Effects of Invasive Plants on Public Land Management of Pinyon-Juniper Woodlands in Arizona

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Abstract—*After a short discussion of terminology used in the fairly new discipline of weed science, specific examples are given to illustrate effects of invasive plants on recreation and scenic values, biodiversity, forage for domestic animals and wildlife, soil stability, fire hazard and frequency, maintenance costs for roads and highways, property values, and funding for other resource management activities.*

Introduction

Weed Science is a new discipline, (the first courses in weed science taught in a university were probably at the University of California at Davis in the late 1930s). One result of this is that basic terminology is still the subject of discussion and disagreement among those who work full-time managing invasive plants. Miscommunication with the public may occur, since many of these terms are commonly used words that have technical meaning for the weed professional. For the purpose of clarity, a few definitions will be given at the outset of this paper.

The definition of an invasive plant by President Clinton's Executive Order 13112, February 1999 (Clinton 1999), while anthropologically-based rather than based on ecological processes, serves the purpose of a widely recognized definition: "An **invasive plant** is an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health." Further, "**alien species**" means, with respect to a particular ecosystem, any species, including its seeds, eggs, spores, or other biological material capable of propagating that species, that is not native to that ecosystem. **Noxious weeds** are those plants that have been designated by some governing agency as a regulated pest, often due to invasive characteristics. Thus, "noxious weed" is more of a legal than ecological term. **Exotic species** is another term for alien species, except that it normally implies the species has been introduced not only from outside the ecosystem, but outside the country.

Below is a list of invasive plant species that may be found growing in the Pinyon-juniper grassland vegetation type in central Arizona (table 1). Starred species are those discussed in this paper.

Deterioration of Recreation and Scenic Values

Invasive plants such as yellow and Malta starthistle (*Centaurea solstitialis* and *C. melitensis*) and leafy spurge (*Euphorbia esula*) aggressively move into relatively undisturbed plant communities, often in and around sites that have been valued for both dispersed and developed recreation. Objectionable characteristics

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Table 1—Invasive plants that grow in pinyon-juniper grassland vegetation type in central Arizona[1].

Russian knapweed*	*Acroptilon repens*
Tree of heaven*	*Ailanthus altissima*
Camelthorn*	*Alhagi maurorum* (lower elevations)
Giant reed	*Arundo donax*
Onionweed	*Asphodelus fistulosus*
Wild oats*	*Avena fatua*
Black mustard*	*Brassica nigra*
Red, ripgut, downy, Japanese bromes*	*Bromus rubens, B. rigidus, B. tectorum, B. japonicus*
Lens-podded & globe-podded hoary cress	*Cardaria chalepensis, C.draba*
Hairy white-top	*Cardaria pubescens*
Plumeless thistle	*Carduus acanthoides*
Musk thistle	*Carduus nutans*
Southern & field sandbur	*Cenchrus echinatus, C. spinifex*
Diffuse knapweed	*Centaurea diffusa*
Malta starthistle*	*Centaurea melitensis*
Yellow starthistle*	*Centaurea solstitialis*
Spotted knapweed	*Centaurea stoebe ssp. micranthus*
Rush skeletonweed	*Chondrilla juncea*
Canada thistle	*Cirsium arvense* (higher elevations)
Bull thistle	*Cirsium vulgare* (higher elevations)
Field bindweed	*Convolvulus arvensis*
Common teasel	*Dipsacus fullonum*
Russian olive	*Eleagnus angustifolia* (lower elevations)
Quackgrass	*Elymus repens* (higher elevations)
Weeping & Lehmann's lovegrass	*Eragrostis curvula & E. Lehmanniana*
Leafy spurge*	*Euphorbia esula*
Euryops subcarnosus*	Sweet resinbush
Dyer's woad	*Isatis tinctoria*
Dalmatian toadflax*	*Linaria dalmatica*
Yellow toadflax*	*Linaria vulgaris*
Purple loosestrife	*Lythrum salicaria*
Yellow sweetclover	*Melilotus officinalis*
Globe chamomile	*Oncosiphon piluliferum*
Scotch thistle*	*Onopordum acanthium* (higher elevations)
Fountain grass	*Pennisetum setaceum* (lower elevations)
Karoo bush	*Pentzia incana*
Japanese knotweed	*Polygonum cuspidatum*
Russian thistle	*Salsola kali*
Wild mustard*	*Sinapis arvensis*
Salt cedar*	*Tamarix pentandra, T. chinensis, T. ramosissima*
Siberian elm	*Ulmus pumila*
Periwinkle	*Vinca major*

[1] Occurrence in pinyon-juniper ecosystems according to the following sources:

USDA Forest Service Fire Effects Information System:
http://www.fs.fed.us/database/feis/plants/index.html

CRISIS (California Regional Invasive Species Information System) database:
cain.ice.ucdavis.edu/crisis/crisismaps/

SWEPIC (Southwest Exotic Plant Information Clearinghouse) database:
http://sbsc.wr.usgs.gov/research/projects/swepic/swemp/sbscmain.asp

University of California Exotic Pest Plant Council
http://ucce.ucdavis.edu/datastore/datareport.cfm?reportnumber=42

such as spines, sap that is extremely irritating to skin, or toxicity to humans and/or domestic animals create environments that people prefer to avoid. The nearly inch-long spines of yellow starthistle plants growing in dense infestations make walking across a meadow a daunting endeavor. Malta starthistle grows in camping areas on the Tonto National Forest that have been abandoned by the public.

