Mojave Desert land-use change: revisiting conservation values after a decade of growth and development

Michael J. Clifford[a], Sophie S. Parker[b], Brian S. Cohen[b], Elaine York[c], Joel Tuhy[c*]

[a] The Nature Conservancy, Nevada
[b] The Nature Conservancy, California
[c] The Nature Conservancy, Utah
[*] Retired

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Introduction

The Mojave Desert has some of the most intact landscapes in the Unites States (Randall et al. 2010) but has experienced rapid anthropogenic development since the 1990s, placing great pressure on wildlife and previously undisturbed land. Over the past three decades, sprawling cities such as Las Vegas, Nevada and St. George, Utah have become some of the fastest growing cities in the United States. In addition to the population growth within the Mojave Desert, adjacent urbanized regions have grown rapidly as well, particularly those in southern California and Phoenix, Arizona. The expansion and densification of urban regions in and near the Mojave Desert has led to an increase in human impacts in the region. Recreation opportunities in deserts adjacent to cities and infrastructure projects concomitant with development that require expansion to meet increased demands have greatly increased pressures on the Mojave Desert. For example, off-highway vehicle (OHV) use in desert land adjacent to cities is extensive. OHVs create large networks of roads, degrade and fragment habitat, and spread invasive species (Brooks and Lair 2005). Since 2010 there has been a substantial increase in utility-scale solar facilities and other proposed renewable energy projects in the American Southwest. Utility-scale renewable energy requires the expansion of transmission lines and roads, and large amounts of water are used for construction and maintenance (Grodsky and Hernandez 2020). The footprint of such facilities reduces the conservation value of Mojave Desert lands (Parker et al. 2018). The pressures of anthropogenic development are likely to increase as cities in the Mojave Desert continue to grow and as development extends further into the deserts. The additional pressure of climate change will also further stress wildlife and habitat and may force some species to attempt to shift ranges to a more appropriate climate space (e.g., Parmesan and Yohe 2003). However, shifts in species distributions may be blocked or disrupted by current infrastructure or planned infrastructure, making the addition of climate change in the planning process of future infrastructure projects more important.

The Mojave Desert, located in the Basin and Range Province, has large topographic and elevational variability, a small area of perennial surface water, and as a result of Pleistocene climate change, a high number of endemic, threatened, and endangered species, and isolated and unique ecosystems. Most human development and infrastructure projects are built in the flat and gently sloped valleys and bajadas, which are also the preferred habitat of the Mojave Desert tortoise (*Gopherus agassizii*). The desert tortoise was listed as a threatened species under the endangered species act in 1990. The desert tortoise requires large, intact landscapes with minimal disturbance and is highly susceptible to predators such as ravens and coyotes that take advantage of human infrastructure and food subsidies provided by human habitation (Kristan and Boarman 2003; Berry et al. 2010). While great conservation efforts have led to large-scale protections of desert tortoise habitat - additional habitat fragmentation from development, wildfires, and prolonged drought has led to a decrease in most desert tortoise populations over the past several decades (Allison and McLuckie 2018). Shifts towards more wildlife friendly designs of renewable energy facilities have begun (Wilkening and Rautenstrauch 2019), however data on the efficacy of such designs are still limited.

Understanding how the growth of the region has impacted conservation value is critically important for planning infrastructure and growth to minimize impacts to high value conservation lands. We revisited the 2010 Mojave Desert Ecoregional Assessment with imagery collected eight years after the original data were collected and analyzed. We focused on understanding the patterns and intensity of disturbance in two locations, southern Utah and the Piute-Eldorado Valley, Nevada. The time from 2010 to 2018 was a period of rapid population growth for Las Vegas, Nevada and St. George, Utah as the regions recovered from the Great Recession of the late-2000s and a housing-boom began in the mid- and late-2010s. Additionally, state mandates and changes in energy portfolios shifted Nevada towards increasing renewable energy development to meet carbon emission standards, resulting in the building of utility-scale renewable energy facilities in the Mojave Desert.

