New Habitats for Old: Tamarisk-Dominated Riparian Communities and Marshes in the Grand Canyon

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ABSTRACT

The Grand Canyon has been invaded by novel vegetation communities. After Glen Canyon Dam restrained historical water flows, the old scour zone was colonized by native and exotic plant species. This paper focuses on two novel vegetation communities that resulted; a tamarisk (*Tamarix ramosissima*) dominated riparian 'forest' and fluvial marshes. The marsh and tamarisk communities overlap, but I discuss them separately for their respective pros and cons. Tamarisk is an invasive weed threatening southwestern riparian communities. With limited competition, it has the ability to expand its range by prolific seed dispersal and the ability to alter soil conditions to exclude native species. Marshes, found in the fluctuation zone of the Colorado River, were rare pre-dam (Stevens et al. 1995, Kearsley and Ayers 1999). Although marsh species are mostly native, prior to the dam they were restricted to tributaries and springs where the water supply was constant. The current flow regime supplies a constant hydrograph which maintains these communities along the main stem. While experimental flow objectives target these communities, the high flow events have had little impact on them. Tamarisk and marsh communities have changed the system by increasing productivity and biodiversity in the riparian areas of the lower Colorado River.

INTRODUCTION

Pre-Glen Canyon Dam, the riparian system along the Colorado River in the Grand Canyon had low plant species diversity and low productivity. The old high water zone favored riparian plant species such as Fremont cottonwood (*Populus fremontii*), Goodings willow (*Salix gooddingii*), and coyote willow (*S. exigua*) which are adapted to seasonal scouring floods. With most of the sediment stored behind the dam, and decreased frequency and magnitude of river flows, perennial plant communities are no longer restricted above this old high water zone. Survival and growth of riparian plants in arid environments is dependent on water from stream flow and a high ground water table (Zimmerman 1969). Without scouring floods and a stable water level, fluvial marshes and the invasive tamarisk have greatly expanded their range over sandbars and channel banks (Stevens et al. 1995).

With the object of mimicking natural flow regimes, the Bureau of Reclamation released a controlled flood in 1996. Objectives were to remove or reduce vegetation on sandbars and backwater channels (Kearsley and Ayers 1999). Due to the low magnitude and duration of the flows, vegetation was not scoured. Instead, the flood covered herbaceous and woody vegetation with up to 4.5 feet (1.5 m) of fine grain sand (Parnell et al. 1999, Stevens et al. 2001). Unexpectedly, this increased the decomposition rate and mineralization rate, releasing phosphorous, nitrogen, and carbon into the root zones of the sand bar (Parnell et al. 1999). The resultant nutrient surge increased terrestrial production in backwaters and sand bars for two years (Schmitt 2001). Another controlled flood was released in November 2004 but the results have not yet been examined.

In this paper, I describe the two main types of riparian plant communities (tamarisk and marshes) and assess the effects of pulse flooding on each. I then discuss implications for management.

HISTORICAL CHANGES IN RIPARIAN VEGETATION

Pre-Glen Canyon Dam, riparian vegetation in the Grand Canyon was restricted above the scour zone (Figure 1). With decreased magnitude and flows from the dam, riparian vegetation has expanded its range into the new high water zone above the water fluctuation zone (Figure 1). Density, diversity and productivity of riparian vegetation have increased. These communities were rare and restricted in area under pre-dam conditions (Stevens et al. 1995), but they now are apparently important components of both the terrestrial and aquatic systems.

