THE RESPONSE OF SALT CEDAR, *TAMARIX CHINENSIS*, TO EXPERIMENTAL FLOWS IN THE GRAND CANYON

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Abstract

We examined the response of an exotic tree, *Tamarix chinensis,* to an experimental low steady flow and a four-day spike flow along the Colorado River in the Grand Canyon. Plant density data in newly exposed beach areas were collected for 52 transect lines throughout the river corridor study site. These data were collected over a 3-month period at a time when the river flow remained near 8,000 cfs and once after a spike flow of approximately 31,500 cfs, plant capacity flow. During the experiment a significant establishment of *Tamarix* seedlings was observed in the newly exposed beach areas, but a 31,500 cfs spike flow in the fall resulted in a similarly significant mortality in the seedlings. The experimental low steady flow through the Grand Canyon was designed to create habitat and a food base for native endangered fish. It is important to understand the different responses that an experimental hydrograph will have on a system when making management decisions. From the results found in this study, it appears that the rapid establishment of exotic plant seedlings needs to be taken into consideration when altering a stream-flow regime.

Introduction

Riparian ecosystems are an endangered environment in the American Southwest, comprising less than 3 percent of the total landscape area (Naiman and Decamps 1997). Riparian plant communities have several effects on riverine ecosystem functions. Stabilization of stream channels (Riedl and Zachar 1984) and stored sediments (Lowrance et al. 1986) are attributed to riparian vegetation. In addition, riparian plants act as nutrient sinks and improve water quality for the surrounding watershed (Schlosser and Kar 1981). They influence water temperature through shading, decrease flood peaks by providing flow resistance, and act as important recharge points for restoring ground water supplies (Debano and Schmidt 1990; McGlothin et al. 1988). A wide variety of animals and plants are found within riparian habitats, and these areas are known for supporting a great amount of biodiversity (Carothers 1977). Therefore, river ecosystem processes and biodiversity are dependent on their surrounding riparian plant community.

River processes are drastically altered by dam construction. Dams alter river hydrology by reducing sediment load, causing channel incision, and drawing down water tables (Reily and Johnson 1982). Dam construction also promotes the establishment of exotic species (Smith et al. 1998) and alters the fauna that are dependent on historical river conditions. Dams are also known to decrease the temperature of water flowing through a river corridor by releasing cold water from the bottom of a reservoir or lake.

Tamarix is a summer-germinating species that covers approximately 500,000 ha of floodplain land in the western United States (Stromberg 1997); it is a dominant tree in the Grand Canyon. This exotic plant is responsible for disrupting native willow and cottonwood stands in many southwestern riparian areas (Ohmart and Anderson 1982). *Tamarix* was introduced to the United States during the nineteenth century as an ornamental plant (Robinson 1964). These trees are adapted to establish after spring flood disturbances (Brock 1994) in moist open sites (Everitt 1980). *Tamarix* can be reproductively mature the first year following establishment (Brock 1994), and can produce prolific amounts of seeds through much of the growing season (Warren and Turner 1975).

The Colorado River is one of the most used and anthropogenically manipulated rivers in the world (Malanson 1993). Since the construction of Glen Canyon Dam in 1963, the Colorado River corridor has been critically altered with regard to the disturbance regime, sediment load, flora, and

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many other biotic and abiotic factors (Webb et al. 1999). Experimental flows took place on the river from May through September of 2000. The purpose of the low steady flows was to create habitat and a food base for the native endangered humpback chub juveniles (*Gila cypha*). The stream flow hydrograph during this period consisted of a four-day spike flow of approximately 33,200 cfs in May and also in September; between the spike flows, water was maintained at a low steady flow of about 8,000 cfs. The spike flow in May was designed to allow juvenile fish to gain access to tributary mouths. After the spike flow the water in the Colorado River corridor was decreased to about 19,000 cfs to create a pooling effect. Managers hypothesized that the pooling would keep the juvenile fish from getting swept from tributary mouths into the main-stem Colorado River.

We know that hydrologic regimes greatly influence the structure and function of riparian vegetation (Bedford 1996; Poff et al. 1997). The purpose of our study was to observe *Tamarix chinensis* seedling colonization in the beach areas that are exposed by lowering the water in the river corridor from power plant capacity (31,500 cfs) to a low steady flow of 8,000 cfs. Here we examine the response of *Tamarix chinensis* over time to low steady flows and a September spike flow.

