Alien Grasses in the Mojave and Sonoran Deserts

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Abstract

Alien annual grasses are widespread and common in public wildlands of the Mojave and Sonoran deserts. They are dominated by red brome (*Bromus madritensis* ssp. *rubens*)and Mediterranean grasses (*Schismus arabicus* and *Schismus barbatus*), along with locally abundant cheatgrass (*Bromus tectorum*) and Chilean chess (*Bromus trinii*). The dominance of alien annual grasses can increase levels of water and mineral nutrients in the soil, and they can effectively compete with native annuals for these resources. Increased levels of atmospheric nitrogen and carbon dioxide may increase their dominance in the future, especially during years of high rainfall. Periods of low rainfall may temporarily reduce the dominance of species that evolved in mesic ecosystems (e.g. red brome). Alien perennial grasses are less widespread and common than alien annual grasses, especially in the Mojave Desert. They are mostly found at urban-wildland interfaces, but have invaded some wildland areas in the Sonoran Desert, especially in Sonora. It is currently unknown if their distributions are stable or in the process of expanding. Dominant species include buffelgrass (*Pennisetum ciliare*), fountain grass (*Pennisetum setaceum*), Natal grass (*Rhynchelytrum repens*) and Lehmann lovegrass (*Eragrostis lehmanniana*). These species appear to be less tolerant of frost and require more summer rainfall than the alien annual grasses, which may explain why they have not spread north into the Mojave Desert.

Alien annual and perennial grasses both facilitate the spread of fire and thrive in post-fire landscapes, possibly due to reduced competition with natives and increased levels of available soil nutrients. Shortened fire return intervals caused by alien grasses pose serious threats to plants and animals in the Mojave and Sonoran deserts. These grasses can also compete with native plants for limiting nutrients, reducing their reproductive potential and possibly their diversity. Control of alien grasses is difficult once they are established, so eradication of new populations is critical for their management.

Alien Annual Grasses

Descriptions

Alien annual plants are particularly successful in the Mojave and northern Sonoran desert regions because they can avoid harsh environmental conditions by remaining dormant as seeds, and they can grow rapidly and produce large numbers of seeds during ephemeral periods of high rainfall (Beatley 1966, Inouye 1991). Three of the four most widespread and abundant alien plants in these deserts are the annual grasses red brome (*Bromus madritensis* ssp. *rubens*) and Mediterranean grass (*Schismus arabicus* and *Schismus barbatus*) (Brooks 1998, Kemp Brooks 1998, Brooks and Berry in press, Peter Stine and Kathryn Thomas, unpublished data).

Red brome is considered an invasive weed in its Mediterranean home range (Jackson 1985, Brooks in press a), and it is on the California Exotic Pest Plant Council's (CalEPPC) "Exotic Pest Plants of Greatest Ecological concern in California", (CalEPPC 1999) A-2 list because it is recognized as an invasive wildland pest in California. Red brome is found throughout western North America from British Columbia to northern Mexico (Wilken and Painter 1993, Pavlick

1995). It was established in cismontane California by 1848, and apparently naturalized there by the 1890s. Red brome became common in the Mojave Desert by 1950, but its spread north into the Great Basin appears to be limited by its sensitivity to low winter temperatures. The dominance of red brome is affected primarily by rainfall and soil nitrogen levels (Brooks 1998), and a period of high rainfall during the late 1970's was followed by a dramatic increase in its dominance in the northern Mojave Desert (Hunter 1991). It is most abundant where soil nutrients are concentrated beneath woody shrubs (Brooks in prèss b) and across the landscape where fires have occurred (Brooks 1998). Successive years of low rainfall may cause population crashes of red brome (Richard Minnich, personal communication), but these effects appear to be localized at relatively arid low elevation sites (Matt Brooks, personal observation).

Mediterranean grass is not invasive in its home range (Brooks in press c), but it is on the CalEPPC Annual Grass list because many land managers consider it to be a potential wildland pest and virtually nothing is known about its ecology in North America. Mediterranean grass is found in open areas of the central and southern coastal and desert regions of California (Brooks in press c), through southern Arizona and Utah (Esque and Schwalbe in review), and into Texas (Allred 1993). It appears to have spread from Arizona into California during the early 1900s, first appearing in Califomia in 1935 and becoming common in the Mojave and Sonoran deserts and cismontane regions of southern California by the 1950s (Oscar Clarke, personal communication). *Schismus arabicus* is most abundant in arid regions whereas *Schismus barbatus* is most abundant in semi-arid regions (Brooks in press c). Mediterranean grass can germinate and reproduce even during the driest years in the Mojave Desert (Brooks in press c), although its growth can increase dramatically when and where soil water and mineral nutrient levels are high (Brooks 1998, Brooks in press b).

