

## Threats to Sky Island Communities of Southeastern Arizona

**Patti Baynham**

Boyce Thompson Arboretum  
37615 E Highway 60  
Superior, AZ 85173  
pbaynham@cals.arizona.edu

### Introduction

Islands are traditionally defined as relatively small, isolated areas surrounded by water. In a broader sense they are isolated areas surrounded by any dissimilar environment. Sky island, sometimes referred to as mountain island, is a name given to freestanding inland mountains. Tenets of the theory of island biogeography, based upon oceanic island studies by Robert MacArthur and E.O. Wilson, also apply to the flora and fauna of sky islands.

Approximately twenty sky island regions have been identified around the world (Warshall 1994). They can be classified according to origin, in a manner similar to that used for oceanic islands. For example, some sky islands were originally part of nearby mountain ranges (i.e., continents) but have separated from the primary range over time. Some formed initially on the outer fringes of major ranges, never having been connected but sharing many common elements of origin. Other sky islands were formed independently from any large mountain system, erupting or being thrust upwards near geologic hot spots, and are typically more remote from other ecosystems of similar elevation.

### Biogeography of the Madrean Archipelago

The Madrean archipelago, to which Arizona sky islands belong, is classified as a stepping stone chain. It links the Rocky Mountains, on its north end, with the Sierra Madres of Mexico to the south (Warshall 1994). In central Arizona, the Mogollon Rim marks the southernmost edge of the Rocky Mountains and Colorado Plateau (Skroch 2008). This region is characterized by temperate-zone, ponderosa pine forests. Just over 100 miles into Mexico, the Sierra Madre Occidental range is home to subtropical parrots and pine forests, but it tapers down to its northernmost extent about 150 miles south southeast of Tucson.

Shifting from the north-south axis to an east-west focus, another important convergence significantly increases biodiversity of the Madrean archipelago (Figure 1). This region is situated directly between the Sonoran Desert on the west and the Chihuahuan Desert on the east (Skroch 2008). Flora unique to the Sonoran Desert include its signature saguaro cactus, in addition to mesquite, palo verde, acacia, and ironwood trees (all legume trees). The Chihuahuan Desert is at a higher elevation. It includes many different shrubs and more grasses but does not typically have trees. Approaching each other near the lowest point in the North American continental divide, crossover of species between the two deserts does sometimes occur.

Roughly forty islands make up the sky islands of Arizona (Figure 2), with Mount Graham being the tallest peak (10,712 feet) and summit to valley elevation changes ranging from 1,250 feet to 6,750 feet (Warshall 1994). This high number of islands within

the system is just one of many features that make the Madrean archipelago unique from a global perspective.

### Island Biodiversity – Species Richness

A bimodal precipitation pattern contributes to much greater plant diversity in southeast Arizona than would otherwise be expected, but several additional factors complement each other to make the Madrean archipelago a hotspot for biodiversity in southwest North America (Poulos *et al.* 2007). On one of Arizona's sky islands researchers have documented the presence of more than half of all bird species known to exist in the United States (Figure 3) (Skroch 2008). The region's position between and near two "continents" (i.e., mountain ranges) provides two sources for ongoing species introduction, which raises the equilibrium number of species on the islands that one would expect according to the theory of island biogeography (Warshall 1994). Being aligned on a north-south axis and separated by eight degrees that divide temperate and subtropical latitudes, these two sources of species introductions to the islands are characterized by quite different climates and contribute correspondingly different species. Comparison with the nearby Great Basin archipelago highlights the significance of a north-south alignment in source mountain ranges, as we see much less biodiversity in that sky island grouping.

Of all sky island regions recognized in the world, the Madrean archipelago is the only one that straddles two different floristic realms (Holarctic and Neotropic), in addition to straddling two faunal zones (Neotropic and Nearctic) (Warshall 1994). The intermingling of flora from different Holarctic and Neotropic communities, in a region with overlapping climate zones and complex elevational profiles, is the unique combination of environmental conditions that provides the principal explanation for unparalleled biodiversity in this ecosystem (Poulos *et al.* 2007). Reflecting the occurrence of all these zonal intersections, the Madrean archipelago represents a geographic limit for many species. It is the northern extent for fourteen plant families, the southern limit for seven bird families, and the northern limit for four bird families (Warshall 1994). In addition, the region is the geographic range limit for thirty individual bird species, over thirty-five reptiles, and approximately fifteen mammals. No other region in the United States supports a greater diversity of mammal species; even Yellowstone is home to only half as many (Figure 4) (Skroch 2008).