Methods

Our study sites are along the Colorado River corridor through Marble Canyon and Grand Canyon, in Arizona. Throughout the summer of 2000, water was released out of Glen Canyon Dam at an approximate steady flow of 8,000 cfs with two spike flows of 31,500 cfs in May and September. These experimental flows marked the first time in history that the Colorado River was being managed for biological purposes. The study area is dominated by small beaches composed of fine-grained sediment. Vegetation along these beaches consists of herbaceous riparian plants (*Equisetaceae, Juncaceae,* and *Cyperaceae*), exotic *Tamarix chinensis* trees, and some native willow (*Salix exigua*). Farther away from the river and up the canyon walls the vegetation shifts dramatically from riparian to arid plants such as *Agavaceae* and *Cactaceae* species.

Sites were selected based on the vegetation present and the structure of the beach. We selected beaches with few cobble bars and other obstacles that could potentially impede seedling establishment. Most of the sites are in reaches of the river corridor where sand bar studies are being conducted, so topographic layouts are readily available. Figure 1 shows the spatial distribution of the sites along the river. Sites RM1, RM7, and RM68

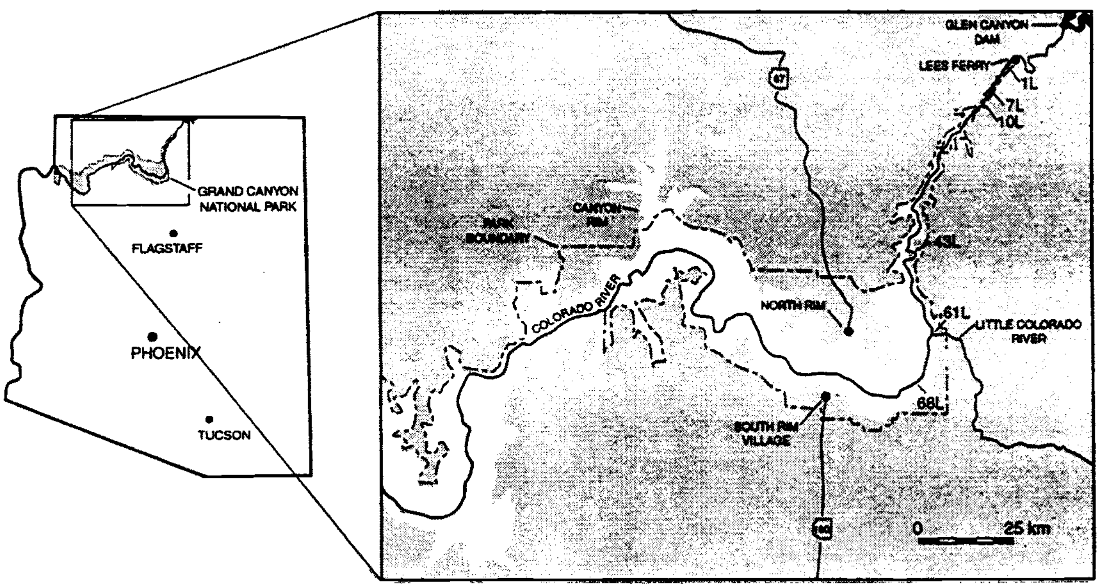

Figure 1. The location of the six sites surveyed for this study. Sites RM1 and RM7 are in close downstream proximity to the Paria River confluence. Site RM68 is downstream of the Little Colorado River. Sites RM11, RM43, and RM61 are not near any tributary confluences.

are downstream of confluences with the Paria and Little Colorado Rivers.

Vegetation density was measured at specified transects within a site. Vegetation was censused using a 0.25 m^2 at each meter down each transect. *Tamarix* seedlings in this area were counted in a 0.25 m^2 from the 19,000 cfs edge down to the approximate 8,000 cfs edge of water. These data were collected in June, July, and August, and in September after the four-day spike flow of 33,200 cfs. The data were analyzed using Manova repeated measures analysis of time in JMP 4 (SAS Institute). Dam discharge and flow data were collected from USGS gauges at Lees Ferry (RM0) and at Phantom Ranch (RKM124.5).

Results

The stream flow hydrograph taken at Lees Ferry shows the amount of water flowing out of Glen Canyon Dam from May through September 2000 (Figure 2). The dam released a 4-day spike flow in May followed by a pooling period and flow decrease to 8,000 cfs. There was very little variation in the water level for the remainder of the summer. The water remained low and steady at 8,000 cfs. At the beginning of September another four-day spike flow occurred, and water flowed out of the dam at 31,500 cfs.