Two other alien annual grasses are locally abundant, cheatgrass (*Bromus tectorum*) and Chilean chess (*Bromus trinii*). The negative ecological effects of cheatgrass are well documented in the Great Basin Desert (Young in press), justifying its inclusion on the CalEPPC A-1 list, but its effects in the Mojave or Sonoran deserts remain poorly documented. Cheatgrass was common in the western and central Mojave Desert by the 1930's, and appears to have been replaced by red brome in much of this region since then (Oscar Clarke, personal communication). Chilean chess remains unstudied in North America, and it may be native to western South America (Wilken and Painter 1993, Andy Sanders, personal communication).

Ecological Effects

Alien annual grasses can outcompete native annual plants for limiting resources. Red brome is known to deplete soil water faster and at greater soil depths than native annual species (Lesley DeFalco, unpublished data), and along with cheatgrass, effectively compete with native species for water (Eissenstat and Caldwell 1988, Melgoza and Nowak 1991). Red brome and Mediterranean grass also appear to compete effectively with native annuals for soil nitrogen (Brooks 1998). Experimental thinning of red brome and Mediterranean grass seedlings significantly increased the density, biomass, and species richness of native annuals (Brooks 1998, Brooks in press d). Although cases of exotics displacing natives have not been documented, a University of California Riverside botanist, Oscar Clarke, observed that a previously common native annual grass, *Vulpia octoflora*, became uncommon after the invasion of the ecologically similar Mediterranean grass during the 1940s.

High densities of annual plant seedlings can inhibit germination of Sonoran Desert annuals (Inouye et al. 1980, Inouye 1991), and densely packed alien annual grass seedlings may reduce the subsequent germination of natives in the Mojave Desert. Plant litter created by alien annual grasses is likely to decompose more slowly than that of native annuals because shoot fiber content is higher in aliens than in natives (DeFalco 1995). Accumulated plant litter can impede germination by shading the mineral soil, reducing the amount of water that reaches the mineral soil, and suspending seeds above and out of contact with the mineral soil (Facelli and Pickett 1991). Experimental removal of alien annual grass litter increased the density and diversity of native annuals in the Mojave Desert (Matt Brooks, unpublished data).

Little is known about competition of alien annual grasses with native perennial shrubs. Perennial shrubs such as creosotebush (*Larrea tridentata*) and bur-sage (*Ambrosia dumosa*) can facilitate the establishment and growth of native and exotic annuals (Holzapfel and Mahall 1999). Enhanced nutrient and water availability beneath shrub canopies is associated with high biomass of annuals in general (Charley and West 1977, Romney et al. 1978, Lajtha and Schlesinger 1986), and red brome in particular (Brooks 1998, Brooks in press b).

Alien annual grasses can alter fire regimes in the Mojave and Sonoran Deserts. Red brome and Mediterranean grass stems remain rooted and upright through the summer fire season and into successive years, whereas those of most native forbs crumble soon after senescence (Brooks in press e). High frequency and cover of this standing dead biomass facilitates the spread of fires. Biomass of red brome is positively correlated with frequency and size of fires, especially at higher elevations in the central Mojave Desert (Brooks 1998). Levels of nitrogen can increase after fires in the Great Basin (Blank et al. 1994) and Mojave deserts (Matt Brooks, unpublished data). Increased nitrogen levels lead to greater biomass of alien annual grasses that may promote recurrent fire (Brooks 1998, Brooks in press d).

Alien Perennial Grasses

Descriptions

The alien perennial grasses described here represent a cohort that were imported from Africa (Burgess et al. 1991) to increase production and reduce soil erosion in the arid southwest. Two of the most prominent alien perennial bunchgrasses in the Sonoran Desert are buffelgrass (*Pennisetum ciliare*), and Lehmann lovegrass (*Eragrostis lehmanniana*). Two additional species, Natal grass (*Rhynchelytrum repens*) and fountain grass (*Pennisetum setaceum*), are locally common and may present a problem in the future. Buffelgrass and Lehmann lovegrass are so well integrated into Sonoran desertscrub, semi-desert grasslands, and local agroecosystems that the uninformed would not guess they are alien species. Both species have established in the backcountry of natural reserves such as Saguaro National Park and pose a threat to native biodiversity (Cecil Schwalbe and Todd Esque, unpublished data, Burquez et al. 1999). Our objective for highlighting these perennial species is to increase awareness of their potential importance and to ensure that they do not become a dominant part of the landscape in desert regions of California.

