Invasive Grassland-Rangeland Plants of China and the United States of America

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Key points : Alien invasive plants can transform biotic communities and interfere with ecological processes . Invasive plants in the 17 western United States are estimated to cover 53 .8 million ha with an expansion rate of 680 ,000 ha per year . Similar information for the grasslands of China was not found . Total cost of invasive plants in the USA has been estimated at $40 billion per year , while total economic loss from invasive organisms in China has been given at $14 .5 billion . The commonality of climate , floral and faunal affinity and increasing commerce and travel between the China and North America and other entities provides for high potential for biotic invasions to what many consider pristine grazing lands . It is suggested that a survey for invasive species in China grasslands be initiated . A general invasive species management plan would include : prevention , early detection and rapid response , control techniques and restoration of invaded sites .

Key words : alien , invasive , plants , survey

Introduction

Biological invasion is one of six symptoms of global environmental change (Vitousek et al . , 1996) . Introduced species , those dispersed outside their natural ranges by humans , now cause almost all biological invasions" (Alpert , 2006) . Biological invasion between China and the United States of America is potentially large and is a growing threat to both nations (United States Geographical Survey , no date) . The similarity in climate , flora and fauna (Guo , 2002) and increasing commerce and travel between the two nations is recognized . The variety of habitats and environmental conditions makes China especially vulnerable to the establishment of invasive species of foreign origin (Yan et al . , 2001) . In addition , there is much horticultural and agricultural prospecting" for plant materials for the USA markets (United States Geographical Survey (USGS , no date) . Hence , examining the presence or potential of invasive plants originating from both countries as invasive threats is of mutual interest . Invasive plants occupy over more that 53 .8 million ha in the western USA and are spreading at a rate of 0 .68 million ha per year (Western Forestry Leadership Coalition , 2005) .

Invasive plant species have been attracting more attention within the past 15 years , because this is an emerging area of ecological study and global biological impacts , and they carry a large associated economic cost . Liu et al . (2005) found that socio-economic factors , such as human density and economic Gross Domestic Product (GDP) positively correlated with species richness of alien invasive plants in China . Richness of invasive species was influenced by natural conditions , and human disturbances , while native plants richness was determined by natural processes . Direct and indirect economic losses from invasive species in China were given to be $14 .45 billion (Xu et al . , 2006) . Economic loss from all alien invasive species in the United States given by Pimentel et al . (2000) was $138 billion . Xu et al . (2006) reported that the proportion of economic loss from invasive species between China and the US is similar . The US data included losses associated with Acquired Immune Deficiency Syndrome (AIDS) and losses to native birds from alien pet cats . If those data had been included in the Chinese estimates , the damage by alien invasive species in China would be more serious that in the United States (Xu et al . , 2006) .

Exchange or introduction of biological organisms among continents and ecosystems adds to ecological complexity .
Trade between China and the United States has grown from about $200 million in 1978 to over $6 billion in 2002 (Jenkins and Mooney , 2006) . Normile (2004) reported that scientists in the United States and China are trying to cope with an unintended consequence of increasing economic activities and a two-way flow of unwelcome plants and animals . Considering increasing global economic activity , the prospect that some organisms may escape their point(s) of introduction , invade local habitats and become a naturalized alien invasive species is realized . Rules of ten" states that species that become truly invasive are rare compared to the total population of all introduced species (Williamson , 1996) . For example , if one hundred different species are introduced , about ten become established outside their point of introduction but only one of those ten aggressively invades through the landscape . The percentage of plants that become invasive is low but those that do can greatly transform ecosystems (Richardson et al . , 2000) .

The objectives of this paper are : (1) to examine the invasive plant species of China and the western United States , (2) briefly describe the ecological state of grasslands of China and western USA , and (3) outline a general invasive plant species strategy for their management and control .

China Grassland-Rangeland Invasion

Ellis (1992) reported total grasslands in China were 400 million hectares or about 42 % of China's land area . About half of

those grasslands are in northern China . Zhang (1992) describes three general vegetation types for northern China including , steppe , meadow and desert steppe . These lands are reported to have declining productivity because of degradation and are degraded by wind and water erosion . Simultaneously , large areas are reported to be desertified . In the description of the vegetation of the northern China grasslands , there is no mention of plant invasive species . Zhang (1992) provides a rational management plan for northern China grasslands that follows seven basic steps , primarily emphasizing range and livestock management practices , without any indication of invasive plant species being a problem .

