THE ROLE OF BIODIVERSITY IN THE HYDROLOGICAL CYCLE

The Case of the American Southwest

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INTRODUCTION

The progressive biodiversity loss caused by human population growth and the associated economic activities is aggravated by climate change, particularly in semi-arid areas such as the Southwestern United States **(Figure 1)**.

Changes in water availability and temperature in arid and semi-arid areas can rapidly have significant impacts on species composition, distribution and density, because the organisms living in operate very close to their physiological limits. In turn, the number and types of species that inhabit a region determine the organismal traits that influence the functioning of local ecosystem processes, including the hydrological cycle.

Composition and properties of the soil are among the main factors that affect the cycle of water and, therefore, any organism that modify the characteristics of the soil will have an impact on the hydrological system.

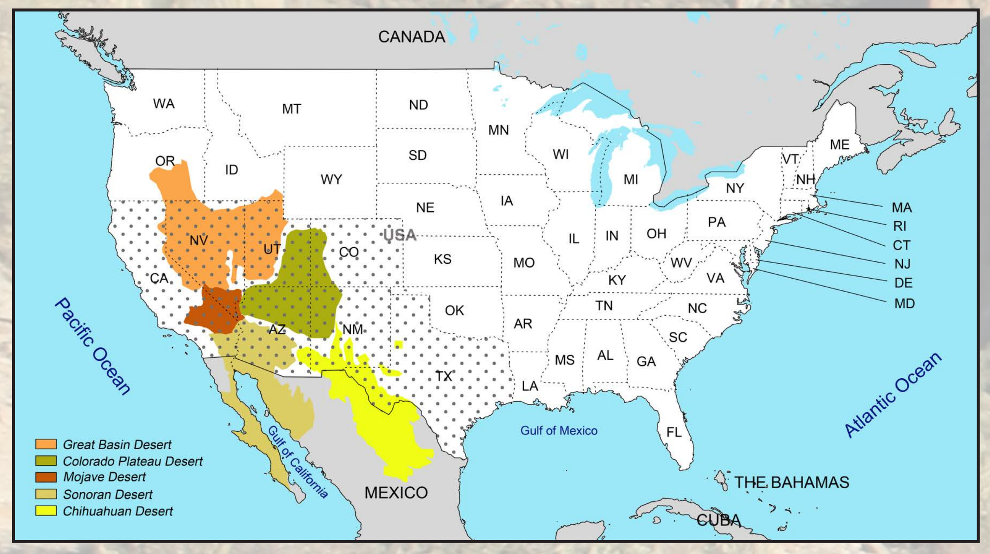

Figure 1. Main deserts of North America. Dotted area: states that form the American Southwest.

BURROWING RODENTS & THE WATER CYCLE

Small burrowing rodents such as ground squirrels, prairie dogs, marmots, kangaroo rats, and pocket gophers are the among most important bioturbators in the desert landscape of the Southwest. They modify the soil by the construction of burrows **(Figure 2 & 3)**, which are composed of several entrances, mounds (i.e., accumulated soil deposited as a result of the burrowing activity), tunnels, branches used for foraging, and chambers used for nesting, food storage and fecal mater deposition.

Burrows affect the dynamics of the water at different levels. They may act as subsurface pipes, redistributing the water throughout the horizon. When they are connected downslope to the ground surface or to a seepage face, they can act as local conduits for lateral flow providing an important control on runoff generation. Mounds can act as barriers to runoff. Moreover, the mixing of the soil during the construction activity may increase the water infiltration into the soil.

Furthermore, animal burrows can provide plants with a direct source of water (by maintaining higher water conductivity in the undercanopies and by promoting deeper percolation of water) and nutrients (organic material stored in the chambers), which in turn may increase vegetation density, thereby further modifying the infiltration characteristics of the soil.

