ECOLOGY OF THE CALIFORNIA DESERT

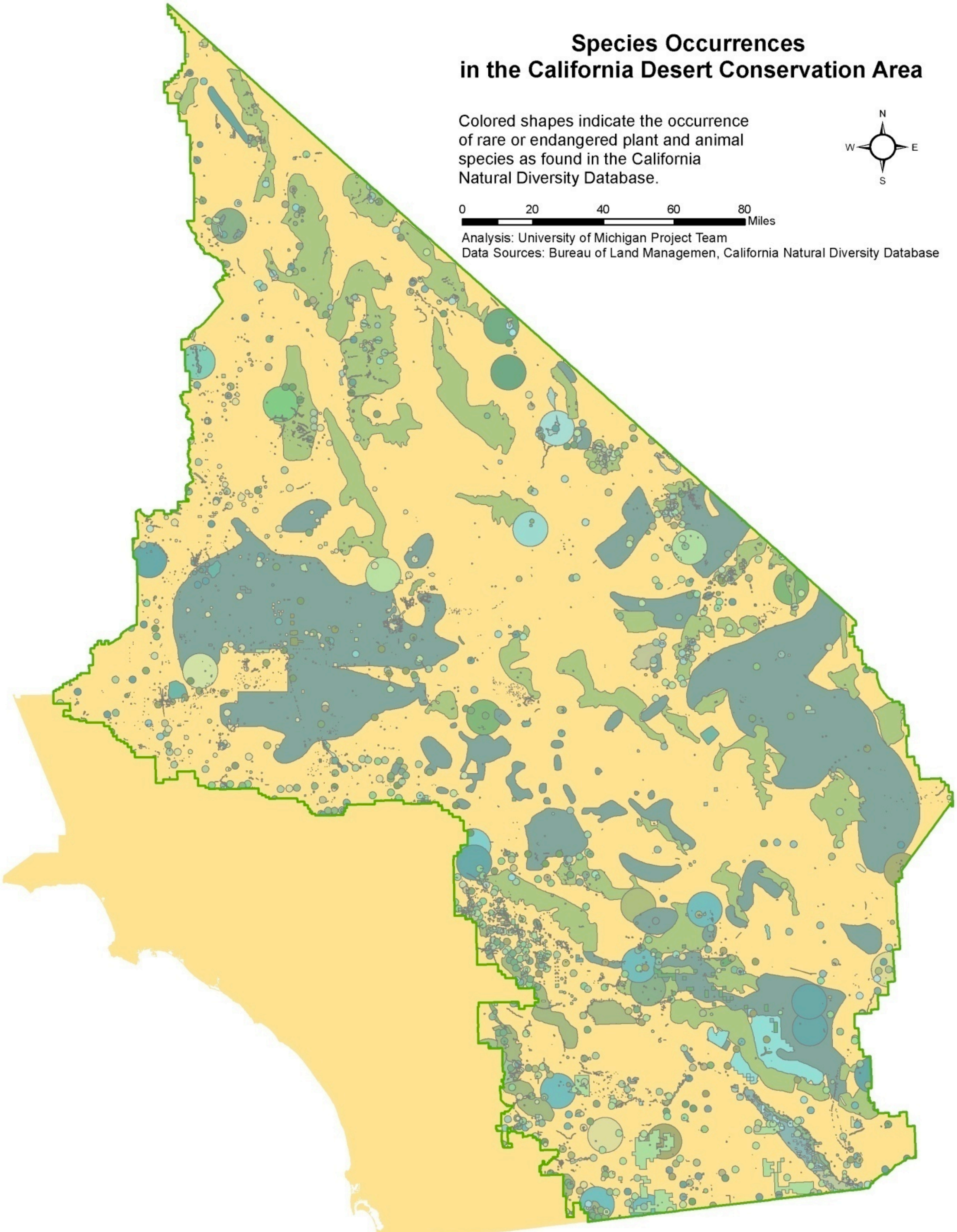
As can be seen from the land management designations described above, there are several ecologically important habitats and species found throughout the CDCA. Severe aridity, extreme temperatures, intense sunlight, and high winds create a harsh environment for life in the California desert. Biological diversity can persist due, in part, to complex and interconnected ecological processes that sustain these ecosystems. Climate drives regional and local weather patterns, determines seasonal temperatures, frequency and size of precipitation events, and wind patterns. These processes in turn drive plant productivity and nutrient cycling. Geomorphology and desert landforms (e.g., mountains, alluvial fans, ephemeral streams, sand dunes) directly affect water infiltration, run-off, erosion, storage, and salt accumulation, as well as soils and nutrients.[1] Wind, water, and biota interact with soil through processes of erosion, deposition, bioturbation, and compaction, making it more or less suitable for desert life.[2] Wind patterns, wind erosion, rainfall, water erosion, and water distribution are critical processes that shape the structure and dynamics of desert ecosystems. The sum of these processes determine if, where, and what biodiversity can persist. Impacts to these processes can result in fundamental changes to the ecology and biology of the California desert.