Invasive plants are able to out-compete native vegetation in several ways. Many of central Arizona's invasive plants are cool-season annuals. They begin growth in the late fall, overwinter as rosettes, and complete their life cycle in the early spring. They typically germinate and put down roots before native annuals do, so that they are able to monopolize use of water in the top few inches of soil. In addition, they germinate through a continual period of a few months, so that there are roots at varying soil depths, using soil water completely.

Leafy spurge, a perennial, has an extremely fast-growing root system and also reproduces by seeds that are shot out of fruit capsules to a distance of 15 feet when temperatures are high and humidity is low (Simonin 2000). The seeds typically have high viability. Roots are covered by buds that can form new plants if the mother plant is tilled and broken into parts. Root reserves of perennial weeds allow them to sprout earlier than native annual plants growing in the same area. Leafy spurge has milky white sap that may cause severe irritation to human skin and is reported to cause blistering and hair loss on the legs of horses in heavily infested areas.

Salt cedar (*Tamarix* spp.) has invaded floodplains of several rivers in the western U.S. Salt cedar is not restricted to a greenline adjacent to rivers, but can withstand xeric conditions much better than native riparian woody species such as cottonwood (*Populus fremontii*) and willows (*Salix* spp.), and grows in a much broader band along streams. In areas with dense infestations of salt cedar, it may be difficult for river recreationists to find take-out points, or camping spots anywhere on the floodplain or adjacent low terraces.

Salt cedar has rapidly invaded streambanks of the Upper Verde River in recent years. When the season of seed dispersal of salt cedar, as compared to the native cottonwood and willow, is considered, it is easy to understand its competitive advantage even in natural, undisturbed situations. Salt cedar produces seed over a period of many months, from spring through October or later, while cottonwood and willow produce seed for only a period of weeks in the spring (Merkel and Hopkins 1957). Native riparian trees have evolved to produce seed in synchronicity with winter snowmelt/precipitation events in early spring. This climatic pattern produces high stream flows that leave deposits of fine silt as they recede, which are prime locations for germination and establishment of native tree species. Salt cedar uses this scenario to establish, but is also able to establish after summer storms have left similar silt deposits along the river.

Russian knapweed (*Acroptilon repens*) reduces competition from other plants by what is called allelopathy, or the production of biochemicals that inhibit the growth of other plants (Beck 2004). While conversion of a biologically diverse community to a monoculture of Russian knapweed is not aesthetically pleasing, this plant can also have devastating effects on members of the recreating public who enjoy bringing horses onto public lands.

Ingestion of significant quantities of Russian knapweed or yellow starthistle by horses can cause "chewing disease" which is characterized by fatigue, lowered head, an uncontrolled rapid twitching of the lower lip, tongue-flicking, involuntary chewing movements, and an unnatural open position of the mouth. Poisoning occurs after a horse has ingested at least 60 percent of its body weight over a two month period (Panter 1990, 1991). There is no effective treatment for either yellow star thistle or Russian knapweed poisoning because the affected areas in the brain undergo necrosis and do not regenerate.

Opportunities for anglers in streams within the pinyon-juniper vegetation type can be reduced by invasive species. Plants such as bull thistle (*Cirsium vulgare*), Scotch thistle (*Onopordum acanthium*) and yellow starthistle are extremely spiny, changing the activity of walking streambanks from a pleasant stroll to a fight to avoid or pull spines out of gear or clothing. Plants such as Japanese knotweed (*Polygonum cuspidatum*) spread quickly to form dense thickets that exclude native vegetation and greatly alter natural ecosystems. Knotweed is able to rapidly colonize riparian areas after scouring floods, making impenetrable thickets that prevent anglers from accessing the water's edge.

Reduction of Biodiversity

Russian knapweed was mentioned above as producing chemicals that serve to reduce its competition. Leafy spurge also exhibits allelopathy: extracts from the roots of leafy spurge are leached into the soil wherever the weed grows. These extracts inhibit the germination and growth of other plants in the surrounding area (Nova Scotia Department of Agriculture and Fisheries 2003).