### Topography

Topography is a key determinant of plant distribution patterns in any situation. Complexity of the topography in sky island regions makes its role particularly evident (Poulos *et al.* 2007). In addition to elevation, topographical elements considered here include aspect relative to the sun, soil type, and bedrock. These physical characteristics exert strong influences on soil moisture, temperature, and structural diversity of plant communities. In the Madrean archipelago, studies have shown that both high species richness and high species turnover are driven, at least in part, by steep elevation gradients and irregular topography.

The array of rock substrates and geologic phenomena that gave rise to sky islands in the Madrean archipelago is surprisingly diverse (Warshall 1994). Continental rifting that occurred roughly 13 million years ago resulted in very large linear blocks of land sinking and rising, creating what we call a basin and range terrain. The rifts exposed rock layers from many different geologic eras, and we see evidence of those different snapshots in history in the various Arizona sky islands. The Chiricahuas are volcanic



**Figure 1.** Converging biogeographic influences on the Madrean sky islands archipelago (© 2012 P. Baynham)

in origin, whereas the Pinalenos, the Rincons, and the Santa Catalina mountains are metamorphic. The Huachucas are primarily limestone. Limestone outcroppings are found on virtually all of the mountain islands and play a significant role in increasing plant diversity where they do occur.

#### Biomes

By far, the most widespread vegetation type in Arizona's sky island region is grassland (Webster 2001a). It is the equivalent of salt water surrounding oceanic islands. Both are barriers to many species living on the islands they surround. Mountain islands are compact vertical stacks of three or more biomes. In the Madrean archipelago these typically start at the bottom with evergreen

shrubs and oaks, rising into an oak-pine woodland, then ponderosa pine forests, and, finally, fir forests atop the tallest mountains (Figures 5 and 6). This vertical compression of biomes is a key aspect of species diversity on sky islands. It not only provides tremendous variety in habitats and microclimates for species to evolve and through which they may move over time, but it also allows for vertical migration in cases where that is part of an animal's normal pattern of living.

Sky island flora in this region of North America is estimated to include approximately 4,000 vascular plant species, 233 of which are trees (Felger and Johnson 1994). Oak-pine woodland, located midway up Madrean sky islands, is the signature biome of this



**Figure 2.** Map of Madrean archipelago, with elevations above 8,000' depicted in black. Southern tip of Rocky Mountains and northern extreme of Sierra Madres are shown (Skroch 2008)



**Figure 3,** Elegant trogon (left) and flame-colored tanager seen in Madera Canyon of the Santa Rita Mountains (© Stiver May 2, 2008).



Figure 4. Wild ocelot recorded near Arizona-New Mexico border in sky island region (© Skroch 2008)

region. It is where the greatest biodiversity is found (McLaughlin 1994). Grasslands also support significant diversity, but pine forests (above 2000 m elevation) and low deserts have shown less than 25 percent as many species as were found in the oak woodlands. Refer to Figure 7. Strong correlation is evident between elevation range for each sky island and the number of species present on the island. The Pinalenos, Rincons, and Sierra el Tigres have the greatest elevation ranges and also support the highest number of species. Topographic extremes and fewer wet canyons lower the species count a bit for the Pinalenos, but it is still higher than others. Refer to Figure 8.

#### Threats to Archipelago's Heritage

Humans have had significant and rapidly increasing impact on the ecology of Arizona's sky island region over the last 100 years. In 1854, less than 80,000 people lived along the entire United States-Mexico border; today approximately 10 million people live in these borderlands (Webster 2001b). Nearly all of the population explosion occurred after 1945, and it has taken place on both sides of the border.