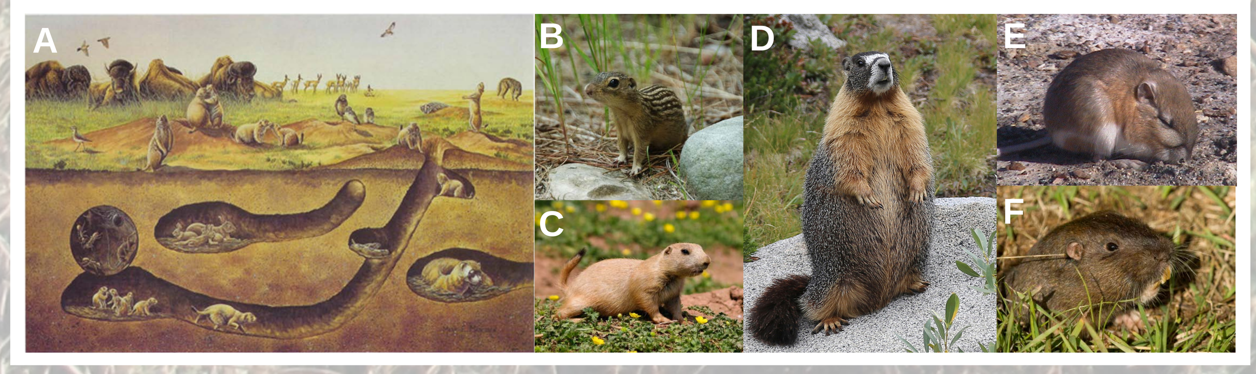

Figure 2. A: Cross section of a prairie dog burrow ; B: Ground squirrel; C: Prairie dog; D: Marmot; E: Kangaroo rat; F: Pocket gopher

