Exotic Plants in the Sonoran Desert Region, Arizona and Sonora

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Introduction

Introduced exotic plants abound throughout the Sonoran Desert Region in Arizona, U.S.A. and Sonora, Mexico. Their abundances and ecological roles can be viewed from several perspectives. With the notable exception of riparian habitats in Arizona and northern Sonora, introduced species usually account for relatively low percentages of local floras. For example, a total of 5.9% of 738 taxa in the tropical deciduous forest flora of the Río Cuchujaqui near Alamos in southern Sonora is introduced.

Exotics in the riparian zones include grasses *(Arundo donax, Cvnodon dactylon, Dactyloctenium aegyptium, Dichanthium annulatum, Echinochloa colonum, E. crusgallii, Eleusine indica, Polypogon mospeliensis, Rhynchelvtrum repens,* and *Sorghum halepense),* herbs *(Cannabis sativa, Chenopodium murale, Coriandrum sativum, Coronopus didymus, Leonotus nepetaefolia, Melilotus indica, Papaver somniferum,* and *Sonchus oleraceus),* vines *(Citrullus lanatus, Cryptostegia grandiflora,* and *Solanum seaforthianum),* a shrub *(Ricinus communis),* and trees *(Leucaena leucocephala* and *Psidium guajava).* In general, most of these exotics are relatively innocuous with few serious impacts on the flora and vegetation. Along the Río Cuchujaqui, only *Pennisetum ciliare* (buffelgrass) poses a serious threat to the tropical deciduous forest ecosystem.

Ecologically, the diversity and abundance of introduced species are greatest in riparian (river bottoms, arroyos, washes. etc.) and pseudoriparian (edges of roads, etc.) habitats because they are naturally disturbed and unstable dispersal corridors that harvest water, nutrients and seeds from large areas (Stromberg and Chew 1997). Successful invaders are often short-lived, grow rapidly, and have high reproductive effort. Longer-lived exotics are usually "mortality resistant" -- a term used to describe survivors not easily killed by environmental stresses (floods, fire, drought, freezes, heavy grazing, etc.).

Unfortunately, a few exotics have the potential to cause ecological and economic havoc in the Sonoran Desert Region and threaten to change landscapes irrevocably. Competition with native species is typically intense, illustrated by the examples below. However, when a new species is introduced into an ecosystem as a result of an introduction of a new species, vegetation structure and species composition can be dramatically altered. The role of fire in subtropical and tropical desertscrub, thornscrub, and tropical deciduous forest can be devastating. A suite of annuals native to Mediterranean areas are especially troublesome. They are preadapted to the winter rainfall climate and fire regimes of the chaparral vegetation in California. As they move into the Mojave Desert, they directly compete with the native spring flora and introduce fire. As they move eastward into the biseasonal climatic regimes of the Sonoran Desert, their ecological interactions are more complex. Burgess (1995) discussed the different water-use strategies of seasonally competing subshrubs (winter-spring active) and perennial grasses (summer active) in desert grassland. A similar seasonal competition occurs between spring and summer annuals in desertscrub. In the spring, introduced annuals compete directly with native spring herbs for water, space, and nutrients. Often the introduced annuals are so prolific that few nutrients remain for summer ephemerals. However, the alterations of community structure and competition due to fires are much more serious impacts.

This paper will present brief discussions of the most ecologically troublesome species introduced into the Sonoran Desert Region in Arizona and Sonora.

The Sonoran Desert Region

The ecology of the Sonoran Desert is very complex with remarkable environmental and biological gradients. From north to south, the temperate climates of Arizona merge into the New World tropics in central and southern Sonora. Both annual rainfall and the percentages of summer rainfall increase to the south. The northern edge of essentially frost-free tropical vegetation is at about 28° 30' N latitude as freezing temperatures set the northern distributional limits of tropical species (Van Devender et al. 1994). At higher elevations, Sonoran desert scrub is replaced by interior chaparral or desert grassland in the north, and thornscrub to the south. Búrquez et al. (1992) presented an excellent discussion of the dramatic environmental and vegetation gradients in central Sonora from Sonoran desert scrub in Hermosillo to the pine-oak forests near Yécora in the Sierra Madre Occidental.

