Herbaceous Exotics in Arizona's Riparian Ecosystems

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Introduction

Riparian ecosystems of the desert Southwest support a surprising variety of plant species. The native trees include the (by-now) familiar Fremont cottonwood (*Populus fremontii*), Goodding willow (*Salix gooddingii*), and mesquites (*Prosopis* sp.), and a less celebrated supporting cast of shrubs such as seep-willow (*Baccharis salicifolia*), burro brush (*Hymenoclea* sp.), and rabbit brush (*Chrysothamnus nauseousus*). But the true indicators of diversity are the non-woody herbs of the riparian understory. During a three-year collection period at the Arizona Nature Conservancy's Hassayampa River Preserve (Figure 1). Wolden et al. (1994) documented over 340 plant species along 8 km (5 mi) of the stream and associated riparian corridor. "New," previously undocumented species continue to appear at the site. According to Naiman et al. (1993), factors contributing to such high floristic diversity in desert riparian areas include:

1. continuous input of seeds from upstream reaches and uplands;
2. sharp environmental gradients in the floodplain (e.g., depth to groundwater, soil texture, and light availability); and
3. repeated disturbance by flood flows of varying intensities and durations.

Thus, desert riparian areas meet the popular, simplified criterion of "biodiversity." But this diversity should be celebrated with caution. A large proportion of the plant community at the Hassayampa River Preserve and along other rivers in the desert Southwest is composed of species considered to be exotic to such systems. These plants are believed to have been introduced from other continents during the past few hundred years, a process inevitably associated with European settlement of the region (Nilsson et al. 1989; Du Preez and Venter 1990; DeCamps 1993; Stromberg et al. 1997). When an ecosystem is "invaded" in such a way, at least some individual exotic plants displace individual native plants. The systemic effects are complex, and hard to sort out – not least because there's no representative "before" condition left for comparison. Plant species have always come and gone, whether via wind, bird, truck tire or cattle gut. It seems unlikely that any two species would perform wholly analogous functions, but the task of comparing all possible analogs is beyond the technical capabilities and funding availability. We aren't going to say much about the "good" and the "bad;" we're mainly going to cover the "what" and the "where," as we know it so far. Most of the exotic species in desert riparian areas (like most of the natives) are herbaceous. At the Hassayampa River Preserve, about 280 of the 340 species are herbaceous; about 25 percent of these are exotics. Most of the exotics cover only small areas and are encountered infrequently, but others have become "dominant" in the floodplain. (See back cover)

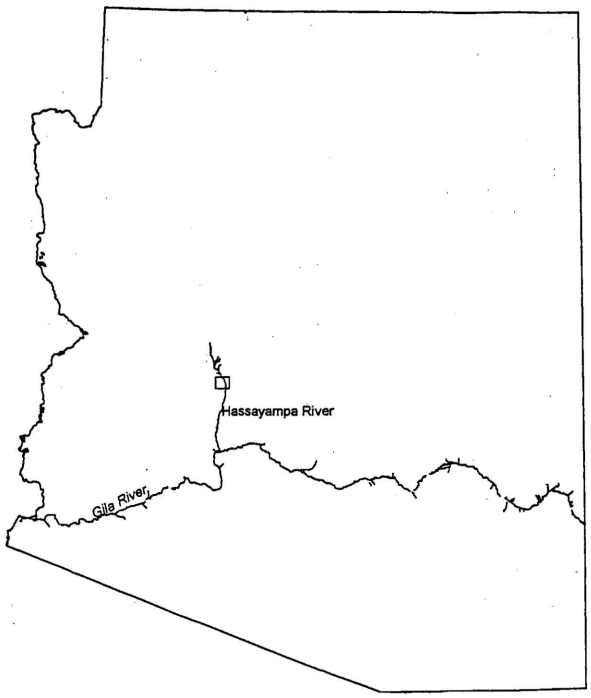

Figure 1. Arizona Nature Conservancy's Hassayampa River Preserve

A number of important conditions contribute to the abundance of exotics in Arizona's desert river floodplains. Roads and railways often follow rivers, introducing and spreading seeds from distant locales (Frenkel 1977). The practice of utilizing fertile floodplain soils for agriculture results in the spread of accidentally introduced, non-native crop weeds. Mesic floodplain conditions allow crop weeds to establish and persist beyond the limits of the irrigated fields (Baker et al. 1993). Early in the 20th century, McClatchie (1901) warned that wild (foxtail) barley would become a "problem invasive" in floodplains of the Salt River, if no measures were taken to halt its spread from agricultural fields. Domestic livestock grazing, since Spanish Colonial times in some places, has altered vegetation composition by selecting for (and favoring) unpalatable and grazing-tolerant species (Burgess et al. 1991). Damming and water diversions have changed

annual flooding and flow patterns of most rivers, effectively favoring species (such as salt cedar (*Tamarix* sp.)) that are adapted to the new flow conditions (Brock 1994).