Buffelgrass is native to Africa, Asia, and the Middle East (Ibarra-Flores et al. 1999). Seeds from buffelgrass were selected for drought-tolerance and brought to North America from semi-arid regions of Africa between 1940 and 1945 as part of a program to restore overgrazed grasslands in arid western North America (Cox et al. 1988, Ibarra-F. et al. 1995). Seed stock was multiplied and distributed from Texas and exported to eastern Mexico, Sonora, as well as parts of New Mexico and Arizona (Ibarra-F. et al. 1995). By 1995, 4 million ha of native habitat were mechanically converted to buffelgrass stands in Texas, 6 million ha on the east coast of Mexico, and 400,000 ha of Sonoran Desert in Mexico (Cox et al. 1988; Martin-R. et al. 1995). Buffelgrass is well-adapted to the warm-season precipitation of southern Arizona and northern Mexico (Burgess et al. 1991). Although somewhat intolerant of freezing, buffelgrass is apparently less susceptible to freezing than some Sonoran Desert natives (Burgess et al. 1991). However, efforts are underway to develop strains of buffelgrass that are even more tolerant of low temperatures in order to expand the range of this invasive species (Hussey and Bashaw 1996). In the Sonoran Deserts of northwestern Mexico and southern Arizona, buffelgrass has escaped cultivated sites and naturalized into backcountry areas. Where this occurs, summer precipitation ranges from 150-550 mm and winter precipitation is below 400 mm (Cox et al. 1988). Winter temperatures rarely fall below 5° C where buffelgrass is most successful (Cox et al. 1988). Buffelgrass grows well in loamy textured soil, and not as well in clay and sandy soils (Cox et al. 1988). Buffelgrass grows in roadside riparian habitats west of Tucson (Todd Esque, personal observation) and is identified as a problem at Organ Pipe National Monument, but is not currently known to exist in California (Hickman 1993).

Lehmann lovegrass was collected from South Africa in 1932 and sent to Superior, Arizona to provide the source for seed production programs, the products of which were distributed throughout warm deserts in North America (Cox et al. 1988). This perennial bunchgrass is dominant in a localized area south of Tucson, Arizona where it is experimentally manipulated, but has also been found naturalized at low densities in the backcountry of Saguaro National Park (Todd Esque and Cecil Schwalbe, unpublished data). Lehmann lovegrass may become dominant where summer rainfall exceeds 150 mm and soil textures are sandy or sandy loam (Cox et al. 1988). Lehmann lovegrass occurs in areas that range in elevation between 1100-1540 m, and daily mean minimum and maximum temperatures vary annually from -4° C to 20° C and 13 to 38° respectively (Cox et al. 1988). Active growth occurs during periods of summer precipitation (Cox et al. 1988).

Natal grass was originally brought to North America for erosion control (Kearney and Peebles 1960). Most of the information available on the distribution and ecological effects of natal grass are anecdotal at this time.

Fountain grass is noted in the flora of California (Hickman 1993) and is the only one of the four alien perennial grasses identified as a problem by CalEPPC: it is listed in the A-1 category because of its invasive nature in coastal areas. Although known to be at least locally abundant in coastal areas, fountain grass is not prominent in desert habitats at this time. Fountain grass has been reported in xeririparian habitats in the eastern Mojave Desert (Jim Andre, personal communication), and in the southwestern Mojave Desert near Joshua Tree National Park there is one known infestation numbering several plants (Jane Rodgers, personal communication) and several individual plants were found along a paved highway during spring 1999 (Matt Brooks, personal observation). Control of fountain grass must begin immediately to control this species at the early stages of its invasion into the Mojave Desert.