Rare and Endangered Species

Many of the species in the California desert are endemic, either due to evolution or isolation, and are adapted specifically for this type of bioregion.[3] It would be a misconception to consider deserts devoid of life; in fact the bioregion's extreme landscape and climatic characteristics prove to be important drivers of species evolution. There are over 2,400 native plant and animal species in the California desert, and no less than 72 species are endemic to the California desert, 40 of them specifically to the California expanse of the Mojave.[4] Many of the species in this region are considered rare or at risk (Map 2.4).

Sand Dune Systems

Sand dune systems are microcenters for biodiversity (Figure 2.1).[5] The dynamic nature of sand dune systems forces evolution of unique adaptations that allow them to survive in sand dune habitat; consequently, dune species are ill adapted for survival outside of dune habitat.[6] For example,



Map 2.4 Rare and Endangered Species Occurrences in the CDCA. Different colors represent different species.

Figure 2.1 Tracks in a Sand Dune System. Image Credit: Sarah Tomsky.

psammophiles (plants restricted to active dunes) produce large seeds with larger food reserves than non-psammophiles, allowing psammophile seedlings to emerge even when deeply buried by sand.[7] However, the production of large seeds restricts the number of seeds that a plant can produce, making it more difficult for large-seeded psammophiles to compete in non-dune habitat where the production of smaller, more numerous seeds may be advantageous. Cameron Barrows, a researcher for the Desert Studies Initiative, notes:

> "Sand dunes are incredibly difficult places to live if you're a plant or an animal because the surface of the sand is constantly moving, almost on a daily basis – certainly on a weekly basis. So if you're a plant you're always in danger of having your habitat being eroded out from underneath you or being dumped on top of you, and if you're a small mammal or a small animal of any kind the same thing is true. If you burrow into the sand you're going to get buried, if you burrow in the sand you might get eroded away – so they have to be able to deal with a high level of dynamics. All of the adaptations that enable them to do that (there is a fascinating array of adaptations that both the animals and plants have) don't function at all off of the sand dunes, so they are less competitive when they get off the sand dunes. As a result, most of the species that evolve on sand dunes are unable to move very far distances in between sand dunes. There's not a huge list, but virtually every sand dune system in the warm desert areas of the desert southwest there is at least one endemic plant, at least one endemic beetle, usually another endemic species of arthropod, and often an endemic lizard, and very often the list is much longer than that. In larger dune systems you can have a dozen or more species that are only found on that dune system, and in some cases only one or two of them have been identified so far."

The evolution of unique dune adaptations is evident in the array of dune-endemic or dune-restricted species, such as the flat-tailed horned lizard (*Phrynosoma mcallii*), desert kangaroo rat (*Dipodomys deserti*), Peirson's milk-vetch (*Astragalus magdalenae* var. *peirsonii*), and Hardy's dune beetle (*Anomala hardyorum*). These species and many others are dependent on wind to transport sediment to and from these habitats. The loss of these transport processes could result in the extirpation of dune endemic species and the habitat on which they depend, as well as jeopardize the continued existence of critical habitat for threatened and endangered species, such as the Coachella Valley fringe-toed lizard (*Uma inornata*).[8]

One of the greatest threats to the persistence of sand dune systems is the interruption of the sand transport processes. Because sand dune systems rely on sources of sediment and the availability of wind to transport that sediment, interrupting either of those processes can modify the influx of sediment to an area and therefore alter the balance between sediment deposition to the dunes and sediment transport away from the dunes. Sand transport processes can be interrupted by urbanization and housing development, agriculture, wind breaks, and other structures that prevent sediment deposition or create barriers to natural wind movement.[9,10]