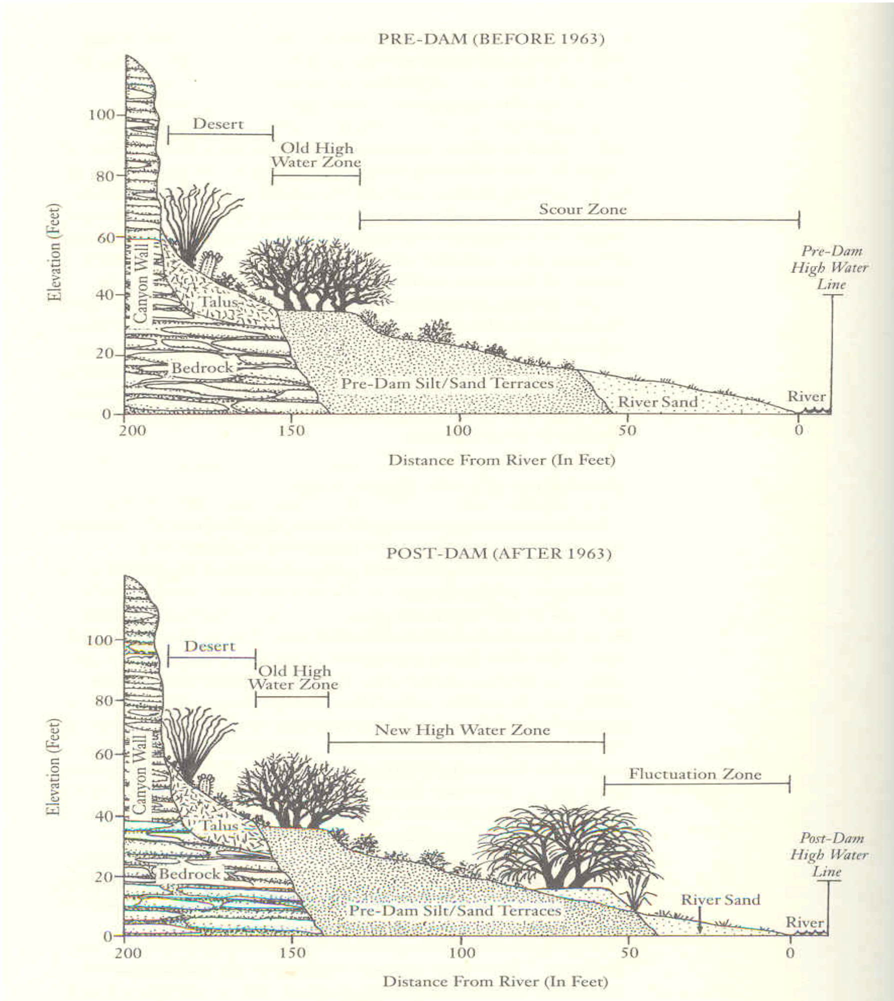

Figure 1. Riparian vegetation zone changes pre and post Glen Canyon Dam (Carothers and Brown 1991).

THE TAMARISK INVASION

Tamarisk as a Threat

Tamarisk was introduced from central-Asia in the late-1800s for ornamental value, windbreak, shade, and erosion control (Conway et al. 2003). It was first recorded in the Grand Canyon in 1938 (Clover and Jotter 1944). Tamarisk dominates the Grand Canyon riparian system both because it is a superior competitor and because native cottonwood and willows no longer have floods to scour substrates which allow their germination and establishment (Shafroth et al. 2001). The current flow regime of Glen Canyon Dam has relatively constant low flows. This has allowed tamarisk to extend its range down to the channel (Shafroth et al. 2001). Once established, tamarisk is a facultative phreatophyte which means it requires ground water but it can utilize surface water in times of stress (Warren and Turner 1975, Busch et al. 1992). Native willows, on the other hand, are obligate phreatophytes meaning they are unable to use surface water and thus require a ground water supply (Jackson et al. 1990). This allows tamarisk to be more tolerant of changing conditions (Nature Conservancy 2000).

Figure 2. Tamarisk (*Tamarix ramosisisma*) on the Colorado River. (left, photo by J. Grahme *In* Stevens 2005; right Randall 2004).

Tamarisk is regarded as a threat to diversity in the southwestern United States (Nature Conservancy 2000). Overall, tamarisk is a superior competitor against native plant species. It is able to change native plant succession by disrupting nutrient and fire cycles. Tamarisk has a higher evapotranspiration rate (Mitsch and Gosselink 2000), which decreases water available for other plants and increases salt concentration of surrounding soils (Nagler et al. 2003). Tamarisk keeps high concentrations of salt in its leaves, thus making it unpalatable to some herbivores. Tamarisk also increases soil salinity by dropping its salty leaves to decompose at the base of the plant (Conway et al. 2003, Nagler et al. 2003). High salt concentrations in the soil can prevent germination of native species, including cottonwood and willows (Jackson et al. 1990, Jackson et al. 1990, Stevens et al. 1999). By preventing other species from germinating, tamarisk promotes its own seeds. Compared to native plant species, tamarisk has earlier onset of maturity, longer seed dispersal period, and higher overall output (Warren and Turner 1975, Tallent-Halsell and Walker 2002, Conway et al. 2003). Seedlings of tamarisk are also suited for harsh conditions. They are able to germinate in presence or absence of light, saline or non-saline conditions, and they have a resistance to fire (Horton et a. 1960, Sher et al. 2001).