Scientific and management attention has mainly focused on the consequences of the spread of exotic trees and shrubs in desert river floodplains. Salt cedar, perhaps the most abundant woody riparian exotic in the American Southwest (Harris 1966; Valencia et al. 1993), can increase fire frequency, floodplain sedimentation rates, and soil salinity, and alter habitat for understory vegetation, insects, birds, and mammals (Brock 1994). However, much less has been written about ecological consequences of the presence of non-native herbs in Southwest riparian ecosystems. More research is needed as we attempt to understand the comparative functions of exotic and native herb species, and the environmental factors influencing the relative abundance of the two groups. Although many details are unclear, we can identify some of the common exotic species of alluvial, perennial rivers dominated by Fremont cottonwood and Goodding willow forests, and discuss factors contributing to their abundance. What we already know allows us to speculate briefly on some of the possible ecological consequences of their presence.

Riparian Patch Types

Environmental gradients in riparian ecosystems can often be discerned by variations in vegetation and soil or substrate composition. Sometimes these gradients are sharp (i.e., the environmental variable changes rapidly over a short distance). There are also areas in which the gradients change little and can be described as "patch types." Most patch types consist of plant associations that occur on specific types of "fluvial landforms." In the case of sparsely vegetated sites like recently deposited gravel bars, a patch type may be named after the landform itself. Several major patch types occur on floodplains of alluvial, perennial rivers of the desert Southwest. We use these as a basis for discussing the distributions of exotic and native herbs in floodplains of alluvial, perennial rivers of the hot desert regions of Arizona.

Species names used below follow Lehr (1978) and recent treatises published in the Journal of the Arizona-Nevada Academy of Sciences (Table 1). Exotic or native status was determined through review of several floras including Kearney and Peebles (1960), Correll and Correll (1972), and Hickman (1993).

Stream Edge Habitats

Patch types located in wet areas in and near stream channels include aquatic and emergent vegetation, riverine marshes, shrublands of seep-willow (often intermixed with young cottonwoods and willows), and gravel bars. These wet streamside areas are often densely covered by exotics. In a survey of six perennial, Fremont cottonwood dominated rivers in central and southern Arizona, stream banks had greater than 55 percent *relative* exotic cover in all seasons of the year (Stromberg et al. 1997). In other words, exotics always covered more area than natives.

Water speedwell (*Veronica anagallis-aquatica*) and watercress (*Nasturtium officinale*) are aquatic exotics (with roots under water, leaves and stems above) that often are abundant on stream edges. Like many other successfully naturalized, perennial exotic herbs, water speedwell and water-cress can spread through vegetative (asexual) propagation as well as by seed, leaving them less at the mercy of successful seedling establishment (Baker 1965; Holm et al. 1977; Crawley 1987). Ability to propogate asexually may contribute to the ability of water-cress to survive floodplain livestock grazing (Rejmankova 1992). However, it remains unclear why the exotics frequently outnumber natives (including water pennyworts (*Hydrocotyle ranunculoides* and *H. verticillata*), yellow water weed (*Ludwigia peploides*), monkey flower (*Mimulus guttatus*), and knot grass (*Paspalum distichum*)), some of which can also reproduce both by seed and asexual spread. Nutrients released into streams from farm fields, sewage treatment plants, or livestock may favor some exotics.

Species with short life-spans, rapid growth rates, and high reproductive effort (traits associated with ruderal species) are often successful invaders. Rabbit's foot grass (*Polypogon monspeliensis*) is one of the many annual exotics that can be found on moist sandbars in the channel. It is a prolific seed producer, and seeds often successfully germinate while still resting on prostrate parent stems. Rabbit's foot has also been reported to increase in abundance in areas intensively grazed by livestock (Hughes 1993), but additional study is needed to determine the actual mechanism of this adaptive strategy. Willow smartweed (*Polypogon lapthifolium*), an exotic annual, tolerates a wide hydrological range from flooded to dry soil conditions (Carter and Grace 1990), and thus, perhaps may have the competitive edge at river sites where diversions cause greater seasonal drying of the river flows. Generally, however, without further research we can only speculate as to why exotics like rabbit's foots grass, willow smartweed, barnyard grass (*Echinochloa crusgalli*), and jungle rice (*Echinochloa colonum*) are often more abundant along stream edges than the native Indian paint brush (*Castilleja cruenta*), flat sedge (*Cyperus odoratus*), spike rush (*Eleocharis montevidensis*), horsetail (*Equisetum laevigatum*), various true rushes (*Juncus xiphioides, J. articulatus,* and *J. torreyi*), sprangletop grasses (*Leptochloa uninervia* and *L. fascicularis*), water smartweed (*Polygonum punctatum*), bulrush (*Scirpus americanus*), and tropical cattail (*Typha domingensis*).