Impacts that threaten ongoing health and biodiversity of the Madrean archipelago include habitat fragmentation, riparian corridor deterioration or elimination, introduction of exotic and invasive species, overgrazing and trampling by cattle, unnatural fire suppression, and intentional killing of top predators (Warshall un-

dated). Both surface water and groundwater sources have been heavily altered and are disappearing in many cases. The Central Arizona Project has created a corridor for introduction of non-native fish and other organisms. Spruce-fir forests in the Pinalenos have been heavily logged, eliminating habitat that is critical for survival of the Mount Graham red squirrel. Many invasives, such as *Eragrostis lehmanniana* (Lehmann's lovegrass) and *Pennisetum ciliare* (buffelgrass), were introduced to support cattle grazing but outcompeted native species. Continued housing development in the sky islands area and heavy recreational use of the mountains themselves are still escalating with no turnaround in sight. Large mammals, in particular, (e.g., gray wolves, jaguars, bears) are losing the corridors through which they must move to survive. In many cases they are still intentionally killed.

#### Conclusion

There are aspects of the sky islands ecosystems in Arizona that are permanently lost or changed, but there is still a great deal to be saved. More than 150 species living in the region today are listed as being species of concern, to varying degrees (Warshall 1994). Among the many actions that can and should be taken to restore health and prospects for the future of this area as an ongoing biodiversity hot spot, three are deemed to be critically important: (1) restore riparian areas, (2) reintroduce large fauna, and (3) return to a "natural" wildfire regime.