Methods

Study areas were selected based on their proximity to development and an understanding of qualitative degradation of conservation values and increased land-use impacts – and general interest in the direction of conservation values of each area over the past 10 years. Our first study area, Southern Utah and the adjacent basin in Nevada and Arizona were selected due to the recent population growth of the region and a better need to understand how rapid development has changed conservation values during the past decade. We selected the Piute-Eldorado Valley in southern Nevada as our second study area because of its partial status as an Area of Critical Environmental Concern (ACEC), high population of desert tortoise, proximity to the Las Vegas Metropolitan area, and potential location for large-scale renewable energy facilities to be built. Both study areas encompass all or parts of the Upper Virgin River, Northeastern Mojave, and Eastern Mojave Desert Tortoise Recovery Units established by the US Fish and Wildlife Service.

To quantify change in conservation value, we used conservation values classified on 2.59 km^2 (1 mi^2) hexagonally shaped planning units (HPUs) from Randall et al. 2010 to identify changes on the landscape occurring between 2010 and 2018. To understand how land-use and development changed between 2010 and 2018, we used 1 m^2 NAIP imagery collected in 2018. Imagery from 2018 was compared to imagery collected in 2010 at each HPU to classify conservation values. A set of decision rules determine how a HPU was classified (Table 1). To classify HPUs, between four and five experts visually inspected each HPU and compared imagery from 2010 to 2018. Based on the set of decision rules these experts agreed if the HPU had changed in the intervening years. If the criteria were met, the HPU was either upgraded or downgraded in its conservation value (for complete methodology see Parker et al. 2018).

Results and Discussion

We examined 1655 HPUs in the Southern Utah area and 604 HPUs in the Piute Eldorado Valley area and downgraded a total of 46 HPUs (Table 2). No HPUs were upgraded in conservation value. The Southern Utah area had 25 downgraded HPUs, or 1.5% of the area examined, which was 64.74 km^2 of 4,286 km^2 of the study area (Figure 2). However, in this study area there are several areas of designated wilderness, conservation areas, and public lands where development is prohibited, and conservation values were expected to not change. When examining only areas that can be developed under land-use management plans (e.g., non-wilderness and non-conservation areas) 13.2% of the landscape was downgraded. Most of the downgraded HPUs in Southern Utah were from increased infrastructure (e.g., building of new roads, airport expansion) or from expansion of residential areas. Some residential expansion occurred in moderately degraded HPUs, which was either the growth of subdivisions or conversion of agricultural lands to residential housing.

In the Piute-Eldorado Valley, we examined 604 HPUs and 21 HPUs (3.4% of the landscape) were downgraded. This was 54.39 km^2 of change in the 1,564 km^2 study area. No HPUs were upgraded in conservation value in the Piute-Eldorado Valley. Similar to the Southern Utah study area, some of the Piute-Eldorado Valley has been designated for conservation (e.g., wilderness, National Conservation Areas, etc.) and is undevelopable. When examining the lands that could potentially be developed (i.e., excluding lands designated for conservation), 10.2% of the developable lands were downgraded. Areas were downgraded because of utility-scale renewable energy projects and the building of a new interstate. Conservation value declined in the Piute-Eldorado Valley because of large infrastructure projects.

The two study areas differed in their location to major cities. The Southern Utah study area encompassed the entire St. George metropolitan area, while the Piute-Eldorado Valley study area was adjacent to the Las Vegas metropolitan area. It is likely both cities followed similar patterns of development, with expansion at the edges and infill of the interior. However, our analyses only captured the edge of development of Las Vegas. Areas adjacent to the cities held the majority of the downgraded HPUs. Additionally, a major source of conservation downgrade within the Piute-Eldorado Valley study area was from utility-scale solar facilities. Utility-scale solar is restricted in growth in the Piute-Eldorado Valley and the expansion we observed between 2010 and 2018 filled most of the area designed for solar, however other land managed by the Bureau of Land Management throughout southern Nevada are not restricted and solar permits are reviewed on a case-by-case basis.