On stream banks and low floodplain terraces just above the water table, common exotic herbs include Bermuda grass (*Cynodon dactylon*) and Johnson grass (*Sorghum halapense*), both of African origin, and white and yellow sweet clover (*Melilotus albus* and *M. officinalis*). Bermuda grass regularly survives floods, drought, and high salinity, and increases under grazing pressure (Horowitz 1972; Rucks 1984; Belsky 1986; Devitt et al. 1993). Newsome and Noble (1986) categorize such long-lived and mortality-resistant species as "survivors." Bermuda grass can maintain itself for long time periods

through rhizomatous spread, and rhizomes can emerge through thick deposits of flood-borne sediment. It thrives on sites affected by livestock and hydrologic alterations. Bermuda grass and other streamside exotics have been reported to reduce growth of woody seedlings and herbaceous species by releasing chemical toxins (allelopathy) or by outcompeting them for soil moisture, soil nutrients, or light (Horowitz and Friedman 1971; Cohn et al. 1989; Meissner et al. 1989). Native species with distribution patterns overlapping this group of exotics, and thus potentially affected, include Buckley's centaury (*Centaurium calycosum*), wild petunia (*Calibrachoa parviflora*), willow weed (*Epilobium californicum*), deer grass (*Muhlenbergia rigens*), and cocklebur (*Xanthium strumarium*). Bermuda grass increases substrate stability during minor floods, but it is unclear how this ability compares with that of native rhizomatous species such as salt grass (*Distichlis spicata*) or knot grass (*Paspalum distichum*) that may have been locally extirpated.

Cottonwood-Willow and Mesquite Forests

As time passes, floods deposit sediment around the bases of young Fremont cottonwoods and Goodding willows that originally established along the edges of stream channels. Depending on flood flow characteristics, sediment accumulation can produce floodplain terraces with surfaces up to about three meters above the water level of the stream. As sediment deposition forces stream channels to migrate, mature cottonwoods and willows are often found growing in rows, or galleries, lining dry, abandonded channels. Mesquites establish underneath mature cottonwood trees. If these high terraces remain intact long enough, the relatively short-lived cottonwoods and willows die out, giving way to mesquite dominated woodlands, or "bosques."

Although some deep-rooted herbaceous species in both forest types can utilize groundwater, many others rely on rainfall or periodic flood pulses. Thus, understory cover and composition vary strongly with seasonal rains and stream flow dynamics. Mesquite woodlands, typically being laterally farther from the stream channel and/or vertically farther from the water table (Stromberg et al. 1996), support fewer species adapted to wet conditions than do cottonwood forests; but understories of the two areas do show considerable overlap in species composition. Exotic spring annuals are usually less abundant under cottonwoods, perhaps due to the denser litter layer, earlier canopy leaf-out, and poorer soils. Mesquite roots, like those of other leguminous plants, harbor nitrogen-fixing bacteria that increase the general availability of this critical nutrient.

After abundant winter/spring rains, mesquite woodlands are carpeted with dense stands of annual herbs. Many of these annuals are exotic grasses, particularly rescue brome (*Bromus catharticus*), ripgut brome (*Bromus diandrus*), red brome (*Bromus rubens*), foxtail barley (*Hordeum murinum*), and Mediterranean grass (*Schismus barbatus*); some are exotic annual forbs like filaree (*Erodium cicutarium*) and tumble mustard (*Sisymbrium irio*). Native winter annuals of the mesquite bosques include coast fiddleneck (*Amsinckia intermedia*) and tansy mustard (*Descurania* sp.). The midsummer understory in cottonwood and mesquite stands is sparse but often species-rich. Understory vegetation again becomes dense after the summer monsoon rains. Where summer rains are abundant, herbaceous understories are seasonally dominated by native species. Typical late-summer natives include western ragweed (*Ambrosia psilostchya*), threeseeded mercury (*Acalypha neomexicana*), bur marigold (*Bidens leptocephala*), horseweed (*Conyza canadensis*), sacred datura (*Datura meteloides*), morning-glory vines (*Ipomoea* sp.), camphor weed (*Heterotheca psammophila*), desert tobacco (*Nicotiana trigonophylla*) and sacaton grass (*Sporobolus wrightii*). Among the exotics are Malta star thistle (*Centaurea melitensis*), Lehmann's lovegrass (*Eragrostis lehmanniana*), prickly lettuce (*Lactuca serriola*), horehound (*Marrubium vulgare*), Russian thistle (*Salsola iberica*), and milk thistle (*Silybum marianum*).