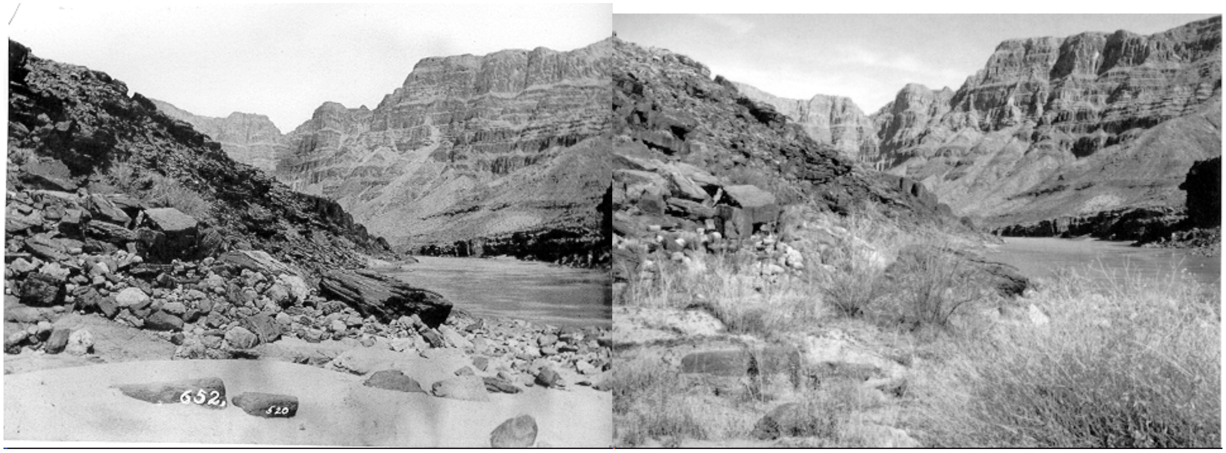

Figure 3. One hundred year change in riverside vegetation (Figure taken from Webb 1996)

Tamarisk Response to Flooding

An objective of the 1996 controlled spring flood was to decrease riparian vegetation (tamarisk and marshes). Not all vegetation was to be removed because of use by endangered species (Purdy 2005, this volume, Schell 2005, this volume). Compared to the pre-dam flows, 45000 cfs (1274 m^3/s) was a small flood. The small magnitude flow did not scour vegetation but rather the vegetation slowed water movement along the edges and in backwaters and sediment was deposited (Stevens et al. 2001). This sediment deposition increased decomposition of buried vegetation, releasing nutrients, and thereby increasing plant growth for two years. Thus, the objectives were not met because riparian vegetation increased post-flood.

The objective for the November 2004 flood was less defined for riparian vegetation. Because of the high sediment load in the Colorado River, some scour of smaller tamarisk communities could have occurred near the water's edge, but the mature communities in the new high water zone were probably not affected. A possible outcome of the flood is removing newly established tamarisk seedlings. Fall flooding inflicts a higher mortality on the previous year's tamarisk seedlings compared to spring flooding (Gladwin and Roelle 1998).

FLUVIAL MARSH EXPANSION

Formation of Fluvial Marshes

Favorable conditions for marsh formation have been created by the present regime's relatively steady flows, which maintains a high water table and has eliminated scouring. Compared to pre-dam conditions, these flows have resulted in improved soil quality, more litter retention, and more complex vegetation structure (Ranswell 1963) in marshes bordering the

Colorado River. Marsh formation is dependent on local scale geomorphic processes which control where the river deposits sediments and alters the location and magnitude of return current channels (Merritt 2000).