# Biomes on a Typical Southern Arizona Mountain

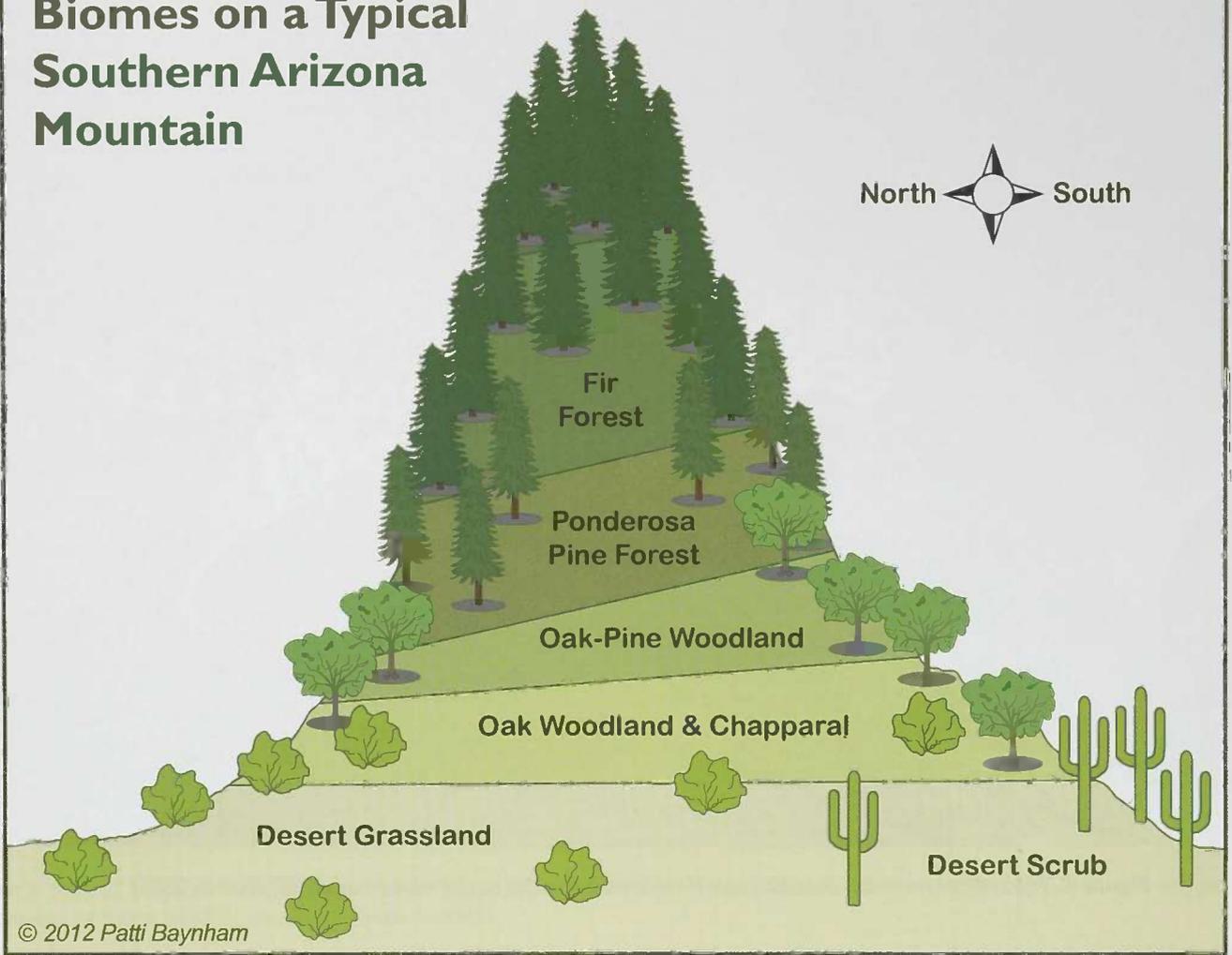


Figure 5. Biomes on a typical southern Arizona mountain (© 2012 Patti Baynham)

# Biotic Community Stacking in Representative Mountains of the Madrean Archipelago

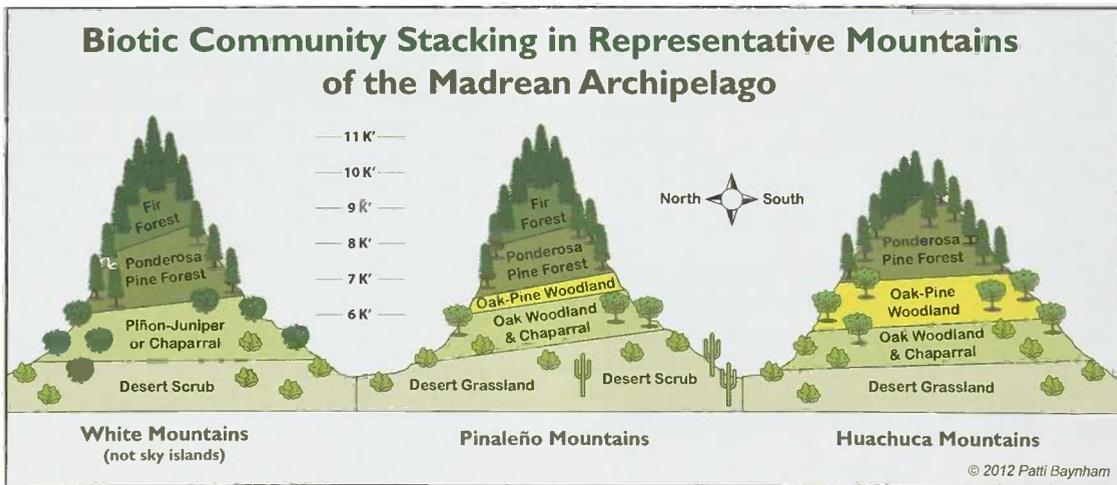
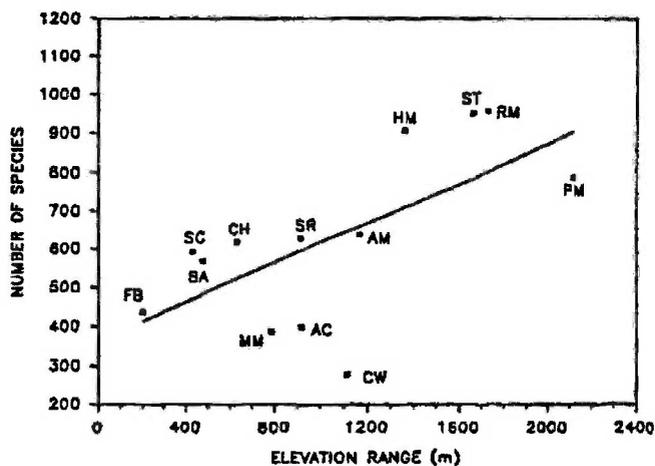


Figure 6. Biotic community stacking in representative mountains from the Madrean archipelago (Warshall 1994)

Community type	Elev (m)	No. of Species
Corkbark fir forest	2720	15
Douglas fir-white fir forest	2640	16
Douglas fir forest	2650	10
Ponderosa pine-white pine forest	2740	13
Ponderosa pine forest	2470	8
Ponderosa pine-silverleaf oak forest	2180	12
Pine-oak woodland	2040	18
Pygmy conifer-oak scrub	2040	20
Open oak woodland	1310	58
Desert grassland	1220	46
Spinose suffrutescent desert	1021	41
Upper Bajada desert	870	33
Lower Bajada desert	760	6