In central Arizona, the landscape changes from *Carnegiea gigantea* (saguaro) - studded mountains at 550900 m elevation to the hyperarid *Larrea divaricata* (creosotebush) - clad lowlands of the Colorado River Valley in western Arizona, northwestern Sonora, and northeastern Baja California, and then to the Mojave Desert in California, as rainfall shifts from biseasonal to winter dominated.

Shreve (1964) recognized seven subdivisions of the Sonoran Desert in southern Arizona, southeastern California, Baja California, and Sonora. The Arizona Upland, the northeasternmost, has obvious floristic affinities with more tropical communities to the south. Near Tucson, open desert scrub dominated by small trees [*Cercidium microphyllum* (foothills palo verde) and *Olneya tesota* (ironwood, palo fierro)], and a columnar cactus *(Carnegiea gigantea)* is typically found on rocky slopes and bajadas.

The Lower Colorado River Valley, Central Gulf Coast, Plains of Sonora, and Foothills of Sonora subdivisions are in Sonora. The Plains of Sonora differs from Arizona Upland in the abundance of legumes, especially *Prosopis glandulosa, P. velutina* (mesquites), and *O. tesota*, and the scarcity of columnar cacti.

The Central Gulf Coast hosts various succulents including *Pachycereus pringlei* (card6n) and has more general ties to the flora of Baja California.

To the east and south in Sonora, the Sonoran Desert merges into thorn scrub which in turn becomes tropical deciduous forest (Búrquez et al. 1992).

In central Sonora, the Plains of Sonora grades into the Foothills of Sonora. Turner and Brown (1980) excluded this vegetation from the Sonoran Desert because it receives too much rainfall and has greater density and biomass than typical desert scrub. This vegetation is now best called "foothills thorn scrub" (Búrquez et al. in press). Here trees are more important, especially *Bursera Jagaroides* (torote copal), *B. laxiflora* (torote prieto), *Fouquieria macdougalii* (tree ocotillo), and *Jatropha cordata* (torote papelío). Foothills thorn scrub has broad contact with the Sonoran Desert along elevational gradients in central Sonora.

Along the coast of the Gulf of California, vegetation reflects the climatic gradient from Sinaloa north to Guaymas. As rainfall decreases, the vegetation becomes less dense, shorter in height, and much more open. Here, many desert species reach their southern range limits, and many tropical species their northern limits.

Sonoran Exotic Plants

The most serious exotic plant introductions in the Sonoran Desert Region are found in various biotic environments. *Bassia hyssopifolia* (smother weed), *Cryptostegia grandiflora* (bejuco), *Parkinsonia aculeata* (Mexican paloverde, bacoporo), *Ricinus communis* (castor bean, higuerilla), and most of the grasses mentioned in the Río Cuchujaqui example above are invaders in riparian habitats.

Tamarix ramosissima (salt cedar) is a 2-4 m tall shrub native to the Old World. In northwestern Sonora, it is abundant in wet, alkaline soils along the Río Sonoyta and the Colorado River and its delta, as an agricultural weed, in roadside depressions, and in many wetlands such as Laguna Prieta and the pozos at La Salina (Felger 1990). This species is very aggressive, displaces most native riparian species, and is difficult to control.

In the Lower Colorado River Valley in southwestern Arizona and northwestern Sonora, rainfall is very low and highly variable from year to year. With unusually heavy winter-spring rains, the wildflower displays in

sandy areas can be dramatic. *Brassica tournefortii* (Sahara mustard) and *Schismus arabicus/S. barbatus* **(**Arabian and Mediterranean grasses) are important exotic winter-spring annuals that compete with native annuals and grasses for rainfall, nutrients and microhabitats. The primary impacts are changes in community composition and species abundances. The vegetation is a sparse desert scrub dominated by relatively few perennials, typically *Ambrosia dumosa* (white bursage), *Larrea divaricata, Pleuraphis rigida* (big galleta grass) and combinations of other species.

In the moderate-elevation Arizona Upland subdivision in Arizona and adjacent Sonora, especially in the Pinacate Region, *Bromus madritensis* ssp. *rubens* (red brome), *Erodium cicutarium* (filaree), and *Sisymbrium irio* (London rocket, pamita) are very common introduced winter-spring exotics.

