Hydrologic Changes and Riparian Forests: THE SALTCEDAR STORY

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Rivers in many regions have undergone changes in their flow regimes, leading to changes in composition of riparian vegetation. My co-workers and I recently completed an ecological survey of the abundance of saltcedar (*Tamarix chinensis* and *Tamarix ramosissima*), Fremont cottonwood (*Populus fremontii*), and Goodding willow (*Salix gooddingii*) along rivers in the Gila and Lower Colorado basins of Arizona (see map) to test whether human alteration of streamflow regimes causes a compositional shift in the riparian vegetation from native to introduced species (Stromberg and others, 2007).

The study sites spanned a range of flow regimes from perennial to intermittent, and free-flowing to flow-regulated. We found that river reaches with perennial flow and a natural flood regime had high abundance of cottonwood and willow, the historically dominant pioneer riparian trees in the region, and low abundance of saltcedar, an introduced species (see chart at right). In contrast, reaches with intermittent and/or dam-regulated flows were dominated or codominated by saltcedar, which is comparatively more stress-adapted and more reproductively opportunistic than cottonwood and willow. Members of the *Populus*, *Salix*, and *Tamarix* genera have co-existed along Eurasian rivers for millennia; in the American Southwest, flow regime changes are creating conditions that favor dominance of a newcomer to the region.

Stream Low-flows

The abundance of saltcedar on intermittent river reaches suggests it is intrinsically adapted to the dry conditions of the Southwest. Further, where perennial rivers have become intermittent due to stream diversion or groundwater pumping (such as portions of the San Pedro), the new conditions favor saltcedar over the more drought-intolerant cottonwood and willow. Where stream flows are intermittent, the riparian water table typically is lower and shows greater fluctuation. As the water table declines to three meters or more below the floodplain surface, cottonwood and willows, but not saltcedar, are shifted out of their tolerance ranges for root-zone soil moisture (Lite and Stromberg, 2005).

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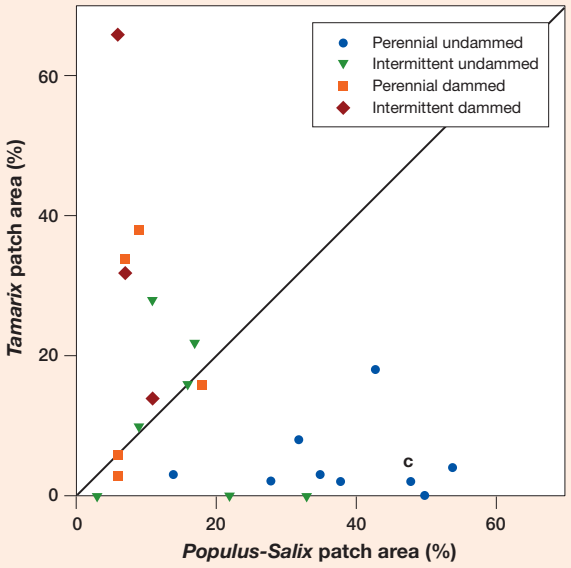
Flood Flows

On unregulated rivers such as the Hassayampa, large winter floods episodically rework sediments, creating patches of seed beds where tree seedlings can establish themselves without competition from an overstory. Receding flows in spring moisten the bare sediments during the short period when viable cottonwood and willow seeds are present. Slow recession of the flood waters and water table allows seedling roots to maintain contact with wet soil.

Saltcedar also is a pioneer plant that colonizes newly disturbed areas, but it remains subdominant to cottonwood and willow on free-flowing perennial rivers for several reasons. First, because cottonwood and willow begin dispersing seeds earlier in the growing season, their seedlings can pre-empt space and out-shade and overtop the later-seeding saltcedar. Second, saltcedar seedlings are suppressed by competition from cottonwood; such stress-adapted plants often have low competitive ability when resource availability is high (Sher and others, 2000). Finally, subcanopy saltcedar may be less able to withstand flood inundation and flood scour.

On dammed rivers, the mechanisms for vegetation change are more complex, but are partly due to influences on pioneer tree establishment. Reductions in flood frequency, shifts in flood timing, and abrupt decline of flood waters, together with changes in river geomorphology, have discouraged establishment of cottonwood and willow along some dammed rivers.