While there is apparently little information about invasive plants in northern China , Yan et al . (2001) report that 380 species of vascular plants have become invasive in China . Xu et al . (2006) and Callaway et al . (2006) stated that there are 283 invasive species in China , of which 55 % originated from America . Invasive alien plants (Table 1) are reported from all areas in China but some of the more remote parts of the country provide little information about the presence of invasive plants . While cosmopolitan invasive plants like *Conysa spp* . (horsetail) and *Traxacum officinale* (dandelion) are likely to be present in northern China , other common invasive plants are also likely present . Liu et al . (2006) reported on 126 alien invasive plant species in China and examined the role of clonality in those species . Almost half of those plants (44%) were clonal and , of the 32 plants considered , the most invasive of the group studied , 66 % were clonal . Liu et al . (2006) also stated that the number of invasive plant species decreases toward the western and northern parts of China . America was the source of most of the alien invasive plants in their study . With the wide range of similar environments and biota , each of these geographical regions (China and North America) may be more susceptible to each other's immigrant plants than species from other parts of the world (Guo , 2002 ; Liu et al . , 2006) .

Table 1 *Partial list of invasive species in China-Plants (China Species Information System) . Alphabetical by family . http ://monkey .ioz .ac .cn/bwg-cciced/english/cesis/invasive .htm) .*

Invasive plant	Common name	Family
Alternathera philoxeroides	alligator weed	Amaranthaceae
Alternathera pungens	springflower alternathera	Amaranthaceae
Amaranthus spp .	pigweed	Amaranthaceae
Ageratum conyzoides	tropic ageratum	Asteraceae
Ambrosia spp .	common ragweed	Asteraceae
Conyza spp .	horseweed	Asteraceae
Erigeron annuus	daisy fleabane	Asteraceae
Eupatorium adenophorum	crofton weed	Asteraceae
Mikania micrantha	South American climber	Asteraceae
Solidago altissma	tall goldenrod	Asteraceae
Opuntia spp .	cactus	Cactaceae
Triodanis spp .	Venus looking glass	Campanulaceae
Chenopodium ambrosioides	Mexican tea	Chenopodiaceae
Plantago spp .	plantagia	Plantaginaceae
Lolium temulentum	Darnel ryegrass	Poaceae
Spartina anglica	common cordgrass	Poaceae
Eichhornia crassipes	water hyacinth	Pontederiaceae
Solanum aculeatissimum	love apple	Solonaceae
Duranta repens	golden dewdrop	Verbenaceae

China has a total of 287 million ha of grasslands (Zhang , 2004) . China's grasslands are often said to be degraded , resulting in areas of bare soil , high soil erosion rates and making the affected grasslands nearly useless . The area of degraded grasslands amounts to tens of millions of hectares . Causes for this degradation are human impacts including : increase in human population , over-extension of agriculture , and overgrazing by domestic livestock (Ellis , 1992) . China's grasslands are threatened by severe desertification and deterioration (Wu and Loucks , 1992) and the tendency of desertification and deterioration is more conspicuous in the grasslands of the Inner Mongolia Autonomous Region (Zhang , 2004) . In describing vegetation dynamics of the Xilingele area of northern China , Wu and Loucks (1992) discussed degradation of the landscape from stable climax states and decreased productivity , however the presence of invasive plant species are not mentioned as part of observed grassland changes . Similarly , Wan and Tian (1992) discussed pests and pathology as factors influencing the grasslands of northern China , but no mention of invasive plant species were made in this portion of their paper . However ,

Zhang (1992), reporting about the Xijiang province of northwest China, stateed that because of land degradation and overgrazing, poisonous weeds propagate easily and cover large areas threatening grazing animals. There was no indication in the paper if these plants were native or of alien origin. According to Xu Zhu, head of the Grassland Research Institute of the Chinese Academy of Agricultural Sciences, as stated in Zhang (2004), China is not behind others in technologies for rehabilitating, improving and managing deteriorated grasslands". While grassland deterioration is recognized in China and is being addressed, it has only been in recent years that the concept of invasive species was introduced to China and their threats to China's natural heritage are not yet widely recognized (Yan et al., 2001).

United States Grasslands-Rangelands Invasion

Approximately fifty percent of the United States Land area can be classified as rangelands. Of that land area, 91 million ha are classified as grasslands and 129 million ha are grazable woodlands, shrublands and deserts (Holechek et al., 2004) for a total of 220 million ha of rangelands. These lands have experienced deterioration over the past 150 years from overstocking by domestic livestock, farming of marginal land, development of human settlements and transportation corridors and from poor management during periods of drought and from suppression of natural landscape processes such as wildfires. In addition to those threats, current threats include division of some of these lands to ranchettes" for people desiring to be away from urban areas and for second homes. The impact of global climate change on the grasslands/rangelands of the United States is poorly documented and may result in many transitions of the current plant communities, such as adjustments of ecosystem limits. For example, the pinyon-juniper woodlands may progress to higher elevations and more northern latitudes as a result of long-term global warming. Another common scenario is for the warm deserts of southwestern USA to expand to adjacent bioregions. There is growing evidence that carbon dioxide, the primary gas contributing to the greenhouse effect and global warming, influences invasive plants. Ziska and George (2004) reported that a review of literature indicated that invasive plants have a larger than expected growth increase to both recent and projected increases of atmospheric carbon dioxide. Rogers et al. (2007) found that grasses showed a smaller growth response to elevated carbon dioxide compared to other invasive plant species. Plant invasions are clearly linked to surface soil disturbances and atmospheric disturbance by changing concentration of gases also in contributing to the ecophysiology of plant invasions.