Ecological Effects

The ecological effects of these alien bunchgrasses in the Mojave and Sonoran deserts are mostly unstudied, but can be easily inferred from the dramatic changes they cause in the structure and function of other native systems. We expect infestations of perennial bunchgrasses that cause monocultures to have both direct and indirect effects on native biota. Of the perennial bunchgrasses, changes due to buffelgrass are the most well documented in warm desert systems. Buffelgrass monocultures that are repeatedly used by livestock may deplete soil nitrogen and carbon rapidly, leaving these systems open to erosion (Ibarra-Flores et al. 1999). Recent studies indicate that livestock production is probably greater when buffelgrass stands are interspersed by native vegetation (Ibarra-Flores et al. 1999). We expect buffelgrass monocultures to change the physical characteristics of soil seedbeds by closing the canopy, thus reducing light and modifying temperatures. It is unlikely that native annual plant populations can coexist within dense stands of buffelgrass. Buffelgrass has the ability to spread into uncultivated areas (Esque and Schwalbe in review). Once established, fires can sweep through buffelgrass stands causing intense fires that selectively reduce densities of arborescent, shrubby, and succulent components of desertscrub communities, increase the dominance of fire-adapted buffelgrass, and thus reduce biodiversity. Buffelgrass is established in several backcountry areas in the arid west including Reserva de la Biosfera El Pinacate y Gran Desierto de Altar, Sonora, Mexico, Cabeza Prieta National Wildlife Refuge, Barry M. Goldwater Air Force Range, and Saguaro National Park (Esque and Schwalbe in review). Although some species will likely benefit from increased productivity in desert habitats, large expanses of alien perennial bunchgrass monocultures are thought to have negative effects on wildlife (Bock et al. 1986), and quail in particular (Hanselka 1988). Lehmann lovegrass is not currently dominant in desertscrub of Sonora (Tom Van Devender, personal communication), but threatens native bunchgrasses in parts of northern Chihuahua (Graciela Melgoza-Hinshaw, personal communication). Lehmann lovegrass is a vigorous perennial bunchgrass capable of escaping cultivated areas even under harsh conditions (Cable 1971) and can dominant plant communities, resulting in changes in their floristic compositions that may be permanent without human intervention (Anable et al. 1992). Lehmann lovegrass is not known to exist in California at this time (Hickman 1993).

Future Trends

Global climate change may increase the dominance of alien annual grasses in the Mojave and Sonoran deserts. Atmospheric concentrations of CO_2 have increased more than 25% since pre-industrial times, and $C0_2$ concentrations in the atmosphere are expected to double before the end of the 21st century (Gammon et al. 1985, Houghton et al. 1990). Large increases in atmospheric $C0_2$ that are characteristic of the past century are known to enhance production of rapidly-growing cool season species such as alien annual grasses (Poorter et al. 1996). The enhancement of alien annual production could ultimately contribute to increased frequency and severity of wildfires in western North America (Mayeaux et al. 1994). Red brome is known to increase total plant production by 20% under elevated atmospheric $C0_2$ with a significant increase in seed production (Lesley DeFalco et al. unpublished data). Increased summer rainfall may also extend the activity period of, or stimulate earlier germination of, exotic annuals thereby increasing their reproductive potentials. Finally, deposition of atmospheric nitrogen from air pollutants may reduce the spatial and temporal heterogeneity of soil nitrogen in the Mojave Desert and alter competitive hierarchies among native and exotic species. For example, experimental addition of nitrogen (3.2 g NH_4N0_3 /m^2/yr) significantly increased density and biomass of exotics and decreased that of natives (Brooks 1998). Species richness of exotics was unaffected, but richness of natives decreased. Deposition rates of 4.5 g/m^2/yr have been recorded in the Los Angeles basin (Bytnerowicz and Fenn 1996), and are associated with high dominance of alien annual grasses and the loss of native shrub communities in that region (Allen et al. 1998). Although current deposition rates are undoubtedly much lower in the Mojave Desert, future rates there will likely increase as human populations and air pollution levels rise.

Management

Preventing invasions is the first and most effective step in managing alien plants. This is especially true for annual plants, which are notoriously difficult to control because of their large seedbanks and efficient modes of dispersal. Remote sensing has been useful in the early detection of alien forb invasions along river drainages in Idaho (Lake 1998), and may be useful in detecting invasions along highways and riparian habitats in the Mojave Desert. Annual grasses such as *Bromus* spp. are best controlled by applying herbicides prior to seedhead formation (Whitson 1998). A naturally occurring black smut often destroys the inner part of the spikelet of red brome (Matt Brooks, personal observation) and may be useful as a biological control agent. Dominance of some alien annual grasses may be minimized by protecting habitat from human disturbances such as sheep grazing and off-highway vehicles (Brooks 1995).

The vast majority of literature about buffelgrass in the desert southwest is focused on the cultivation of this grass rather than its control. However, a control program for buffelgrass has been instituted at Organ Pipe National Monument, and preliminary results from this work will be available soon. In this program participants remove buffelgrass plants by hand (Sue Rutman, personal communication). To date, over 90,000 kg of buffelgrass were removed from the 64 square km treatment area. It took two consecutive years of intensive work to get the upper hand on this species. This program will demand that the treatment area be monitored for signs of re-infestation. Chemical control offers a possibility for the management of buffelgrass, but the results of well-controlled studies of chemical effectiveness are not widely available. This sort of information would be valuable for new control programs. Large control programs are not known in desert habitats of North America at this time.

Isolated fountain grass infestations should be controlled as soon as possible. These grasses are difficult to control once they have established, and can distribute large numbers of wind blown seeds.

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