The production of toxic chemicals by tree of heaven (*Ailanthus altissima)* may explain the success of this plant. An aqueous extract of *Ailanthus* leaves has been shown to be toxic to 35 species of gymnosperms and 10 species of angiosperms (Mergen 1959).

Other invasive plants accomplish this same result by various means: germination occurring over a several-month period serves the same purpose by depleting the entire soil profile of available water. A sharp demarcation zone at the front of a sweet resinbush (*Euryops subcarnosus*) infestation in southern Arizona was not due to allelopathy, but to extremely efficient uptake of water by the resinbush, leaving none for the native plants. The invasive front of sweet resinbush creates monocultures, excluding normally prevalent half-shrubs like false mesquite (*Calliandra eriophylla*), shrubby buckwheat (*Eriogonum wrightii*), and even snakeweed (*Gutierrezia sarothrae*) (Pierson and McAuliffe 1995).

Extensive root systems of some perennial invasives crowd out other species. What is often left is a monoculture. When vegetation is reduced to this level of sameness, biodiversity in the animal community also is reduced drastically.

Salt cedar is able to use salty water by absorbing the salts through cell membranes. It avoids the toxic effects by using special glands to excrete the salts and by dropping salt-filled leaves. The leaves dropped each fall accumulate to a considerable depth under the canopy. Through this process, salt cedar acts as a salt pump concentrating salts from deep in the ground onto the soil surface. Over time, salts in the mulch layer kill existing plants and prevent others, especially desirable riparian species, from becoming established. As a result, the ground under a salt cedar or within a salt cedar thicket is devoid of plants except, on occasion, another salt tolerant species (Johnson and others 2002).

Black and wild mustards (*Brassica nigra, Sinapis arvensis*) replace other native and invasive species by growing in high densities, using soil nutrients and moisture before other plants. It often causes native annuals to die early in the spring, due to lack of available soil moisture (Brooks 2003).

Toadflaxes *(Linaria* spp.) commonly displace existing plant communities and associated animal life. Both yellow (*L. vulgaris*) and Dalmatian toadflax (*L. dalmatica*) are sold commercially as ornamentals, despite being on noxious weed lists of many states in the United States. These species grow in many different habitat types and climatic regimes. They have become very difficult to manage, as they have now evolved biotypes with variable responses to herbicide treatments (Lajeunesse 1999).

Reduced Forage for Domestic Animals and Wildlife

When leafy spurge infests pastures, herbage production can be reduced by as much as 75 percent (Lym and Messersmith 1985). Cattle will avoid grazing an area with as little as 10 percent cover of leafy spurge (Hein and Miller 1992). If horses are permitted to walk in areas with leafy spurge, the sap will cause severe blistering and hair loss on their feet (Nova Scotia Department of Agriculture and Fisheries 2003). It is reported to cause severe irritation of the mouth and digestive tract in cattle, which may result in death (Whitson 2002).

Dense Dalmatian toadflax infestations adversely impacts livestock and wildlife by replacing vegetation that would normally sustain them (Lajeunesse 1999). Dalmatian toadflax is rarely eaten by wild or domestic animals and has a deep and extensive root system that makes it difficult to control.

Increased Soil Erosion

Elimination of grasses by sweet resinbush has led to a dramatic increase in exposure of bare soil, and increased soil erosion (Pierson and McAuliffe 1995). In a sweet resinbush site in Marijilda Canyon, in southern Arizona, the bare soil created by the dominance of this species resulted in soil that moved more easily. Exposed roots and soil pedestals around bases of the few remaining native grasses were evident in the zone adjacent to the resinbush infestation.

Where Dalmatian toadflax replaces sod-forming or bunch grasses, erosion increases (Lajeunesse 1999). Scotch thistle (*Onopordum acanthium*) also has been documented to replace native bunchgrasses and sod-forming grasses (Beck 1999).

In addition to their above-ground attributes, many invasive weeds such as the biennial thistles have taproots, and replace the more fibrous-rooted streamside sedges and grasses. Fibrous roots give structure to loose stream bank sediments, preventing them from caving off during high flows. Fibrous roots actually create fish habitat by holding upper sediment layers in place as overhanging banks, which fish use as hiding or spawning cover. Soil erodes from around tap-rooted plants, leaving a gradually sloping stream bank that provides no cover for fish.

Increased Fire Hazard and Increased Fire Frequency

Salt cedar disrupts the structure and stability of native plant communities and degrades native wildlife habitat by out-competing and replacing native plant species, monopolizing limited moisture, and increasing the frequency, intensity and effect of fires (Muzika and Swearingen 2006).

Wild oats *(Avena fatua)* is a cool-season annual grass, drying out by late spring, to provide a source of dry standing fuel to carry fires from rights-of-way along highway into adjacent lands. It is frequently a contaminant in seed mixes or in straw mulch used during revegetation of highway construction projects.