Bromus madritensis ssp. *rubens* is especially aggressive, germinating early, growing rapidly, filling the best microhabitats, using available soil moisture and nutrients, and diminishing the abundance and diversity of native annuals. Previously, regularly spaced rains from October through February produced spectacular displays of *Eschscholzia mexicana* (Mexican poppy) and *Lupinus sparsiflorus* (lupine). Today, wet winters mostly favor *B. madritensis* ssp. *rubens* and other exotics. At the beginning of the and foresurnmer in April and May, *B. madritensis* ssp. *rubens* along with *Avena fatua* (wild oats) and *Hordeum murinum* (wild barley), die but remain in place.

Fire has not been an ecological process in Sonoran desert scrub, thorn scrub, or tropical deciduous forest because there is rarely have enough fine fuel on the ground to carry a fire. The native annual grasses either do not accumulate much fine fuel (for example,*Vulpia octoflora, V. microstachys*) or are active later in the summer monsoon season (such as *Bouteloua aristidoides, B. barbata).* Most of the dominant plants in these communities, including columnar cacti (*Carnegiea gigantea, Lophocereus schottii, Pachycereus pecten-aboriginum, Stenocereus thurberi),* trees *(Bursera* spp., *Cercidium* spp., *Fouquieria macdougalii, Jatropha cordata, Olneya tesota,* etc.), and shrubs *(Ambrosia* spp., *Encelia farinosa, Larrea divaricata,* etc.) are readily killed by fire. In Arizona, fires in the arid foresummer (mid May to July), primarily fueled by *B. madritensis* ssp. *rubens,* have increased dramatically in recent years. Below about 900 m elevation, the result is a relatively barren landscape dominated by *B. madritensis* ssp. *rubens* and other annuals. At higher elevations, desert scrub has been converted to desert grassland - "Mediterraneanized" by fire.

Pennisetum ciliare is a robust savannah grass native to the warmer parts of Africa, Madagascar and India, has been widely introduced and subsequently established in hot, semiarid regions of the world for forage and fodder. A strain from the Turkana area of Kenya was officially released for planting by the Soil Conservation Service in San Antonio, Texas, in 1946 (Tellman 1997). Since the 1960s it has been extensively introduced for livestock forage in Arizona Upland and the Plains of Sonora subdivision, foothills thorn scrub, and tropical deciduous forest in Sonora (Miller et al. in press).

In central Sonora, more than a million hectares of desert scrub and thorn scrub have been cleared to plant *P. ciliare,* often as part of government programs to support the ranching industry. Unlike most native grasses, *P. ciliare* regenerates from the nodes rather than the base allowing rapid production of leaves and seed in response to rain. The plant burns readily (even when green) and recovers quickly from fires. Decimation of natural vegetation by fires is allowing buffelgrass to expand rapidly into large areas of uncleared vegetation. Along many highways, dense monocultures of *P. ciliare* have replaced other ruderal species, especially *Encelia farinosa* (brittlebush). Recurrent fires maintain the buffelgrass as well as clean up roadside garbage. Fires fueled by buffelgrass are now a serious urban problem in Hermosillo, the capitol of Sonora.

In Arizona, where *P. ciliare* was not actively seeded into cleared areas, the expansion has been slower. However, in recent years, it has begun to rapidly spread along highway rights-of-way both to lower and higher elevations, and to invade desert scrub communities on rocky slopes away from roads. In southern Sonora, *P. ciliare* has been planted in clearings in tropical deciduous forest but apparently is not able to invade undisturbed shady forests. The ecological result of the introduction of *P. ciliare* into fire-intolerant subtropical/tropical communities is the conversion to an African-type savannah with drastically reduced standing crop biomass and overall diversity.

This "grasslandification" of desert scrub and thorn scrub is the opposite of the well-known "desertification" of southwestern desert grasslands - the expansion of shrubs into grass-dominated communities beginning in the late 19th century (Bahre 1991). The shrubs involved were mostly native species.