From 2010 to 2018 the rate of conversion was approximately 14.8 km^2 per year. To reduce future losses of conservation value, particularly lands in unprotected areas, foresight should be used in the development of city plans, infrastructure planning, and land-use plans – particularly with the recent interest and policy aimed at reducing greenhouse gases and electrifying/greening the energy sector. Developing infrastructure using a “smart from the start approach” or “development by design” can greatly reduce conflicts with wildlife, reduce habitat fragmentation, and lower development footprints. Since the late 2000s, most utility-scale solar development in the Mojave Desert of Nevada has ranged in size from 3,000 to 7,000 acres and has been sited on undisturbed public lands. Energy development and the infrastructure serving energy developments can be preferentially sited on brownfields and other disturbed sites to reduce loss of conservation value and keep ecosystems intact (Wu et al. 2019). Additionally, many transmission lines can be placed underground to reduce predation corridors associated with transmission lines.

We did not examine the role of fire in this analysis or how burned areas may impact conservation value in our study areas. However, conservation value is likely negatively impacted by repeated fires over short time periods (e.g., Drake et al. 2015). Shrub dominated ecosystems in the Mojave Desert historically have long fire return intervals (Brooks et al. 2013), and post-fire succession is slow in most Mojave ecosystems (Abella 2009). The colonization of most ecosystems by invasive annual plants during the past century have increased fire frequency and size in some parts of the Mojave Desert (Brooks at al. 2004). Further, landscape-scale restoration efforts in the Mojave Desert have low success at restoring the previous plant assemblage and shrub cover and become increasingly dominated by invasive annual plants (Brooks et al. 2013). Low restoration success has not allowed land managers to increase post-burn conservation values, particularly for desert tortoise, on areas burned multiple times. Future inclusion of burned areas and times burned in this analysis will likely yield an even greater loss of conservation value, particularly in the Southern Utah study area where fires have been common over the past 20 years.

Conclusion

Human populations and land-uses within the Mojave Desert region are expanding. This expansion has contributed to an intensification of public land uses, and a rapid conversion of private lands. Due to these changes, over a 10-year period, over 10% of the non-protected lands in our study areas experienced a downgrade in conservation value. Because land-use changes stem from different activities in different regions of the Mojave Desert, and because the distribution of species is uneven, some desert organisms are more likely to be negatively impacted by continued land-use change. Tracking land-use changes over time is the first step towards understanding the conservation challenges faced by desert species – before these challenges become overwhelmingly difficult to address.

Table 1. Decision rules for classifying hexagonal planning units (HPUs) during the analyses. Decision rules were used from Parker et al. (2018).

Conservation value	**Designation Rule**
Ecologically Core	-Highest conservation value, largely undisturbed and unfragmented -Supports conservation targets -Adjacent to other Ecologically Core cells
Ecologically Intact	-Relatively undisturbed and unfragmented -Not adjacent to Ecologically Core cells -Adjacent to four Moderately Degraded cells -Adjacent to one Highly Degraded cell
Moderately Degraded	-25% to 50% of land within cell has been disturbed or degraded
Highly Converted	-Lowest conservation value ->50% or more of land within cell has been disturbed or converted

Table 2. HPU downgrade for both study regions and reasons for downgrades.

Location	**Reason for downgrade**	**EC to HC**	**EC to MD**	**EI to MD**	**MD to HC**
Southern Utah	Agricultural expansion				1
	Industrial expansion				1
	New road		10		
	Airport expansion	1	1		
	Residential expansion	1	2		8
Piute-Eldorado Valley	Interstate expansion				5
	Solar development			5	11

Figure 1. Location of the study areas in the Mojave Desert. A) is the Piute-Eldorado Valley study area and B) is the Southern Utah study area.