**Figure 7.** Plant community diversity (0.1 ha plots) in the Santa Catalina Mountains (Whittaker and Niering 1975)



**Figure 8.** Relationship between number of native species and elevation range for 13 local floras from the sky island region. Abbreviations are: AC: Aravaipa Canyon, AM: Animas Mountains, BA: Buenos Aires National Wildlife Refuge, CH: Chiricahua National Monument, CW: Chiricahua Wilderness, FB: Fort Bowie National Historic Site, HM: Huachuca Mountains, MM: Mule Mountains, PM: Pinalaño Mountains, RM: Rincon Mountains, SR: Northern Santa Rita Mountains, SC: Sycamore Canyon, ST: Sierra el Tigre (McLaughlin 1994)

## References

- Felger, R.S., and Johnson, M.B. 1994. RM-GTR-264: Trees of the northern Sierra Madre Occidental and sky islands of southwestern North America. In *Biodiversity and management of the Madrean archipelago: The sky islands of southwestern United States and northwestern Mexico*, Tucson, AZ, USA, 1994 Sept 19-23. RM-GTR-264: USDA, Forest Service, Rocky Mountain Forest and Range Experiment Station, pp. 71-83.
- McLaughlin, S.P. 1994. RM-GTR-264: An overview of the flora of the sky islands, southeastern Arizona: Diversity, affinities, and insularity. In *Biodiversity and management of the Madrean archipelago: The sky islands of southwestern United States and northwestern Mexico*, Tucson, AZ, USA, 1994 Sept 19-23. RM-GTR-264: USDA, Forest Service, Rocky Mountain Forest and Range Experiment Station, pp. 60-70.
- Poulos, H.M., Taylor, A.H. and Beaty, R.M. 2007. Environmental controls on dominance and diversity of woody plant species in a Madrean, sky island ecosystem, Arizona, USA. *Plant Ecol.* 193(1): 15-30.
- Skroch, M. 2008. Sky islands of North America: A globally unique and threatened inland archipelago. *Terrain. Org: A Journal of the Built & Natural.* 21(Winter/Spring): 147-152.
- Stiver, H. May 2, 2008. Nature Notes: Southern Arizona-Santa Rita Mountains [online]. Available from <http://www.ontfin.com/Word/southern-arizona-santa-rita-mountains/> [cited Dec 3, 2010 2010].
- Univ of Arizona, Cooperative Extension. Feb 25, 2008. Ecoregions of Arizona: Vertical life zones [online]. Available from [http://ag.arizona.edu/watershedsteward/resources/module/Biotic/ecoregions\\_pg2.htm](http://ag.arizona.edu/watershedsteward/resources/module/Biotic/ecoregions_pg2.htm) [cited Nov 29, 2010 2010].
- Warshall, P. undated. Southwestern Sky Islands Ecosystems (Univ of Arizona Office of Arid Lands Studies) [online]. Available from [http://www.propertyrightsresearch.org/articles5/southwestern\\_sky\\_islands\\_ecosyst.htm](http://www.propertyrightsresearch.org/articles5/southwestern_sky_islands_ecosyst.htm) [cited Nov 26 2010].
- Warshall, P. 1994. RM-GTR-264: The Madrean sky island archipelago: A planetary overview. In *Biodiversity and management of the Madrean archipelago: The sky islands of southwestern United States and northwestern Mexico*, Tucson, AZ, USA, 1994 Sept 19-23. RM-GTR-264: USDA, Forest Service, Rocky Mountain Forest and Range Experiment Station, pp. 6-18.
- Webster, G.L. 2001a. Reconnaissance of the flora and vegetation of *La Frontera*. In *Changing plant life of La Frontera: Observations on vegetation in the United States/Mexico borderlands*. Edited by G.L. Webster, and C.J. Bahre. Univ of New Mexico Press, Albuquerque, NM, USA. pp. 6-2??
- Webster, G.L.B., C.J. 2001b. Introduction. In *Changing plant life of La Frontera: Observations on vegetation in the United States/Mexico borderlands*. Edited by G.L.B. Webster C.J. Univ of New Mexico Press, Albuquerque, NM, USA. pp. 1-5.