

Invasion note

Dominance of non-native riparian trees in western USA

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Abstract

Concern about spread of non-native riparian trees in the western USA has led to Congressional proposals to accelerate control efforts. Debate over these proposals is frustrated by limited knowledge of non-native species distribution and abundance. We measured abundance of 44 riparian woody plants at 475 randomly selected stream gaging stations in 17 western states. Our sample indicates that *Tamarix ramosissima* and *Elaeagnus angustifolia* are already the third and fourth most frequently occurring woody riparian plants in the region. Although many species of *Tamarix* have been reported in the region, *T. ramosissima* (here including *T. chinensis* and hybrids) is by far the most abundant. The frequency of occurrence of *T. ramosissima* has a strong positive relation with the mean annual minimum temperature, which is consistent with hypothesized frost sensitivity. In contrast the frequency of occurrence of *E. angustifolia* decreases with increasing minimum temperatures. Based on mean normalized cover, *T. ramosissima* and *E. angustifolia* are the second and fifth most dominant woody riparian species in the western USA. The dominance of *T. ramosissima* has been suspected for decades; the regional ascendance of *E. angustifolia*, however, has not previously been reported.

Introduction

Along rivers in the dry interior of the western United States, Eurasian trees are replacing native riparian species. The most widely naturalized taxa are *Tamarix ramosissima* Ledeb. (saltcedar; here we include the closely related *T. chinensis* Lour. and hybrids; Baum 1978, Gaskin and Schaal 2002) and *Elaeagnus angustifolia* L. (Russian-olive; Olson and Knopf 1986). Costs of this change include loss of plant and animal diversity and decreased streamflow and channel conveyance (Brock 1994; Di Tomaso 1998; Shafroth

et al. in press; Katz and Shafroth 2003). Benefits include sediment stabilization and provision of vertebrate habitat along regulated, salinized rivers that no longer support native riparian trees (Everitt 1980; Stromberg and Chew 2002).

T. ramosissima and *E. angustifolia* are already targets of chemical, physical, and biological control efforts costing millions of dollars per year (Zavaleta 2000). Greatly accelerated control efforts are under debate in the US Congress and state legislatures. In 2004, US Senate Bill 1516 proposes to spend \$50 million on control of non-native riparian trees for water salvage. The

debate has been frustrated by limited knowledge of non-native species distribution and abundance and the underlying environmental influences. Maps of *T. ramosissima* distribution are still based on a survey carried out more than 40 years ago (Robinson 1965) and even less is known about the distribution of *E. angustifolia* (Katz and Shafroth 2003).

Most of our knowledge of plant distribution comes from herbarium records and other non-systematically collected observations. These observations are important, in part because of their great numbers. Analyses of distribution and abundance based on such observations, however, have limitations. First, because search effort is spatially clumped, and because species absence at a site is typically not reported, it is difficult to distinguish between absence of a species and absence of a search in any location. This limitation degrades the precision of species-environment relations based on herbarium data. Second, herbarium records typically do not include information on abundance, making it difficult to assess the relative dominance of a species. Our goal was to augment ongoing studies based on herbarium samples with a systematic, representative sample of riparian plant communities.

We measured abundance of *T. ramosissima*, *E. angustifolia*, and 42 other widespread native and non-native riparian woody plants at 475 randomly selected stream gaging stations across the conterminous western United States. Here we focus on the present distribution of *T. ramosissima* and *E. angustifolia*, their abundance relative to other common woody riparian species, and the influence of winter cold temperatures on their occurrence.

Materials and methods

We measured abundance of 44 large (>1.5 m tall), widespread woody riparian plants at 475 randomly selected sites in the 17-state region of the USA bounded on the east by the 100th meridian and on the west by the Pacific Crest. Nomenclature follows USDA (2004). Study sites were stream-valley reaches near US Geological Survey gaging stations with daily discharge data for at least 20 years between 1965 and 1994. The

1539 gages that met this criterion were spatially clumped. To achieve a representative sample of riparian areas across the region, we randomly selected 500 gages using a sampling design in which the probability of selecting a gage was weighted by the land area closer to that gage than any other. We eliminated 25 study sites (5%) because of lack of legal access.