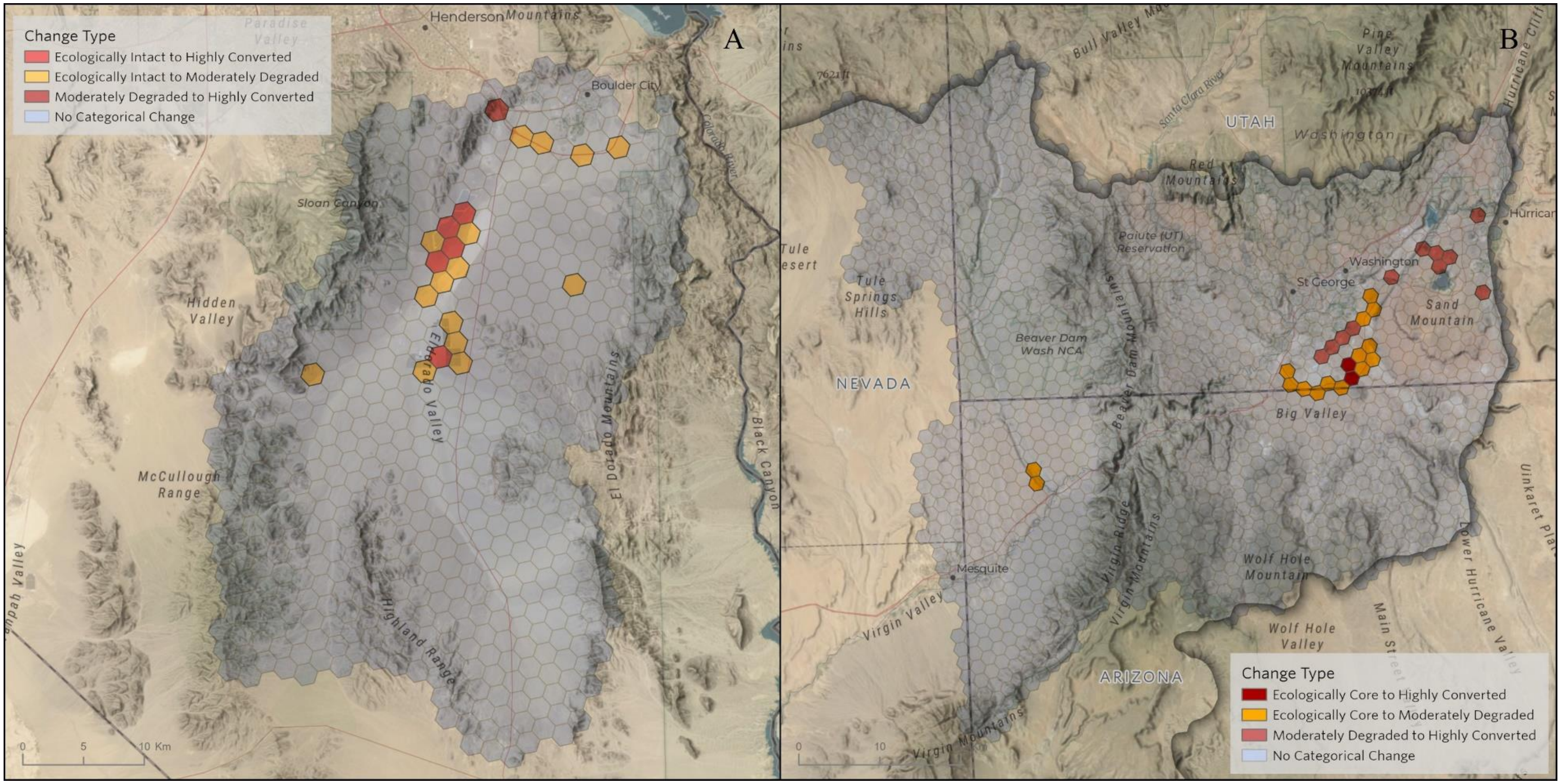

Figure 2. Map of the study areas A) Piute-Eldorado Valley and B) Southern Utah study areas. Colored HPUs highlight changes in conservation value between 2010 and 2018.

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