The only example of an introduced shrub invading desert grassland is *Euryops multifidus* (resinbush), a southern African composite. In 1938 the Soil Conservation Service planted it on a 0.06 ha (26 m^2) test plot on Frye Mesa on the eastern slopes of the Graham Mountains near Safford (McAuliffe 1995) to evaluate its potential for erosion control. Today it covers about 100 ha and has devastated the native desert grassland flora, including shrubs such as *Acacia greggii, Calliandra eriophylla, Ephedra trifurca, Gutierrezia sarothrae,* and small *Prosopis velutina.*

In Hermosillo and the agricultural fields to the west, *Salsola tragus* (Russian thistle) is a locally common "tumble weed." The origin and dispersal of this summer annual are very different from those of exotics of Mediterranean or tropical origins. Apparently the seeds were contaminants in flax seed carried from Russia to South Dakota by Mennonite farmers (Tellman 1997). From there, the species moved southward through the Great Basin as far as Sonora. Interestingly, this new arrival has acquired the common name "chamiso volador" although *Atriplex canescens* (fourwing saltbush) throughout the Chihuahuan Desert region is "chamiso" and *Adenostonia fasciculatum* is "chamisa" in the California chaparral.

The introduction of the South African *Eragrostis lehmanniana* (Lehmann lovegrass) has begun a transformation of desert grasslands in southeastern Arizona (Anable et al. 1992). It produces 2-4 times the annual biomass of native grasses and responds favorably to grazing and fire. It is replacing native grasses in vast areas. In this case, community composition is dramatically altered but the desert grassland is not converted to another vegetation type. It could become a problem in the grasslands of northwestern Sonora.

Rhynchelytrum repens (Natal grass, zacate rosado) is another African grass that is common on roadsides in many areas in Sonora. It is invasive in desert grassland in Sonora south of Nogales and near Maycoba in the Sierra Madre Occidental, as well as eastward in to Chihuahua. In the mountains north of Guaymas on the coast of the Gulf of California, where it has invaded undisturbed steep slopes, it could potentially fuel fires in vulnerable desert scrub vegetation.

Rogues Gallery of Exotics

Six species can be recognized as potentially causing the most ecological damage in the Sonoran Desert Region. They include a mustard *(Brassica tournefortii)* and five grasses *(Bromus madritensis* ssp. *rubens, Pennisetum ciliare, P. setaceum, Schismus arabicus,* and *S. barbatus).* The *Brassica, Bromus,* and *Schismus* are cool-season annuals and the two *Pennisetum* species that are perennials which become facultatively inactive with extended drought, freezing, or near-freezing temperatures. The following accounts are based on literature, label data on University of Arizona Herbarium specimens, and personal observations.

Brassica tournefortii Gouan (Sahara mustard)

The Sahara mustard is a coarse annual that was described from Iran, and is probably native to North Africa and Central Asia. It is now widespread in warm and regions of the world. This species has spread explosively across the lowlands of the Sonoran Desert, especially in places with sandy soils. In California, it was well established in the Coachella Valley by 1938 and was a contaminant in Hubam clover in the Imperial Valley in 1947 (Robbins et al. 1951). The earliest record for it in Arizona is 1957 (Mason 1960) while Sonoran collections date from 1966. By the 1970s it was widespread and well established in the lowland deserts of northern Baja California, southeastern California, southwestern Arizona, and western Sonora as far south as the Guaymas. It is especially common in sandy lowland habitats across the Sonoran Desert, including low dunes, interdune troughs, sandy flats, and sandy-gravelly washes.

Individuals of this species are amazingly variable in size, depending upon the availability of soil moisture. Drought-stressed plants can reproduce with leaves as small as 8 cm long. On sandy soils with sufficient moisture the leaves can grow to more than 50 cm long, giving the plant a 1 m spread, making it the largest herbaceous rosette plant in the region. It flowers from February to May. The small, pale flowers, anomalous petal blade patterns, and stamens that touch the stigma suggest a probability for self-fertilization.

Bromus madritensis L. ssp. *rubens* (L.) Husnot

Red or foxtail brome is a weedy Mediterranean annual that was established in California by 1848, and is presently common through much of the western United States (Burgess et al. 1991). It is seasonally abundant and widespread in the Sonoran Desert Region. In lower, more arid areas, it is mostly found in disturbed habitats, while at higher elevations throughout the Arizona Upland it also occurs in less disturbed habitats. Since the 1970s, it has become well-established around Sonoyta on the Arizona border in disturbed habitats, including urban and agricultural areas and in Puerto Peñasco on the Gulf of California. By 1987, it was at the summit of Pinacate Peak and elsewhere in the Pinacate region in northwestern Sonora. Although it has been present in the town of Ajo since 1916 and in the Ajo Mountains since 1942, it has expanded dramatically in Organ Pipe Cactus National Monument since the late 1970s (Bowers 1980, Felger 1990).