Tamarix seedlings showed a time response between the June and August sample (Figure 3) when we saw a significant increase in tamarisk seedling growth ($F = 93.2556$, $P < 0.0001$). From June to July there was a 34 percent increase in seedling establishment, and from July to August another 68 percent increase occurred in *Tamarix* seedling establishment. After the September spike flow the presence of *Tamarix* seedlings decreased ($F = 22.4511$, $P < 0.0001$). The seedling count in September showed a 64 percent reduction from the August sample.

Different sites responded differently through time (Figure 4). Sites RM1, RM2, and RM68, which are closer to major confluences of the Paria or Little Colorado River, experienced significantly more tamarisk seedling growth from June through August ($F = 2.6272$, $P < 0.0074$) than sites RM10, RM43, and RM61. Sites RM1, RM2, and RM68 also experienced significantly ($F = 4.7321$, $P < 0.0014$) less tamarisk seedling mortality after the 4-day spike flow in September.

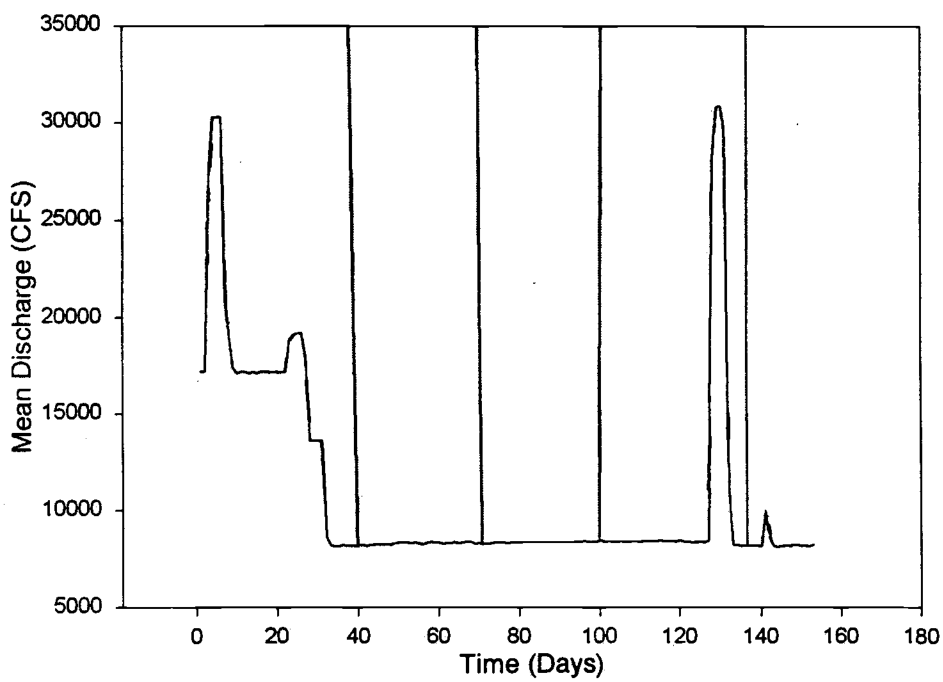

Figure 2. Mean discharge from USGS gauge at Lees Ferry, AZ (in cubic feet per second, cfs). The vertical lines indicate sampling dates throughout the summer's steady low flows. A spike flow went through the system at approximately day 30.