The first requirement of a prospective invading exotic species is physical transport to a new habitat. Some of the riparian woodland exotics, such as foxtail barley, originally invaded from floodplain farm fields. Others, such as Lehmann's lovegrass, were purposely seeded in uplands to promote revegetation of overgrazed grasslands, providing a bountiful seed source for spread to the floodplain (Anable et al. 1992). Once exotics were present on the scene, fortuitously appropriate adaptations to the local climate may have contributed to their persistence and spread. Many of the exotic winter annuals (e.g., red brome, Mediterranean grass, foxtail barley, tumble mustard) are native to Mediterranean Europe, and are pre-adapted to the temperate, winter-rain conditions characteristic of spring in the Sonoran and Mojave Deserts (Jackson 1985).

Continuous or repeated disturbance by domestic grazing and/or floodplain clearing may have given some exotics the competitive edge over natives (Mack 1986; Burgess et al. 1991). Even after removal of a disturbance factor that may have allowed them to invade, populations of exotic annuals can persist for a long time by producing soil and litter conditions that continue to favor weedy annuals over perennial growth forms (Zink et al. 1995). In a comparative study of mesquite woodlands that had been ungrazed for various lengths of time, Rogers (1994) found that although perennial grasses had increased in the long-ungrazed woodlands, exotics still persisted.

Several ecological effects of exotics have been reported in desert ecosystems, and these may provide some clues to corresponding effects in riparian ecosystems. The dense single species stands of winter annuals that carpet mesquite understories may reduce native plant diversity, as has been reported for cheatgrass (*Bromus tectorum*), a dominant invasive in the Great Basin Desert (Billings 1990). Native floodplain species that attempt to germinate late in the season, and shorter natives such as hairy bowlesia (*Bowlesia incana*) and pellitory (*Parietaria hespera*) may be inhibited in a similar way.

Red brome, Russian thistle and other exotics have less specific moisture and temperature germination requirements, allowing them to germinate earlier and dominate the forest floor before other species have a chance (the "gap grabber strategy" described by Newsome and Noble (1986); Beatley 1966, 1974; Davison 1971; Wu and Jain 1979; Allen 1982). Further, many of the exotic winter annuals are more drought tolerant than native winter annuals, allowing them to be abundant in the high terrace woodlands even in relatively dry years and to build up large seed banks for the next year.

The winter exotics also may cause changes in abundance of rodents (Rowland and Turner 1964) and cause local decline of some native bird and insect species (Bock et al. 1986; Anable et al. 1992). The dense cover of the exotics may also increase the spread of fire (Beatley 1966; Anable et al. 1992) in the riparian woodlands, which can result in death of cottonwoods, a very fire sensitive species, while also increasing the relative abundance of salt cedar (Busch and Smith 1995).

Burro Brush and Rabbit Brush Shrublands

Open shrublands, often dominated by burro brush and/or rabbit brush, establish on coarse-soiled flood deposits, usually about one to four meters above the water table. Surface soils often are dry due to their coarse textures and exposure to intense sunlight. This habitat has much in common with windblown sand dunes. The sediments are regularly disturbed, and there is little opportunity for soil development. The sparsely occurring shrubs are deep-rooted. Groundcover usually is meager, and tends to be dominated by native species such as six-weeks needle grama (*Bouteloua aristidoides*), skeleton weed (*Erigonum deflexum*), dropseed grasses (*Sporobolus* sp.), and plicate coldenia (*Tiquilia plicata*). Many of the exotics in this patch type, including Mediterranean grass (*Schismus barbatus*) and puncture vine (*Tribulus terrestris*), also occur in desert uplands.

Future Outlooks

The impact of exotic species on native ecosystems is receiving global attention and concern. Much more research will be needed to help us understand the effects herbaceous exotics are having on riparian ecosystems of the Southwest. At the same time, we must work to recognize environmental conditions and identify management practices that promote reestablishment of native species patch types now dominated by exotic herbs. This information is vital to deciding what can and should be done to help restore degraded systems.