There is bias in the location of US Geological Survey gaging stations toward perennial, intensively used streams and accessible locations. Because *T. ramosissima* is drought tolerant compared to native species in the *Salicaceae* (Busch and Smith 1995) the bias against ephemeral streams should lead to under-representation of *T. ramosissima* in our data set. On the other hand, the bias toward intensively used streams and accessible reaches should lead to over-representation of the non-native species. We countered the tendency of gages to occur at bridges by sampling a long reach (mean = 1.3 km), by sampling only naturally established vegetation, and by shifting the location of the mapped reach as much as a few kilometers when patterns of natural vegetation at the gage were obscured by human activity.

We visited every site once between 1997 and 2002 and used aerial photographs to map the overstory cover of each of the 44 species within the area that is inundated at least once every 30 years. Reach length ranged from 0.14 to 5.07 km (mean = 1.3 km). To ensure uniform search effort across sites, visits were limited to 1–3 h regardless of the size or complexity of the area. We used a telescope for identification of inaccessible plants. Aerial photographs were acquired from the National Aerial Photography Program (image scale 1:40,000; date > 1986) and enlarged by a factor of four. Using clear overlays we divided each study area into relatively uniform patches of vegetation and visually determined the canopy cover of each species in each patch. All field visits were carried out by one of the first six authors. Prior to the study, this team standardized the method by training together at sites in Arizona, Colorado, and Montana. Overlays were scanned and areas of polygons were determined using ArcInfo (Version 8.1, Environmental Systems Research Institute, Redlands CA).

Distinguishing *Tamarix* species is difficult in the field. *T. ramosissima*, *T. parviflora* DC., *T. canariensis* Willd., *T. aphylla* (L.) Karst., and other species and hybrids are present in the western United States (Gaskin and Schaal 2002), and only *T. aphylla* is easily distinguished from the others. Therefore, when we found *Tamarix* other than *T. aphylla* we collected specimens for identification by John Gaskin (Gaskin and Schaal 2002).

We related occurrence of *T. ramosissima* and *E. angustifolia* to the mean annual minimum temperature. We used ArcInfo to register gage locations to a gridded climate data set (grid cells 2 km × 2 km) based on weather station data from 1961 to 1990 (The Climate Source, Corvallis, OR, www.climatesource.com). Finally, we fit Gaussian logistic curves relating species presence or absence to mean annual minimum temperature (ter Braak and Looman 1995; PROC LOGISTIC, SAS, Release 8.02, SAS Institute, Cary, NC).

Results and discussion

Our sample indicates that *T. ramosissima* and *E. angustifolia* are already the third and fourth most frequently occurring woody riparian plants in the region (Figure 1). Based on mean normalized cover, *T. ramosissima* and *E. angustifolia* are the second and fifth most dominant woody riparian species (Figure 1). The dominance of *T. ramosissima* has been strongly suspected for decades (Robinson 1965; Brock 1994) though systematic regional measurements have not been available to confirm this suspicion. Although concern has been raised about spread of *E. angustifolia* (Olson and Knopf 1986; Katz and Shafroth 2003), its regional ascendance was not previously known.

All but one of the 93 collected saltcedar samples were identified as *T. ramosissima* (Gaskin and Schaal 2002). The one exception was *T. canariensis* collected at the Pecos River near Orla, Texas. Although herbarium records indicate that *T. parviflora* is widespread in the region (USDA 2004), its absence from our collections indicates that it is much less abundant than *T. ramosissima*.

T. ramosissima and *E. angustifolia* have contrasting geographic distributions and are arrayed distinctly along a temperature gradient (Figures 2 and 3). *T. ramosissima* dominates low elevation sites in the southwestern USA, but is only locally dominant (especially along reservoir margins) north of the 41st parallel. *E. angustifolia*, on the other hand, is abundant in the northern Great Plains, but uncommon in southern California, Arizona, and Texas. Both species are rare in the mountains. The highest elevation of occurrence was 2006 m for *T. ramosissima* and 2296 m for *E. angustifolia*.