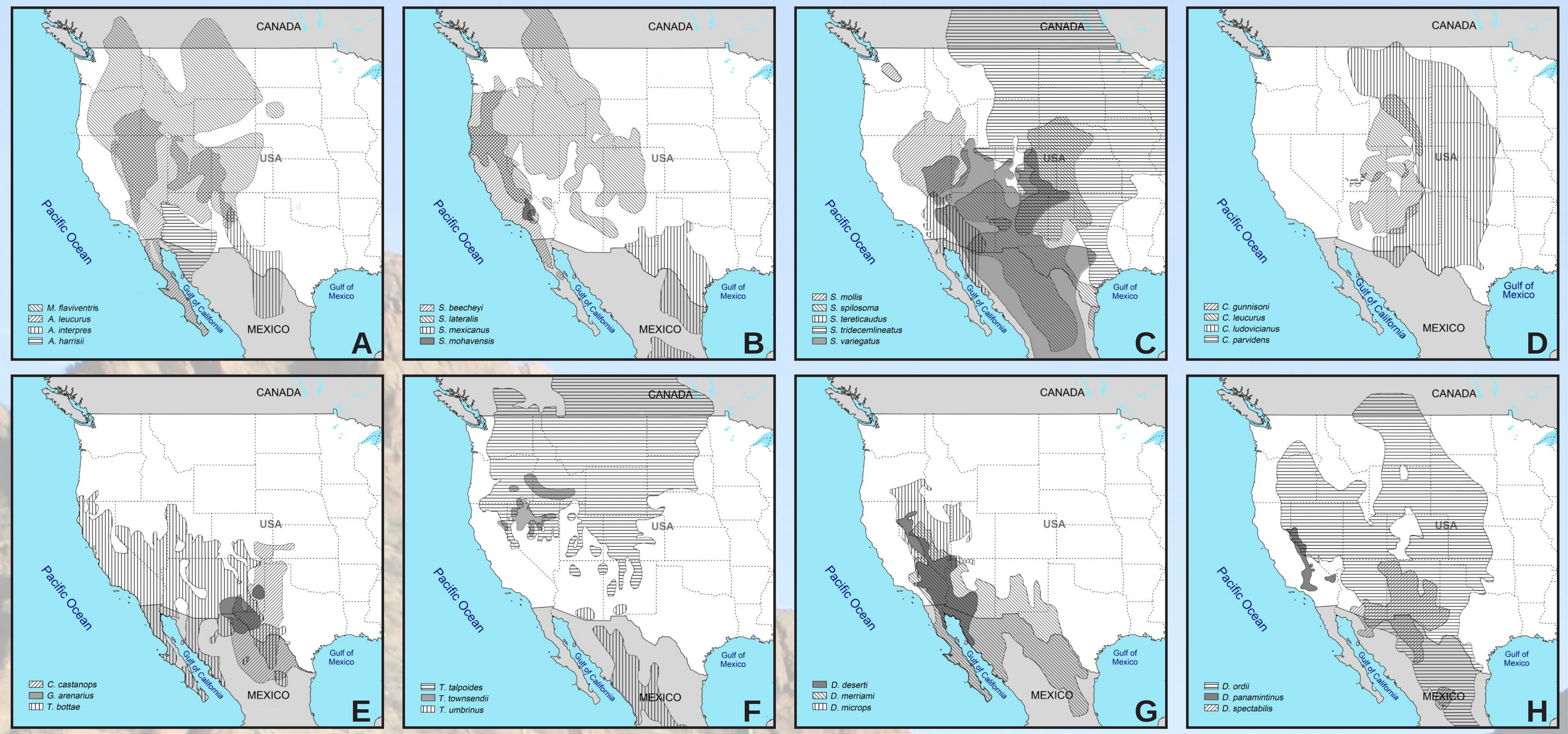

Figure 3. Distribution maps of marmot, *Marmota flaviventris* (A), ground squirrels (A, B, C), prairie dogs (D), pocket gophers (E, F), and kangaroo rats (GL, H).

RESEARCH ON BURROW SYSTEMS & HYDROLOGY

Research of the effects on burrowing rodents on hydrological processes is extremely scarce. The relative impact of burrowing rodents on the hydrological system in the deserts is difficult to estimate because it depends on the structure of the burrows (complexity of the burrows, depth and diameter of the tunnels, size of the mounds, and extent of mounds across the landscape). In turn, the burrow structure varies with both the species and the characteristics of the soil. Moreover, the density of the species is positively correlated to the degree of the bioturbation.

To know which group of species would have more impact on the hydrological system as a whole is challenging. Most likely each species will have a different kind of impact on infiltration, runoff or percolation:

A rough calculation of the maximum volume of water per unit area that can be held in the burrows in case of flooding can provide context for the potential impact of burrowing mammals on hydrologic response. Assuming that the tunnels of the burrows have cylindrical shape, and using their length and diameter, and the density of burrows per area unit as input variables, we can estimate that the water held in the burrows' system can be as low as 0.80 ft^3/ac (55.65 l/ha) in the case of the pocket gophers or as high as 589.77 ft^3/ac (41,240.57 l/ha) for prairie dogs **(Table 1)**. This water has the potential to infiltrate or contribute to subsurface runoff, but its behavior will depend on several factors that would require a site-specific assessment.

To more precisely know how burrowing rodents influence the water dynamics in the desert soils of the Southwest, additional research is necessary to:

- Quantify the population density of these species in the deserts of the southwest.
- Better characterize burrow systems and quantify burrow densities in the deserts of the Southwest (including burrow length, depth, diameter, volume, mound characteristics, etc.)
- Conduct research on water dynamics in burrow systems, to determine how burrows influence variability of soil moisture in space and time.
- Study the population trends and conservation needs of these species, because declines in burrowing rodents can have cascading effects throughout the ecosystems in which they occur.

Table 2. Burrows/mound measures for the different groups of burrowing rodents' species inhabiting the deserts of the Southwest.

Species Gropus	Burrow's cross section area (inches²)	Tunnel length (feet)	Tunnel depth (inches)	Mound Diameter (inches)	Mound height (inches)	Total Volume per area (feet³/acre)	
						min	max
Ground squirrels	3.05 – 12.69	0.33 – 138	1.97 – 72	36 – 590 .55	6 – 39.37	12.22	42.80
Marmots	26.23 – 68.44	12.47 – 14.44	15.75 – 64	NA	NA	1.06	76.91
Prairie dogs	7.79 – 61.65	9.35 – 108.27	7.87 – 196.85	24 – 240	6 – 39.37	181.06	589.78
Pocket gophers	3.05 – 19.63	31 – 341	3.11– 51.97	7.87 – 60	1 – 12.50	35.77	54.45
Kangaroo rats	1.91 – 21.24	1.64 – 104.99	0.66 – 134.19	2.6 – 248	3.94 – 48	0.80	3.27

RODENTS & ECOSYSTEM SERVICES

Besides being important to the water cycle, burrowing rodents provide a host of other ecosystem services **(Figure 4)**:

- Increasing soil organic matter and inorganic nutrients by soil mixing and urine and fecal deposition around mounds.
- Increasing soil stability.
- Increasing soil productivity.
- Increasing storage of atmospheric carbon in grasslands
- Providing habitats for other animals
- Serving as prey for predators such as raptors, canids, felids, herpestids, mustelids, and some snakes
- Enhancing seed capture, seedling germination, recruitment, and plant diversity via foraging tunnels and food storage chambers.
- Redistribution of soil surface contaminants in the soils, such as lead (Pb). Burrowing rodents decrease Pb transport time through the soil profile as a result of soil mixing, reducing the amount of Pb that arrives to the groundwater.