Percentage of the floodplain occupied by Tamarix*-dominated patches plotted against the percentage of the floodplain occupied by* Populus-Salix *dominated patches. Each data point represents a study site. Sites above the diagonal line have greater relative abundance of* Tamarix*, those below the line have greater relative abundance of* Populus-Salix*. The "c" denotes a site from which Tamarix has been cleared. "*Tamarix*-dominated patches" are wooded areas in which at least 50 percent of the stem coverage is composed of* Tamarix*.*

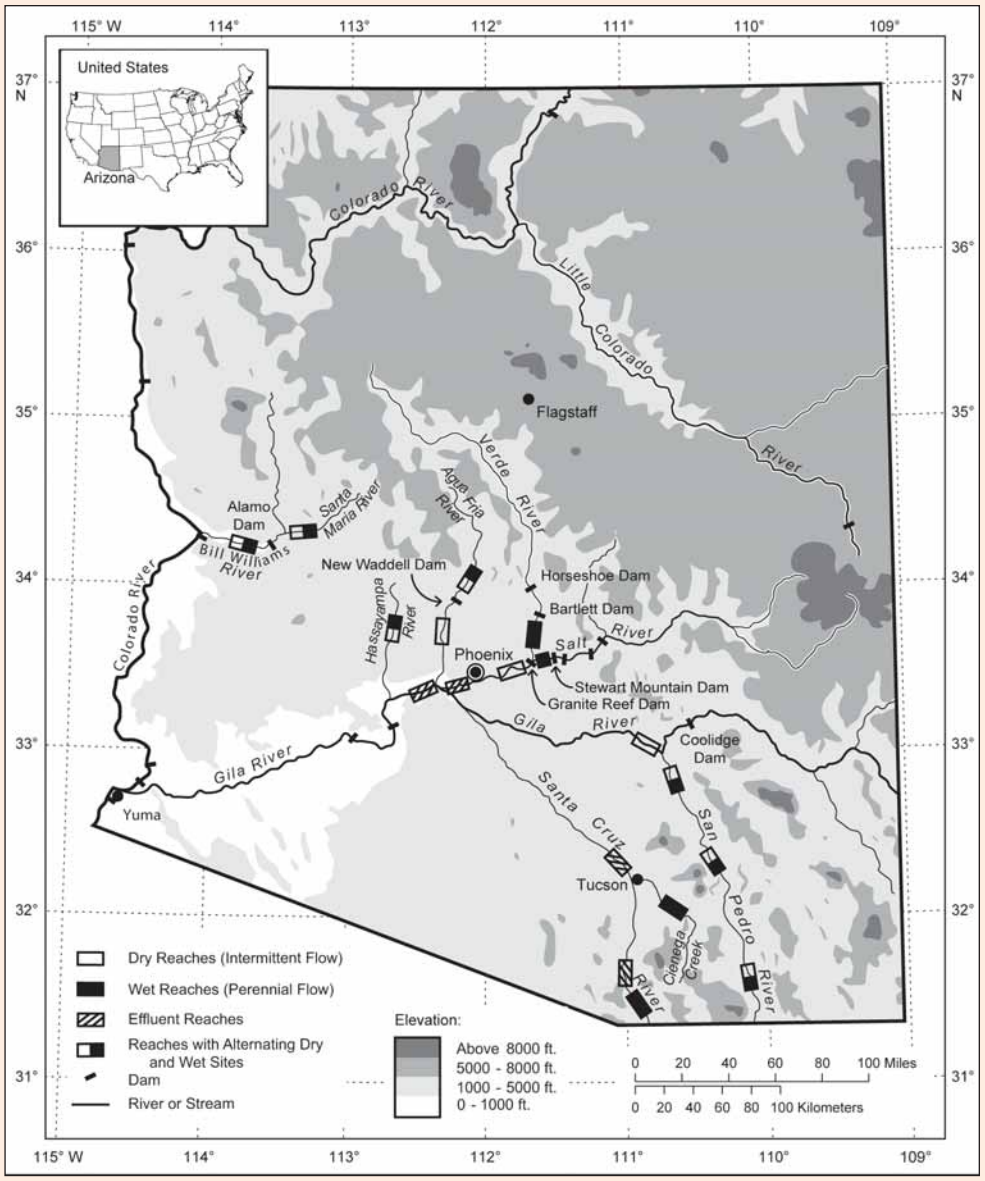
Where this occurs, such as along the lower Gila and Salt rivers, saltcedar seedlings don't have to compete. However, abundance of cottonwood and willow varies widely among regulated reaches. In rivers with a low ratio of reservoir storage capacity to watershed runoff, for example the lower Verde, the reservoir can be overwhelmed in wet winters. The ensuing "run-of-the-river" spring-season flow regimes allow the successful establishment of cottonwood and willow (Zamora-Arroyo and others, 2001). But because saltcedar disperses seeds over a long period and its seedlings have wide tolerance for moisture conditions, it can establish where the river flow pattern differs from the climatic norm with respect to flood timing and recession rate. If floods are suppressed for a few years (as is common on regulated rivers), saltcedar seedlings that germinate on the low surfaces can grow to a size that enables high survivorship of subsequent disturbances.