Watercourse modifications can also interrupt aeolian processes. One study found that modification of river channels within the Coachella Valley reduced the amount of sediment deposited in the valley during flood events, which reduced the amount of sediment available for transport by winds to replenish dune sediments.[11] The reduction in deposited sediment resulted in the accelerated reduction, degradation, and stabilization of the major active dune habitat in the Coachella Valley.[12]

Dust Emission

Though often overlooked, the storage, release, and transport of dust play significant roles in ecosystem processes, at scales that range from site up to global scales.[13] Some dust particles are small enough to travel long distances (even up to hundreds of kilometers in one wind event), carrying soil nutrients and organic matter to areas of deposition.[14,15] Dust from the Mojave Desert has been documented in areas as far west as California's Channel Islands, and as far east as the Colorado Plateau.[16] The soil fertility of source and sink areas can therefore be impacted by wind erosion that serves to deplete source areas of nutrients, while delivering it to deposition sites.[17] Wind erosion and dust emission therefore play a role in nutrient cycling across landscapes and ecosystems (both terrestrial and aquatic).

Several biotic and abiotic factors control both the sequestration and the emission of dust. The accumulation and sequestration (or storage) of dust at a particular site depends on the rate of supply from the origin, vegetative cover at the end point, wind speed, air turbulence, and rainout during transport.[18] Dust emission is a function of wind turbulence (which fluctuates with meteorological conditions), the ability of surface materials to resist erosion (controlled by particle size, soil moisture, and soil crusting), and the amount and type of vegetation at the point source.[19]

In addition to influencing ecosystems, dust emission can negatively impact human health through particulate matter (PM10) pollution (particulate matter that is less than 10 microns in diameter). The U.S. Environmental Protection Agency (EPA) lists the major concerns for human health from exposure to PM10 air pollution as effects on breathing and respiratory systems, damage to lung tissue, cancer, and premature death.[20] The EPA warns that the elderly, children, and people with chronic lung disease, influenza, or asthma, are especially sensitive to the effects of particulate matter.[21] In the Coachella Valley, PM10 pollution has been linked with death from cardiorespiratory complications and mortality in individuals older than 50.[22]

The contribution of windblown dust to PM10 air pollution has been well-studied in relation to Owen's (dry) Lake, California. Windblown dust erosion off of the dry lake bed can cause 24-hour average PM10 concentrations to exceed 12,000 μg m^{-3}; federal air quality standards require the PM10 concentration to be below 150 μg m^{-3}.[23]

Three Controls of Dust Emission in the Desert

1. Soil moisture binds soil particles together, making the surface more resistant to erosion.[24] Arid regions, therefore, are more prone to dust emission, and climate change-induced temperature increases (leading to increased evaporation), compounded by expected decreased precipitation, may boost dust emission from California's desert regions.

2. Soil crusts help buffer the effects of wind erosion; studies indicate that lichen/moss biological soil crusts are the most resistant of desert soil types to wind erosion (on par with desert pavements).[25] However, the ability of soil crusts to withstand erosion is drastically decreased when disturbed; they are particularly susceptible to disturbance in dry conditions, becoming easier to crush when trampled.[26] Several studies have shown that sediment loss increases dramatically as these surfaces are disturbed, and more severe types of disturbance (especially those that have higher downward compressional force – such as impaction of heavy vehicles driving over them) can also increase dust emission.[27, 28]

3. The presence of vegetation across a potential dust source area can also act as a control for emissions. Plants act as a protective cover, decreasing the ability of wind to reach the desert surface and therefore inhibiting wind erosion. As cover decreases, and unvegetated gaps increase in size, the surface becomes more vulnerable to erosion and sediment loss.[29] Plant type may also play a role in the level of protection provided by vegetation; in a 2009 study of sites in the Mojave Desert, Urban et al. showed a negative correlation between dust emission and the presence of annual plants, which offer dense cover and may continue to act as protection even after death.[30] In addition to decreased soil moisture and increased soil crust vulnerability, climate change threatens the role of vegetation in the California desert as a dust control as well, since dryer and hotter conditions may reduce plant cover and therefore erosion resistance.