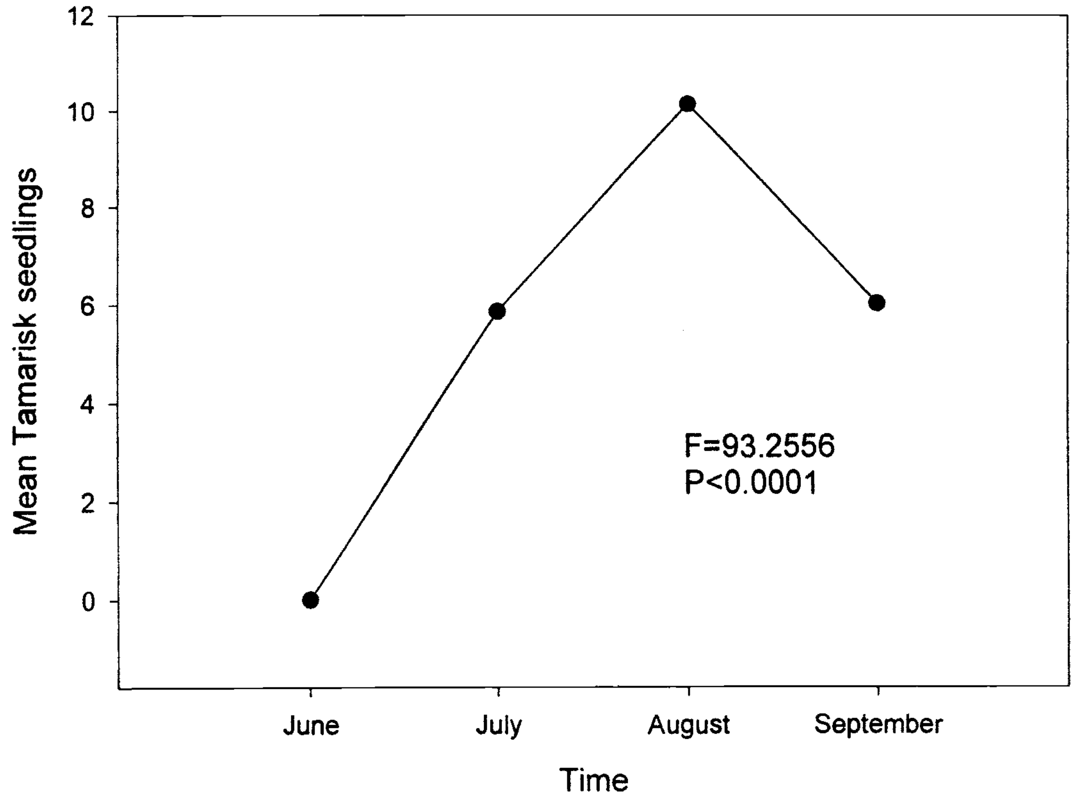

Figure 3. *Tamarix* seedling establishment, June to September. There was a 38% increase from June to July, a 68% increase from July to August, and a 64% reduction after the spike flow in September.

Because we determined a site by time interaction, we did an analysis on individual site differences over time. For sites RM1 and RM7 below the Paria confluence and for RM68 below the Little Colorado River confluence we did not determine a significant difference within sites over time ($F = 0.5861$, $P = 0.6392$; $F = 0.5333$, $P = 0.6739$; and $F = 2.0519$, $P = 0.2493$ respectively). Sites RM10, RM43, and RM61 without an upstream confluence had significant time differences within sites ($F = 0.0714$, $P = 0.9667$; $F = 0.0774$, $P = 0.9689$; and $F = 1.7634$, $P = 0.3264$ respectively).

Discussion

Al six sites showed significant tamarisk seedling establishment from June through August. However, following the 4-day spike flow in September, there was enormous seedling mortality; a 64 percent reduction in *Tamarix* seedling density was observed in September compared to the August sample. We attribute the seedling mortality to the spike flow. These results showing inundation mortality are consistent with the literature; it is well documented that salt cedar does not respond well to fall flooding and inundation (Gladin and Roelle 1998; Stromberg 1997, 1998).

This research on *Tamarix chinensis* has many implications for management of the Colorado River in the Grand Canyon. Rapid establishment of *Tamarix* seedlings along newly exposed beaches should be considered when managing for native endangered fishes. Converse et al. (1998) have shown that fish densities are nearly twice as great along vegetated shorelines as on talus or debris fans. Managers can therefore allow *Tamarix* to help create fish habitat, but this increases the range of this exotic tree, which dominates beaches in the Grand Canyon. Other studies (Stromberg 1998) have shown that *Tamarix* and cottonwood (*Populus fremontii*) are essentially equivalent in riparian ecosystems along free-flowing rivers. If this is the case along the regulated Colorado River, then perhaps *Tamarix*, although an exotic tree, can maintain the riparian functions of the system and provide fish habitat.

