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INVASION NOTE

Invasion of tamarisk (*Tamarix* spp.) in a southern California salt marsh

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Abstract Exotic plants have been demonstrated to be one of the greatest threats to wetlands, as they are capable of altering ecosystem-wide physical and biological properties. One of the most problematic invaders in the western United States has been salt cedar, *Tamarix* spp., and the impacts of this species in riparian and desert ecosystems have been well-documented. Here we document large populations of tamarisk in the intertidal salt marshes of Tijuana River National Estuarine Research Reserve, a habitat not often considered vulnerable to invasion by tamarisk. Initial research demonstrates that there are multiple species and hybrids of *Tamarix* invading the estuary and that the potential impact of tamarisk within this salt marsh is significant. This highlights the need for managers and scientists to be aware of the problems associated with tamarisk invasion of coastal marine habitats and to take early and aggressive action to combat any incipient invasion.

Keywords Adaptive management · Cryptic species · Hybrid · Non-native species · Salt marsh · Salt cedar

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Introduction

Exotic organisms that physically or chemically modify ecosystems are among the most detrimental of invaders because they can strongly influence community structure and function (e.g., Vitousek et al. 1996; Mooney and Hobbs 2000; Talley and Levin 2001; Crooks 2002). Early detection of incipient invasions and quickly coordinated responses are essential to effective management and/or eradication of invasive species before they become widely established (Federal Interagency Committee for the Management of Noxious and Exotic Weeds 2003). Thus, this letter documents an extensive invasion and modification of coastal salt marsh habitats by multiple species of trees and shrubs in the genus *Tamarix*.

Examples of ecosystem-altering plants can be found in wetlands across the United States (e.g., Zedler and Kercher 2004 and references therein, Neira et al. 2005). Despite these numerous wetland invaders in North America, until now most of the coastal salt marshes of southern California have been relatively free from the invasion of habitat-altering plants. The invasion of tamarisk or salt cedar (*Tamarix* spp.) into the Tijuana River National Estuarine Research Reserve (TR NERR) contrasts this trend, as the high intertidal, native pickleweed, *Sarcocornia pacifica* (=*Salicornia virginica*), marsh now supports dense stands of these salt-tolerant trees. This invasion converts the salt marsh from a succulent-dominated canopy of less than 1 m to a landscape dominated by stands of woody trees that can grow to over 3 m tall (Fig. 1).

The genus, *Tamarix*, includes approximately 54 species several of which are known to hybridize. Nominated by The Nature Conservancy as one of America's twelve worst invaders (Stein and Flack 1996), tamarisks can be aggressive, woody invasive plants, and some species have become established over 1.5 million acres of floodplains, riparian areas, and freshwater wetlands in the western United States (Stenquist 2000). Tamarisks are native to Eurasia and Africa and are believed to have been first introduced into North America in the early 1800s by nurserymen (Di Tomaso 1998). Their westward spread was facilitated by use as windbreaks, shade cover, erosion control or ornamental plants (Neill 1985). At least seven species of the genus have become established in the US (Baum 1978), and in riparian areas of the western United States, tamarisks, as a group, are the third most frequently occurring woody plant (Friedman et al. 2005).

Study site

The Tijuana River National Estuarine Research Reserve (TR NERR) is situated near Imperial Beach, in San Diego County, CA, on the US-Mexican border. The estuary is located at the mouth of the Tijuana River watershed, with over two-thirds of the 4420 km^2 watershed lying within Mexico (Zedler et al. 1992). Within the TR NERR, tamarisk is present throughout much of the reserve, including high pickleweed salt marshes, riparian habitats, and upland transition zones. Although tamarisk is known for its ability to tolerate relatively saline soils, it has not been typically viewed as an invader in areas of full marine salinity, such as coastal salt marshes, vegetated areas that are regularly inundated by at least the highest spring tides of each lunar month (Grossinger et al. 1998; California Exotic Pest Plant Council 1999).

Methods

Samples were collected from morphologically or geographically distinct plants and stored in vials

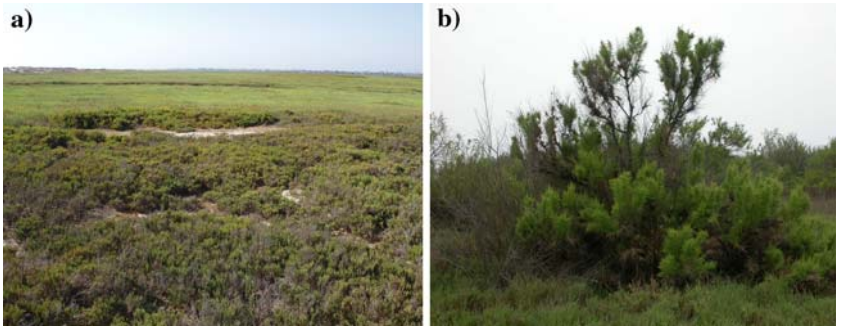

Fig. 1 Photographs showing contrast between (**a**) the natural marsh landscape with short, succulent-dominated canopy (mainly *Salicornia virginica*) and (**b**) an area invaded by invasive *Tamarix* spp., a woody plant that can grow to over 3 m tall. Pictures were taken in Tijuana River National Estuarine Research Reserve, Imperial Beach, CA

with desiccant until analysis, and the fourth *Pep*C intron region of the genomic DNA was analyzed according to methods outlined in Gaskin and Schaal (2002, 2003). In addition, full cross sections of the trunk from each plant were obtained. Once back in the laboratory, these cross sections were sanded and polished with 400 grit sandpaper so that growth rings could be readily distinguished. The precise age of each plant (and thus the year of its invasion) was determined by cross-dating growth rings in the sections using standard dendrochronological techniques (Stokes and Smiley 1996).