The frequency of occurrence of *T. ramosissima* has a strong positive relation with the mean annual minimum temperature (Figure 3), which is consistent with hypothesized frost sensitivity (Lesica and Miles 2001; Sexton et al. 2002). If this inference is correct, anticipated increases in winter cold temperatures with global change can be expected to lead to northward expansion of *T. ramosissima*.

The frequency of occurrence of *E. angustifolia* has a strong negative relation with the mean annual minimum temperature (Figure 3). *E. angustifolia* was not present at any of the 40 sites with mean annual minimum temperature higher than -8.7 °C. This could reflect a chilling requirement for bud break or seed germination (Katz and Shafroth 2003), or the effect of some other environmental factor correlated with low temperature. The success of Russian-olive at mean annual minimum temperatures below -35 °C is consistent with controlled-freezing experiments showing a killing temperature of -55 °C (Gusta et al. 1983).

T. ramosissima and *E. angustifolia* have been widely planted in the United States and Canada since around 1900 (Brock 1994; Katz and Shafroth 2003). Given the ability of *T. ramosissima* to flower in the first year and to disperse its seeds over long distances by air and water (Everitt 1980), it seems unlikely that the relative scarcity of this species in the northern USA is due to incomplete dispersal. Factors that could lead to future spread in the north include climate warming, reservoir construction, and evolution of increased frost hardiness. *E. angustifolia* matures at a later age and has larger, less mobile seeds (Katz and Shafroth 2003). Therefore, *E. angustifolia* is less

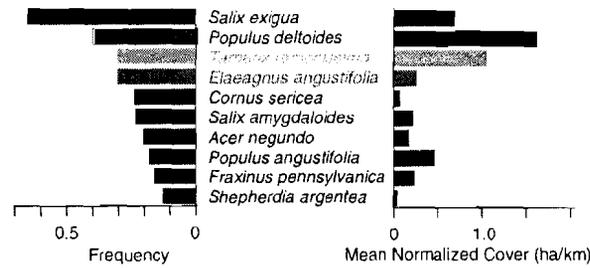


Figure 1. Frequency of occurrence and mean normalized cover of the 10 most frequently occurring woody riparian plants in the western USA. Normalized cover is the area covered by a species at a site divided by site valley length. *Salix exigua* here includes *S. exigua* Nutt., *S. interior* Rowlee, *S. melanopsis* Nutt., and *S. sessilifolia* Nutt. *Populus deltoides* Bartr. ex Marsh. includes ssp. *monilifera* and ssp. *wislizeni* (USDA 2004).

likely to have occupied all suitable locations than *T. ramosissima*. Relatively slow dispersal may explain why *E. angustifolia* has apparently taken longer to become dominant in the region.

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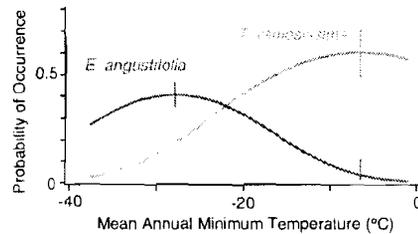


Figure 3. Gaussian logistic regression of occurrence of *Tamarix ramosissima* and *Elaeagnus angustifolia* as a function of mean annual minimum temperature. Vertical bars are 95% confidence intervals.