Biological Soil Crusts

The name "biological soil crust" is derived from the fact that living organisms, primarily cyanobacteria, bind the surface of the soil together, forming a cohesive crust.[31] Biological soil crusts are common in ecosystems with high light input on the surface of the soil, including arid ecosystems like the California desert; up to 70 percent of soil surface may be covered by biological soil crusts in desert regions (Figure 2.2).[32, 33] In recent decades, the importance of these crusts to ecosystem functioning has been increasingly understood and highlighted in scientific journals. In arid ecosystems, biological soil crusts enhance soil stability, fertility, and erosion resistance, in addition to controlling water infiltration, surface albedo, and carbon sequestration.

Figure 2.2 Soil Crusts, Mojave National Preserve. Image Credit: Sarah Tomsky.

Hydrology

Water infiltration is an essential process that enables desert plants, especially plants whose roots do not reach the water table, to capitalize on rare and variable precipitation events.[34] By physically slowing down vertical and horizontal water movement, plants can improve water infiltration in arid ecosystems and create microhabitats more suitable for their own survival.[35] Plant stems and foliage break up raindrops, with water both flowing down the stems and into live root channels into the soil, and dripping more slowly off of foliage.[36] By slowing down precipitation, plants increase water infiltration into the soil. Vegetation patches can also slow the horizontal movement of water by obstructing runoff and storing that water as runon.[37] In a 2005 study by Ludwig et al., the authors found that by trapping water runoff, vegetation patches enhanced plant growth.[38] Increased plant growth could lead to increased seed and biomass production, creating greater plant densities within a vegetation patch, and a greater ability of the vegetation patch to trap water, resulting in a positive feedback cycle.[39] Ludwig et al. found that vegetation patches also encouraged more active soil macroinvertebrates (e.g. termites, ants, and earthworms).[40] Macroinvertebrates and plant roots move and mix the soil through burrowing and excavating, root penetration and decay, in a process called “bioturbation.”[41] The spaces, or macropores, generated by bioturbation can improve water movement and infiltration through the soil.[42, 43]

In addition to altering the movement of water across the landscape, plants affect soil moisture by modifying the microclimate beneath and around them. In a 1998 study by Breshears et al., the authors found that during the summer season in a semiarid ecosystem, soil beneath the canopies of woody plants had temperatures that were as much as 10 degrees C lower than soils that were not beneath their canopies.[44] These lower soil temperatures substantially reduced soil evaporation rates and loss of soil moisture.[45]

Figure 2.3 49 Palms Oasis, Joshua Tree National Park. Image Credit: Sarah Tomsky.

Aquatic habitats in deserts include pools, rivers, springs, and seeps (Figure 2.3). Fed by subterranean freshwater aquifers, they support a variety of sensitive and rare species due to their relatively low occurrences in arid regions. Desert springs are just one example of a rare aquatic habitat; they are seldom encountered in arid ecosystems and their distribution is scattered.[46]

Habitat Connectivity

Habitat connectivity is considered to be one of the most important factors in maintaining biological diversity.[47] Maintaining gene flow is essential for genetic fitness, allowing for evolutionary adaptation to environmental changes or pressures. Many conservation initiatives are focused on maintaining connectivity, particularly when increased urbanization threatens to fragment habitats. For some species with limited range, especially reptiles and small mammals, the loss of habitat itself threatens population viability, particularly if species cannot migrate to suitable replacement habitat.[48] Maintaining connectivity allows limited-range species to make small spatial shifts in habitat to adjacent patches if populations experience loss of home-range habitat. For larger species, particularly those with a wide range like bighorn sheep, connectivity is required across a much larger swath of the landscape.[49] Resources are dispersed across a broader geographic scope, and gene flow often occurs between smaller populations within a metapopulation. This gene flow is important to avoid inbreeding depression.

In 2000, several conservation and research organizations participated in a workshop for the purpose of identifying “linkages” between important core habitat areas across the State of California.[50] Maintaining or reestablishing connectivity between these core areas is seen as critical for protecting the state’s biodiversity. Within the Mojave Desert ecoregion, the group identified 37 linkages, utilizing information on several species (including mammals, birds, amphibians, and reptiles).[51] Importantly, the group also identified primary barriers to migration, with highways and major roads accounting for nearly 70 percent of the existing barriers.[52] As urbanization increases in the California desert, maintaining connectivity and mitigating existing barriers to migration are considered a conservation priority. In the face of climate change, which may require species to move in response to habitat range shifts, connectivity to potential future habitats will be essential for adaptation.

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Chapter 2

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