Invasion of North American grasslands and rangelands began with the arrival of European people. The earliest plant invasion sites were in the southwestern part of the continent following Spanish settlements. The greatest increase in invasive plants occurred after 1850 as the western part of the United States was settled by peoples of foreign origin, primarily European, however, persons from Asia also were immigrating to North America. Some of the invasive plants were intentionally introduced and others were hitch hikers" that arrived as contaminates in agricultural crops or in the hair/wool of domestic animals. Invasive plants in the 17 western United States are estimated to cover 53.8 million ha with an expansion rate of 680,000 ha per year (Western Forestry Leadership Coalition, 2005).

About 3,310 non native plant species occur within natural areas of the 48 continental United States (Duncan and Clark, 2005). In the seventeen western United States, Duncan and Clark (2005) reported that 16 key invasive plants occupied 44.2 million hectares. Invasive plants from China to the grasslands of North America include: *Tamarix ramosissima* (saltcedar), *Salsola spp.* (Russian thistle and other tumbleweeds") and *Carduus* and *Cirsium spp.* of the thistles" genera.
Table 2 contains a list of 25 invasive plants from Whitson et al. (2002) that indicates origins from Eurasia or Asia. Probably the most invasive plant in the western USA, *Bromus tectorum* (cheatgrass), is of more European origin and may be a likely invasive weed in China or one that has great invasion potential.

Table 2 *Invasive plants, in alphabetical order by family, of Asian or Eurasian origin commonly found in the western United States of America (Whitson et al., 2002).*

Invasive plant	Common name	Family
Acroptilon repens	Russian knapweed	Asteraceae
Carduus acanthoides	plumeless thistle	Asteraceae
Centurea maculosa	spotted knapweed	Asteraceae
Chondrilla juncea	rush skeletonweed	Asteraceae
Cirsium arvense	Canada thistle	Asteraceae
Cirsium vulgare	bull thistle	Asteraceae
Tragopogon dubius	western salsify	Asteraceae
Chorispora tenella	blue mustard	Brassicaeae
Lepidium latifolium	perennial pepperweed	Brassicaeae

Invasive plant	Common name	Family
Stellaria media	common chickweed	Caryophyllaceae
Halogeton glomeratus	halogeton	Chenopodiaceae
Kochia scoparia	kochia	Chenopodiaceae
Euphorbia esula	leafy spruge	Euphorbiaceae
Alhagi pseudoalhagi	camel thorn	Fabaceae
Sphaerophysa salsala	Swainson pea	Fabaceae
Abutilon theophrasti	velvet leaf	Malvaceae
Polypogon monspeliensis	rabbitfoot polypogon	Poaceae
Taeniatherum caput-medusae	medusa head	Poaceae
Polygonum aviculare	prostrate knotweed	Polygonaceae
Polygonum cuspidatum	Japanese knotweed	Polygonaceae
Linaria vulgaris	yellow toad flax	Scrophuluriaceae
Veronica biloba	bilobed speedwell	Scrophuluriaceae
Veronica persica	Persian speedwell	Scrophuluriaceae
Tamarix ramosissima	salt cedar	Tamaricaceae
Peganum harmala	African rue	Zygophyllaceae

Invasive Plants Survey and Management Planning

Invasion ecology may profit from collaborative study with a group of scientists for a survey of the invasive plants of the grasslands/rangelands of northern China . The first step in such a survey would be to examine existing taxonomic floras . Factors that determine invasive species distributions are important to know to develop effective strategies for their control and management . Guo (2006) suggests that studies of the invasive species compared to its distribution in its native and invaded areas could help in this matter . Suggested items for study included : (1) limiting factors for distributions in native ranges , (2) factors associated with a high degree of invasiveness , (3) changes in genetics and morphology since introduction , and (4) future directions and rates of invasion for developing detection and warning systems (Guo , 2006) .

Knowing whether introduction tends to give organisms specific ecological advantages or disadvantages in their new habitats could also help to understand and control invasions (Alpert , 2006) .

Yan et al . (2001) suggested using middle to large sized cities and the surrounding countryside to inventory all life forms of invasive plants and predict their impacts to native species composition , plant production and food chains in a large watershed . Another step would be to integrate this information into a long-term monitoring plan to document changes in the ecology of the area and species structure in the study area . A strategic plan for invasive plant management should include : (1) inventory of existing plant populations including mapping of species distribution , (2) prevention of new introductions of known invasive species , and policies concerning transporting known invasives to adjacent landscapes , (3) early detection of small populations of new invasives , (4) rapid response to control new invasions , which may be more easily controlled that extensive infestations , (5) develop integrated control treatments using biological , chemical , mechanical , fire and cultural practices for established infestations using an integrated pest management approach , (6) restoration of the site after invasive species removal (Brock , 2005) .

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