Salinity

Salty conditions favor saltcedar over cottonwood and willow. Although many rivers in the Southwest have relatively low solute content, others (such as portions of the Salt), have high salinity due to passage through ancient marine salt deposits. Our study did not include any free-flowing, salty river reaches, and saltcedar may have a natural competitive edge over cottonwood and willow in such settings. Discharge of municipal effluent or agricultural tail water, interbasin transport of salty water, and increased evaporation rate of water due to passage through multiple dam-reservoir systems can also increase salinity. And where floods are reduced in frequency, salts can accumulate in floodplains. This process may contribute to the vegetation patterns observed on dammed rivers such as lower reaches of the Gila and Colorado.

Disequilibria

Tree abundance patterns varied widely within hydrologic reach types, a finding that may reflect differing histories of water and land use and climate. Cottonwood, willow, and saltcedar live for at least a century, and their population structure reflects the influence of past and present



Location of study reaches. Also shown are locations of major dams. (Map is based on templates provided by Arizona Geographic Alliance).

environmental conditions. Past decades of drought, intensive agricultural groundwater pumping, or livestock grazing on the more palatable cottonwood and willow, for example, would favor survivorship of saltcedar during that time period. Indeed, along the San Pedro River, we see shifting patterns of forest dominance by decade, with saltcedar giving way to cottonwood-willow and vice versa (Stromberg, 1998).

Regional Variation

In our study area, where rivers remain perennial and free-flowing, local riparian trees (cottonwood and willow) are more abundant than introduced species such as saltcedar. This may not be true for other North American river basins, depending on factors such as local plant species composition, climate, streamflow regime, and hydrogeomorphic setting. In some parts of the West, saltcedar grows on sites that formerly supported riparian grasslands, and livestock grazing may be a key driver of vegetation change in such areas.

Another topic worthy of investigation is the role of local flood regimes. Floods in Sonoran Desert rivers are very powerful and occur in multiple seasons. Frequent scour and sedimentation may contribute to low abundance of saltcedar along free-flowing rivers of the Sonoran Desert; in contrast, saltcedar may have greater survivorship in regions where floods are less intense, transport fewer sediments, and are restricted to early summer.

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River Restoration

These results imply that restoration of cottonwood-willow forest ecosystems will require the return of perennial stream flows, shallow groundwater, and flood timing and intensity in keeping with climatic norms. The findings have management implications with respect to saltcedar removal efforts currently underway on many southwestern rivers, including those that are free-flowing and perennial. Saltcedar appears to remain subdominant where the processes are present that allow cottonwoods and willows to establish and survive, raising questions about the rationale for saltcedar eradication efforts in settings such as the Upper Verde River.

On many naturally intermittent, free-flowing rivers, saltcedar is codominant with cottonwood and willow. Some saltcedar clearing efforts in such settings are conducted with the goal of removing an invader. If ecosystems are viewed as open systems, in which immigration is an ongoing process and shifting species assemblages are the norm, then the mere presence of an introduced species is not in itself a call for action. Rather, studies should be conducted to determine if valued ecosystem functions have been affected along the reach of interest and to identify the causes of those changes before initiating restoration interventions.

Large-scale saltcedar removal involving bulldozing, aerial herbicide application, fire, and biocontrol insects are underway at several highly modified rivers in the western United States. On these rivers, saltcedar may fall within the "invasive species as passenger" rather than the "invasive species as driver" model of ecosystem degradation. If indeed a passenger, the removal of saltcedar, without simultaneous restoration of streamflow regimes, may not restore the desired riparian vegetation. Furthermore, vegetation clearing without other restorative actions could reduce habitat for the federally endangered Southwestern willow flycatcher and other bird species that utilize saltcedar. From a river restoration perspective, it may be fruitful to view saltcedar dominance (not simply presence) as an indictor of altered riverine processes and thus as trigger for restoration of the key physical processes that influence riparian biotic communities.

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