A dramatic increase in fire size and frequency has been observed in pinyon-juniper woodlands as cover of nonnative annuals such as cheatgrass (*Bromus tectorum*) increases (Miller and Tausch 2001). Where fires have burned in pinyon-juniper woodland invaded by cheatgrass in Nevada, the woodland is being replaced by great expanses of annual grassland dominated by cheatgrass. (Billings 1994)

Cheatgrass forms a dense, uniform carpet that out-competes native grasses, trees and shrubs. It greens quickly, dries quickly and produces a very flammable cover that often burns completely, without allowing native plants to reestablish. In pinyon-juniper woodlands, the combination of cheatgrass and fire may effectively prevent the re-establishment of the original woodlands (Mitchell 2000).

Red brome (*Bromus rubens*) is a similar cool-season annual exotic grass that dries by early monsoons, and is easily ignited. Dense populations that grow during wet winters fuel fires through the several vegetation types where this species grows, including the pinyon-juniper type (personal observation). Japanese brome (*Bromus japonicus*) typically grows at higher elevations than red brome. The fire hazard it creates is not as significant an effect to the vegetation types in which it grows, which are typically adapted to fire frequencies of 5 to 7 years. However, it moves into forests and rangelands where grazing or other disturbance have reduced the competitiveness of native grasses, and replaces them, changing perennial grasslands to annual grasslands (Howard 1994).

Buffelgrass (*Pennisetum ciliare*) and fountaingrass (*Pennisetum setaceum*) currently grow in Arizona at elevations below the pinyon-juniper vegetation type. They are moving north, and are currently moving into the edges of higher elevation vegetation types (personal observation). New varieties of buffelgrass have recently been developed by the Texas Agricultural Experiment Station and USDA Agricultural Research Service that will be able to withstand lower winter temperatures, giving this plant a new ability to invade higher elevation ecosystems in Arizona (Hussey and Burson 2005). Both species are perennial bunchgrasses that provide enough fuel to create intense fires that can destroy native shrubs, trees and cacti.

Increased Maintenance Costs for Roads and Highways

Camelthorn (*Alhagi maurorum*) can grow through pavement, and the thorns can flatten car tires. Where it grows near highways, it causes extensive cracking in the asphalt, and constant road repairs are necessary (Horsley 2004). Other invasive species, such as knapweeds and starthistles can grow densely along highways, where they are likely to catch fire and burn guardrail support posts (personal observation).

Reduction in Property Values

At the 2005 meeting of the Western Governor's Association, a resolution was passed, recognizing that invasive or undesirable aquatic, riparian and terrestrial species influence the productivity, value, and management of a broad range of land and water resources in the West (Western Governor's Association 2005). They listed "significant negative economic, social and ecological impacts that include, but are not limited to:

a. Reduction of the yield and quality of desirable crop forage plants;
b. Poisoning of livestock;
c. Reduction of native biodiversity resulting in a growing number of threatened, endangered and extinct species;
d. Adverse affects upon human health through allergies, poisoning, and harboring vectors;

e. Degradation of natural aquatic systems including obstruction of water flow in irrigation and drainage systems;
f. Reduction of the value of streams, lakes, reservoirs, oceans, and estuaries for fish and wildlife habitat, and public water supply;
g. High cost of control;
h. Increase in facilities maintenance costs such as power plants, water treatment plants, etc.;
i. Detracting from the aesthetics and recreational value of wildlands, parklands, and other areas;
j. Decreased real estate property value and increased costs of property development; and
k. Competition with or transmission of diseases to wild Pacific salmon or other important marine and aquatic species."

Diversion of Funding from Other Resource Management Activities

An estimated 3.5 million acres of National Forest System lands are infested with invasive weeds, according to the 2000 RPA assessment, which summarized local estimates from individual national forests (USDA Forest Service 2001). However, local estimates vary widely, and the agency lacks a comprehensive inventory. Increasing percentages of budgeted funds must go to inventory and manage invasive weeds on National Forest lands. What makes this one of the Forest Service Chief's "Four Threats" to management of National Forest Lands (Bosworth 2006) is that if adequate funds are not allocated and effectively used to control incipient infestations, our cost to control large infestations will be beyond what we will ever receive from Congress.

Summary

Invasive plants have a profound and far-reaching effect on many aspects of management of public lands, yet their management often receives very little emphasis or funding. Especially in areas where invasive species have not developed large infestations, public land management agencies tend to have a fair degree of apathy regarding their management. It is important to educate the public about invasive plants, but even more important to raise awareness among public land management specialists, including range conservationists, soil scientists, wildlife biologists, and recreation specialists about the effects these plants can have on their resources. And finally, unless land management agencies and policy makers at all levels of government—federal, state, county, and local—recognize this issue and provide funding to deal with it, weed infestations will grow to levels where there simply is not enough funding to control the problem.

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