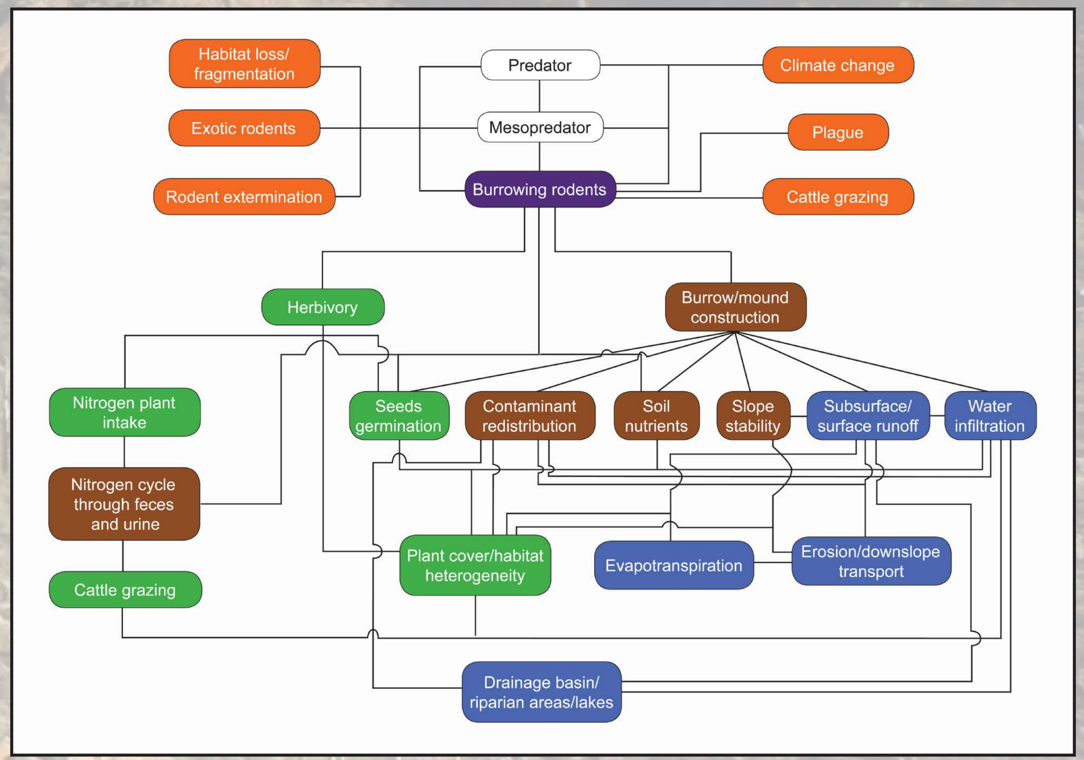

Figure 4. Conceptual diagram of anthropogenic effects on burrowing rodents and their geomorphic effects on the water cycle.

CONSERVATION

Although burrowing rodents are important for ecosystem services, humans have negatively impacted most of their species. The primary threats are: direct extermination of the individuals (trapping, shooting or poisoning), habitat loss/ fragmentation, introduced species, disease, cattle grazing, plague, and climate change.

In order to preserve this important component for ecosystem services measures need to be taken:

- Educational plans on the diverse ecological roles of these species are need in order to change public opinion, address misconceptions, and reverse government policies that continue eradication programs.
- The introduction of several species on conservation lists is needed to put in place conservation plans focused on increasing the population densities when possible. Until now, only few species have been listed as threatened, vulnerable or endangered by the Endangered Species Act (ESA) and/or the International Union for Conservation of Nature (IUCN) Red List of Threatened Species.
- Re-introduction plans when necessary. Conservation plans are preferable to reintroduction plans, as the latter are intensive, costly, and small-scale.