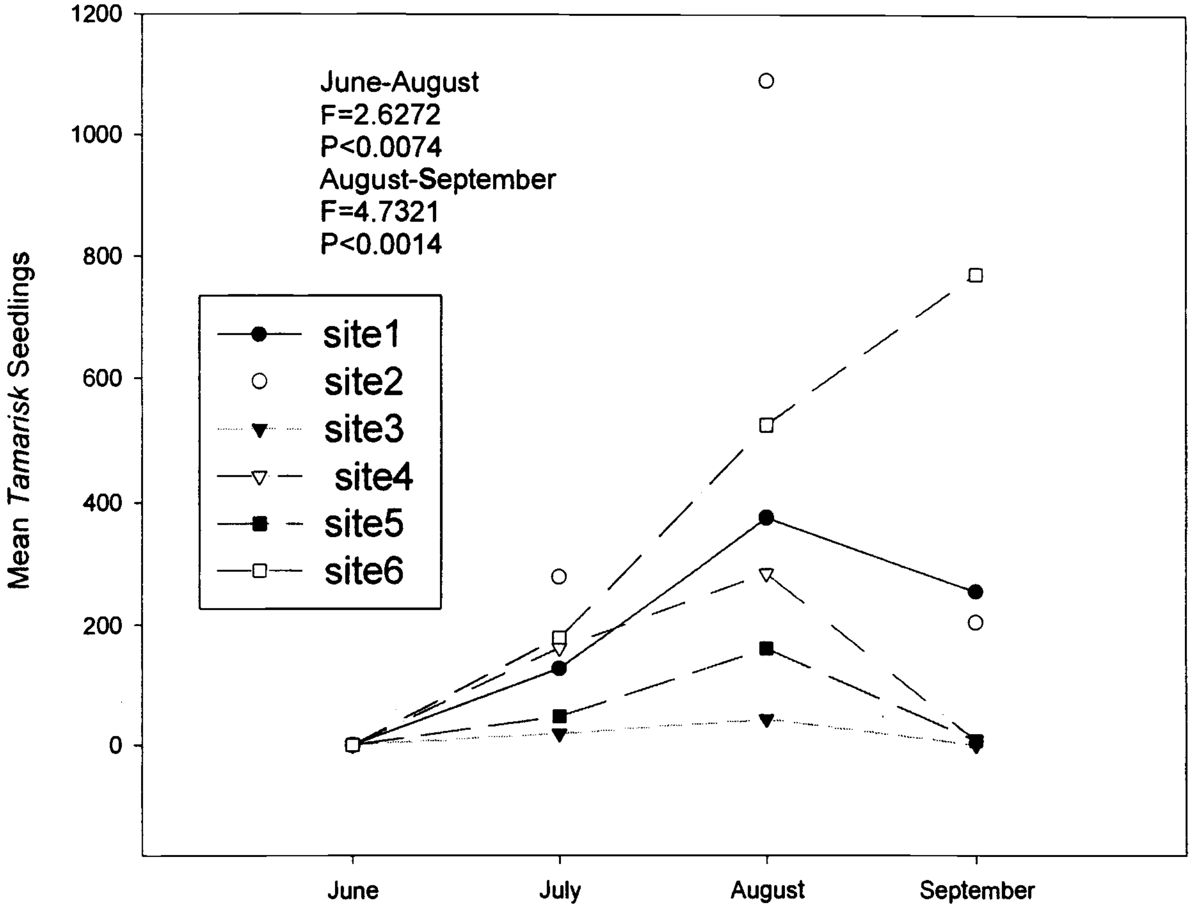

Figure 4. Establishment of *Tamarix* seedlings by site during steady low experimental flow at 8,000 cfs from June through August 2000. Seedlings at sites 1, 2, and 6 downstream from confluences display the most growth.

Geology can also affect the establishment of seedlings. Reaches of the river considered to be wide may have more solar input for better growth, and their shallower slopes allow vegetation to be closer to the water table and less likely to be affected by floods than reaches of the Colorado River considered to be narrow (Schmidt and Graf 1988). All of the sites in this paper are in reaches considered to be wide, with shallow slopes. Sites RM1, RM7, and RM68 have a greater average unit of stream power in pounds per foot than sites without confluence inputs. Sites RM11, RM43, and RM61 also have a greater number of re-circulation zones than sites with confluence inputs.

A final consideration is the quality of recreation in the Grand Canyon. Exposing new beaches, a prime recreation resource, to tamarisk establishment could potentially diminish the usable area of those beaches for camping as the seedlings grow larger. Ultimately, the encroachment of vegetation is almost as important as erosional processes in decreasing beach areas along the Colorado River corridor (Kearsley et al. 1999; Webb et al. 1999).

In summary, *Tamarix chinensis* established seedlings prolifically from June through August during the steady 8,000 cfs flows on the Colorado River through the Grand Canyon. It then experienced great mortality following a 4-day spike flow of 33,200 cfs (power plant capacity) in September. These data provide biology, hydrology, and recreation management implications for the area.

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