Results

Knowing the particular species of tamarisk that invaded Tijuana River NERR was important to understanding overall invasion dynamics as well as to potentially understanding tamarisk's ability to invade coastal salt marsh habitat. Initially, the tamarisk was identified morphologically as *Tamarix ramosissima*. However, genetic analysis revealed that there were, in fact, many species and hybrids within the *Tamarix* genus present in our study area. Out of 35 *Tamarix* spp. samples analyzed from the river valley, haplotypes from four different species were identified (Table 1).

Preliminary tree ring data indicates that 36% of all tamarisk examined (44 of 122 individuals) were established during the period of 1979–1984. Combining age data with historical data documenting extensive flooding in 1978, 1980 and 1983, we hypothesize that the tamarisk invasion within Tijuana River NERR most likely began in the early 1980's, perhaps benefited by flood conditions that decreased salinities and increased sediment deposition, thus creating ideal germination spots along the river channel. Yet the true extent of the invasion and its potential for dramatic impact was fully appreciated only within the last 5 years. Preliminary data on the TR NERR habitat indicate dramatic structural changes to the salt marsh environment as a result of the presence of tamarisk. Tamarisk is acting as a physical support, facilitating *S. virginica* to reach heights far above its natural height. In addition, tamarisk alters physical conditions (such as temperature, humidity, and light regimes) under its canopy. Preliminary data about the sediment environment in tamarisk-invaded areas indicate that the invasion also influences the invertebrate and microalgal community compositions and biomass (Whitcraft et al. unpublished), with additional ramifying effects throughout the food web (Talley et al. unpublished).

Table 1 Genetic species identification of 37 tamarisk samples collected from Tijuana River NERRS and associated river valley

Species	# of plants of 39 sampled
T. aphylla	1
T. chinensis	1
T. chinensis x *T. gallica*	4
T. chinensis x *T. ramosissima*	6
T. gallica	2
T. ramosissima	16
T. ramosissima x *T. gallica*	5

Discussion

Some hybridization and the presence of cryptic species in Tijuana River NERR would not have been surprising. However, the high number of different genotypes present within such a small sample set strongly suggests that a hybrid swarm of *Tamarix* spp. invaded TR NERR. Levels of introgression are unknowable from the single-locus DNA marker used initially, thus we are now genotyping samples using multi-locus AFLP (Amplified Fragment Length Polymorphism) markers and comparing these to the rest of the invasion. The genetic data are particularly worrisome, as hybrid plant lineages frequently demonstrate greater ecological amplitude than their parental species, invading ecological communities or habitat zones that have not been colonized by either parental species (Stace 1975; Daehler and Strong 1997; Neuffer and Hurka 1999). Hybridization is particularly common in populations that exist at the edges of their geographical or ecological range (Rieseberg 1997), as is presumably the case for tamarisk in the TR NERR.

The effects of tamarisk invasions have been well-documented for stream riparian areas. These include alterations of the chemical and physical conditions in its immediate environment as well as larger-scale effects on the entire invaded ecosystem (Ellis 1995; Di Tomaso 1998; Zavaleta 2000). Despite numerous, uninvestigated anecdotal reports, the invasion in Tijuana River NERR is the first studied example of a coastal salt marsh being invaded by tamarisk, and thus very little is known about the potential effects of tamarisk in this novel and particularly threatened habitat. Based on responses of riparian communities, we predict that this invasion will dramatically affect the physical environment, which could translate into community-level effects for marsh biota (Stevens 2000; Crooks 2002). To combat this invasion in southern California, state- and federally-funded tamarisk eradication efforts have recently begun, providing a template for research and adaptive management (California Exotic Pest Plant Council 1999).

The invasion of tamarisk into the Tijuana River National Estuarine Research Reserve provides a clear indication that already dwindling coastal salt marshes are vulnerable to invasion by these plants. More broadly, the study of this invasion will assist us not only to quantify the possible effects of tamarisk invasions in salt marsh habitats but also help us to more broadly understand the structuring roles of invasive plants in wetlands. Studying the genetics aspect of this invasion contributes to theories on rapid evolutionary processes and invasion and paves the way for studies addressing physical, ecological, and genetic pathways of invasion. Friedman et al. (2005) noted that the debate regarding appropriate control of tamarisk has been frustrated by limited knowledge of the distribution and underlying environmental influences. These are particularly important data to collect regarding the tamarisk invasion into salt marsh habitats; knowing the consequences of the invasion into this novel system will provide managers and decision makers with invaluable information about the relative invasion potential of different species (and hybrids) of tamarisk, thus facilitating more informed management decisions.

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