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Table 1. Common and scientific names of exotic (e) and native (n) herbaceous (h) and woody (w) plants by primary location in desert riparian ecosystems. Plants are listed alphabetically by scientific name, within exotic and native groups.

Stream edge habitats	bermuda grass	*Cynodon dactylon*	e	h
	jungle rice	*Echinochloa colonum*	e	h
	barnyard grass	*Echinochloa crusgalli*	e	h
	white sweet clover	*Melilotus albus*	e	h
	yellow sweet clover	*Melilotus officinalis*	e	h
	water-cress	*Nasturtium officinale*	e	h
	willow smartweed	*Polygonum lapathifolium*	e	h
	rabbit's foot grass	*Polypogon monspeliensis*	e	h
	Johnson grass	*Sorghum halapense*	e	h
	water speedwell	*Veronica anagallis-aquatica*	e	h
	seep willow	*Baccharis salicifolia*	n	w
	wild petunia	*Calibrachoa parviflora*	n	h
	indian paint brush	*Castilleja cruenta*	n	h
	Buckley's centaury	*Centaurium calycosum*	n	h
	flat sedge	*Cyperus odoratus*	n	h
	salt grass	*Distichlis spicata*	n	h
	spike rush	*Eleocharis montevidensis*	n	h
	willow weed	*Epilobium californicum*	n	h
	horsetail	*Equisetum laevigatum*	n	h
	water pennyworts	*Hydrocotyle ranunculoides; H. verticillata*	n	h
	jointed rush	*Juncus articulatus*	n	h
	Torrey rush	*Juncus torreyi*	n	h
	rush	*Juncus xiphioides*	n	h
	sprangletop grasses	*Leptochloa uninervia; L. fascicularis*	n	h
	yellow water weed	*Ludwigia peploides*	n	h
	monkey flower	*Mimulus guttatus*	n	h
	deer grass	*Muhlenbergia rigens*	n	h
	knot grass	*Paspalum distichum*	n	h
	water smartweed	*Polygonum punctatum*	n	h
	bulrush	*Scirpus americanus*	n	h
	tropical cattail	*Typha domingensis*	n	h
	cocklebur	*Xanthium strumarium*	n	h

Cottonwood and mesquite forests	rescue brome	*Bromus catharticus*	e	h
	cheatgrass	*Bromus tectorum*	e	h
	ripgut brome	*Bromus diandrus*	e	h
	red brome	*Bromus rubens*	e	h
	Malta star thistle	*Centaurea melitensis*	e	h
	Lehmann's lovegrass	*Eragrostis lehmanniana*	e	h
	filaree	*Erodium cicutarium*	e	h
	foxtail barley	*Hordeum murinum*	e	h
	prickly lettuce	*Lactuca serriola*	e	h
	horehound	*Marrubium vulgare*	e	h
	Russian thistle	*Salsola iberica*	e	h
	milk thistle	*Silybum marianum*	e	h
	tumble mustard	*Sisymbrium irio*	e	h
	salt cedar	*Tamarix chinensis* and related species	e	w
	three-seeded mercury	*Acalypha neomexicana*	n	h
	western ragweed	*Ambrosia psilostachya*	n	h
	coast fiddleneck	*Amsinckia intermedia*	n	h
	bur marigold	*Bidens leptocephala*	n	h
	hairy bowlesia	*Bowlesia incana*	n	h
	horseweed	*Conyza canadensis*	n	h
	sacred datura	*Datura meteloides*	n	h
	tansy mustard	*Descurania* species	n	h
	camphor weed	*Heterotheca psammophila*	n	h
	morning-glory vines	*Ipomoea* species	n	h
	desert tobacco	*Nicotiana trigonophylla*	n	h
	pellitory	*Parietaria hespera*	n	h
	Fremont cottonwood	*Populus fremontii*	n	w
	mesquite	*Prosopis velutina* and other species	n	w
	Goodding willow	*Salix gooddingii*	n	w
	sacaton	*Sporobolus wrightii*	n	h
	dropseed grasses	*Sporobolus* species	n	h
Burro brush - rabbit brush shrublands	Mediterranean grass	*Schismus barbatus*	e	h
	puncture vine	*Tribulus terrestris*	e	h
	six-weeks needle grama	*Bouteloua aristidoides*	n	h
	rabbit brush	*Chrysothamnus nauseosus*	n	w
	skeleton weed	*Eriogonum deflexum*	n	h
	burro brush	*Hymenoclea* species	n	w
	plicate cordenia	*Tiquilia plicata*	n	h