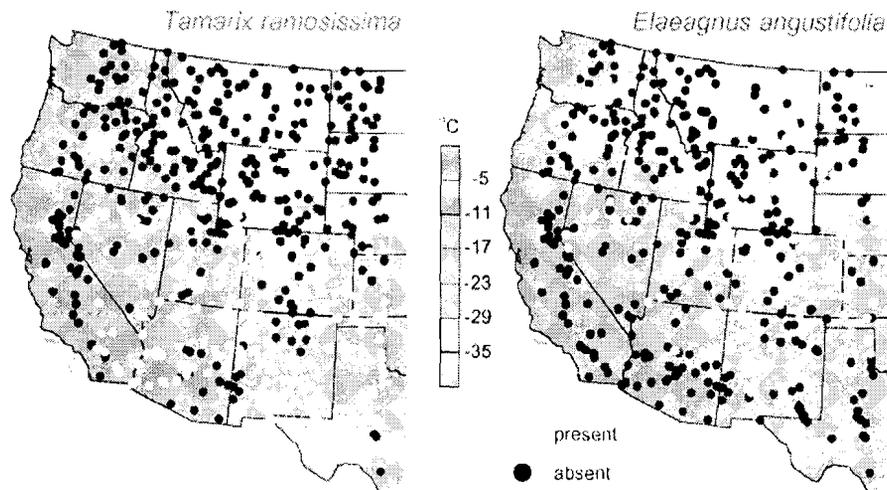


Figure 2. Mean annual minimum temperature and occurrence of *Tamarix ramosissima* and *Elaeagnus angustifolia* across the western USA.

References

- Baum BR (1978) The genus *Tamarix*. Israel Academy of Sciences and Humanities, Jerusalem, 209 pp
- Brock JH (1994) *Tamarix*. In: de Waal LC, Child LE, Wade PM and Brock JH (eds) Ecology and Management of Invasive Riverside Plants, pp 27–44. John Wiley, West Sussex, UK
- Busch DE and Smith SD (1995) Mechanisms associated with the decline and invasion of woody species in two riparian ecosystems of the Southwestern United States. *Ecological Monographs* 65: 347–370
- Di Tomaso JM (1998) Impact, biology, and ecology of saltcedar (*Tamarix* spp.) in the Southwestern United States. *Weed Technology* 12: 326–336
- Everitt BL (1980) Ecology of saltcedar: a plea for research. *Environmental Geology* 3: 77–84
- Gaskin JF and Schaal BA (2002) Hybrid *Tamarix* widespread in US invasion and undetected in native Asian range. *Proceedings of the National Academy of Sciences* 99: 11256–11259
- Gusta LV, Tyler NJ and Chen TH (1983) Deep undercooling in woody taxa growing north of the -40°C isotherm. *Plant Physiology* 72: 122–128
- Katz GL and Shafroth PB (2003) Biology, ecology, and management of *Elaeagnus angustifolia* L. (Russian olive) in Western North America. *Wetlands* 23: 763–777
- Lesica P and Miles S (2001) *Tamarix* growth at the northern margin of its naturalized range in Montana, USA. *Wetlands* 21: 240–246
- Olson TE and Knopf FL (1986) Naturalization of Russian-olive in the Western United States. *Western Journal of Applied Forestry* 1: 65–69
- Robinson TW (1965) Introduction, spread and areal extent of saltcedar (*Tamarix*) in the western United States. US Geological Survey Professional Paper 491-A
- Sexton JP, McKay JK and Sala A (2002) Plasticity and genetic diversity may allow saltcedar to invade cold climates in North America. *Ecological Applications* 12: 1652–1660
- Shafroth PB, Cleverly JR, Dudley TL, Stuart J, Taylor JP, van Riper C and Weeks EP (in press) Control of *Tamarix* spp. in the western US: implications for water salvage, wildlife use, and riparian restoration. *Environmental Management*
- Stromberg JC and Chew MK (2002) Foreign visitors in riparian corridors of the American Southwest: is xenophytophobia justified? In: Tellman B (ed) *Invasive Exotic Species in the Sonoran Region*, pp 195–219. University of Arizona Press, Tucson, AZ
- ter Braak CJF and Looman CWN (1995) Regression. In: Jongman RHG, ter Braak CJF and van Tongeren OFR (eds) *Data Analysis in Community and Landscape Ecology*, pp 29–76. Cambridge University Press, Cambridge UK
- USDA, NRCS (2004) The PLANTS Database, Version 3.5 (<http://plants.usda.gov>). National Plant Data Center, Baton Rouge, LA
- Zavaleta E (2000) The economic value of controlling an invasive shrub. *Ambio* 29: 462–467