributes to the presence or absence of OHV tracks.

Model	K	$\Delta AICc$	Cum. Wt.
Status:Distance to OM ^{ab}	5	0.00	0.26
Status:Cost ^a	5	1.01	0.42
Status+Distance to OM ^{ab}	4	1.40	0.55
Status+Cost ^a	4	1.51	0.67
Intercept	2	6.97	0.98

^aStatus=Wash status (open or closed)

^bOM=Open maintained road

Table 3. Open and closed wash zone study area polygons providing the size of the polygons, the range of habitat potential index values, and the average index values for each polygon in Fig. 6.

Polygon	Wash Area Status	Area (km ²)	Range of Index	Average Index
1	Closed	2,372.8	0.2 – 1.0	0.82
2	Open	497.0	0.3 – 0.9	0.84
3	Open	63.3	0.7 – 1.0	0.89
4	Closed	237.4	0.4 – 0.9	0.79
5	Open	146.8	0.8 – 1.0	0.89
6	Open	184.6	0.3 – 0.9	0.73

Fig. 1. Study area. Chemehuevi Desert Wildlife Management Area (DWMA), San Bernardino County, California (CA) showing open and closed wash zones (DWMA status).

Fig. 2. Photo showing tracks of an OHV detected after a holiday weekend when it passed over the line drawn in the sand across a wash entrance.

Fig. 3. OHV tracks in washes. Number of washes with OHV tracks found during wash monitoring in open and closed wash zones. Pre-hol. = pre-holiday and post-hol. = post-holiday.

Fig. 4. Holiday use of washes. Number of washes with new OHV tracks following holidays in open and closed wash zones, N.Y. = New Year's, Pres. = President's Day (Thanksgiving was not analyzed due to low number of washes monitored).

Fig. 5. Types of OHV tracks in washes. Number of washes with different types of OHV tracks found during wash monitoring in open and closed wash zones. Some washes had more than one type of vehicle track present upon data collection. Pre-hol. = pre-holiday and post-hol. = post-holiday.

Fig. 6. Desert tortoise habitat index. Spatial representation of the predicted habitat potential index values for desert tortoise in Chemehuevi DWMA overlaid with polygons representing open and closed wash zones. Polygon numbers 1 and 4 are designated closed to OHV wash use, while polygon numbers 2, 3, 5 and 6 are designated as open wash zones. The habitat index indicates poor (blue) and best (red) desert tortoise habitat.