Pennisetum ciliare (L.) Link (buffelgrass)

The genera *Pennisetum* and *Cenchrus* (sandburs) are closely allied and the boundary between them is bluffed and disputed. The bristles in *Pennisetum* are distinct or nearly so, while they are clearly united for a substantial portion of their length and usually spines-cent in *Cenchrus.* [Chromosome differences indicate that *Cenchrus* (n =17) evolved from *Pennisetum* (n = 7).] *Pennisetum ciliare* is problematic because its bristles are scarcely fused at the base leading some authors to place it in *Cenchrus* (DeLisle 1963). In most other characters it is a *Pennisetum:* i.e., hard-based perennial growth habit, lack of flattened, retrorsely-barbed spines, a basic chromosome number of n = 9, and the extensive occurrence of apomixis (asexual reproduction without fertilization or meiosis) (John R. Reeder, pers. com., 1995).

Because buffelgrass is such a hardy, droughtresistent and excellent forage grass, great effort has been expended for new selections and introductions (see above discussion). Unfortunately it also is becoming a serious weed, and if it reaches more favorable habitats such as higher elevations in the Pinacate volcanic region it will probably displace native plants. Much of the variation in new selections relates to the variability in reproduction and chromosome numbers (2n = 32, 34, 36, 38, 40, 45, 52, 54; n = 18). Reproduction is largely apornictic but facultative sexual reproduction is common (Bray 1978).

Pennisetum setaceum Forssk. (Fountain grass)

Pennisetum setaceum is a robust perennial clumping grass from Africa, often ca. 1 m tall. It is a common landscape ornamental in southern Arizona, where it is slowly spreading into natural habitats. It has been cultivated in Tucson since 1940 and was established in the nearby Santa Catalina Mountains by 1946. Although it is cultivated in Sonoyta, naturalized plants have not been encountered in northwestern Sonora. A few plants found in 1986 in Organ Pipe Cactus National Monument about 10 km north of the Sonora border on Arizona Route 85 suggest that it is could be spreading southward (Felger 1990). If it reaches the higher elevations in the Sierra Pinacate, it will likely become established.

Schismus arabicus Nees (Arabian grass) and *S. barbatus* (L.) Thell. (Mediterranean grass)

These closely-related winter ephemerals are geographically segregated in the Old World. S. *arabicus* ranges from southwest Africa to the western and northern Sahara and the western Mediterranean region, while *S. arabicus* ranges from Kashmir and southern Russia west to Greece. The differences between *S. arabicus* and *S. barbatus* are subtle (the presence of hairs on the lemma, length of the palea) and plants with intermediate characters are not rare in the Sonoran Desert. Gould (1951) believed that they broadly intergrade and *S. arabicus* has been recognized as a subspecies of *S. barbatus.* Today most modem agrostologists maintain them as separate species (Conert and Turpe 1974; John R. Reeder, pers. com., 1991).

During years of favorable winter rains, these grasses can be abundant across much of the northern part of the Sonoran Desert, forming extensive, dense carpets. The first stems and leaves often spread out close to the ground, effectively excluding or preventing other ephemerals from sprouting.

Arabian grass is native to the Old World but is now widely established in arid and semi-arid regions of the world. It is widespread and well established in southwestern United States and northwestern Mexico. The earliest record for it in North America seems to be 1933 (Hoover 1936). It is seasonally abundant in most of the Sonoran Desert lowlands, especially on sandy soils, sandy flats, arroyos and washes, interdune troughs, at the

bases of larger dunes, and as an agricultural and urban weed. The southernmost record in Sonora is from near Puerto Libertad on the coast of the Gulf of California.

Mediterranean grass is common and widespread in and regions of the southwestern United States and northern Baja California. *S. barbatus* does not seem to be as widespread as *S. arabicus,* and apparently does not extend farther southward in Sonora than Sonoyta on the Arizona border. Interestingly, the earliest North American records for this grass seem to be 1926 from southern Arizona and 1935 from Fresno County, Califomia (Hoover 1936) - the reverse of the typical dispersal pattern of Mediterranean weeds that first became established in California and followed the highways eastward.

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