Fluvial Marsh Composition

Although a majority of the vegetation found in marshes is native to streams and perennial tributaries in the Colorado River system, these marshes were not present in their current locations prior to Glen Canyon Dam (Stevens et al. 1995, Infalt 2005, this volume). In 1991, riparian marshes covered over 25 hectares (Stevens et al. 1995). There are four distinct types of marshes as described by Stevens et al. (1995); clonal wet, nonclonal wet, woody phreatophyte, and dry marshes. **Clonal wet marshes** have silty, loam soil and is inundated 50% of the time by water. The species that typify this type of marsh are cattails and reeds (Stevens et al. 1995). The second wet marsh is the **nonclonal wet marsh** which is dominated by herbaceous horseweed and Bermuda grass (Stevens et al. 1995). These two wet marshes are formed within the intermediate flood zone from steady daily or seasonal discharges from the dam (Figure 1). There are two types of dry marshes which have sandy soils and are rarely inundated. **Woody phreatophyte marshes** are dominated by woody perennials such as tamarisk and arrowweed (Stevens et al. 1995). **Dry marshes** are comprised of horsetails and willows (Stevens et al. 1995). Both of these drier marshes are found in the new high water zone (Figure 1).

These novel habitats are highly productive and support a higher biodiversity than the historic river-edge habitats. The new diversity includes birds, such as the southwestern willow flycatcher and Bells Vireo (Schell 2005, this volume), terrestrial invertebrates (Purdy 2005, this volume), mammals and reptiles (Dettman 2005, this volume).

Response of Marshes to Flooding

The 1996 flood had positive effects on marsh plant communities. These communities are highly resilient to disturbance and are able to rebound after short flood duration (Stevens et al. 1995). It was hypothesized that the 1996 flood would scour marsh communities from return current channels and backwater habitat for fish and invertebrates would be recreated (Purdy 2005, this volume). However, the flood did not create velocities high enough to scour plants or erosion resistant soils. In contrast, the marsh vegetation reduced eddy velocities and caused sediment deposition (Stevens et al 2001). The nutrients from the decomposing buried plants led to a rapid regrowth of vegetation, which further slowed erosion rates (Merritt 2000, Schmitt et al. 2001). Marshes remained or increased as seen in mapping by Kearsley and Ayers (1999).

MANAGEMENT FOR TAMARISK AND MARSHES

Tamarisk Management Options

Tamarisk is well established in the Colorado River riparian system. Without effort to impede its progress, it will continue expanding its range at the expense of native vegetation, including marsh communities. If the current flood management does not slow tamarisk, other control options need to be considered such as herbicides, manual removal or different flow regimes. There are four flood regimes that would reduce tamarisk invasion as outlined by Levine and Stromberg (2001): 1) winter and spring floods to regenerate native seed beds followed by low summer flows to desiccate exotics, 2) long summer floods to drown tamarisk, 3) one, short duration, high magnitude flood to scour tamarisk, and 4) many short duration summer floods, important if there are no spring flood events. These regimes mostly target tamarisk seedlings because it is the only time that tamarisk is an inferior competitor to cottonwood and willow (Sher et al. 2001). It is difficult to eliminate mature tamarisks, but if the flow regimes could decrease further tamarisk recruitment, there is hope that tamarisk will not completely dominate this system.

The positive effects of tamarisk must also be considered in management options. Insects, reptiles, amphibians, and birds have benefited from the increased riparian vegetation, which includes tamarisk (Johnson 1991). Many vertebrates and invertebrates use this novel tamarisk habitat, whereas before they would have used willow and cottonwood stands (Stromberg et al. 2003). However, the endangered southwestern willow flycatcher apparently preferentially uses tamarisk for breeding and foraging habitat as seen by the designated critical habitat from mile 62.8 through 115 on the Colorado River (U.S. Fish and Wildlife Service 1997, Schell 2005, this volume). Terrestrial vertebrate populations have also expanded into this novel community (Dettman 2005, this volume). The invertebrate food base has also colonized tamarisk (Purdy 2005, this volume).

Under current 2005 dam conditions, the water level behind the dam is too low and the flow capacity of Glen Canyon Dam is too little required to scour tamarisk out of its current hold. It is not possible to entirely remove tamarisk from this system. If it was possible to reduce or remove some tamarisk, allowing native vegetation establishment, many species might benefit from the increased structural diversity of the plant community, although this is by no means certain. Tamarisk is presumably a threat mainly if it is allowed to monopolize a system. Without acknowledgment that tamarisk is spreading and needs to be dealt with, the invasion will continue. It is possible to reduce (but not eliminate) tamarisk populations from the Grand Canyon through a combination of physical removal and herbicides, but this would be expensive and time consuming. It might be worthwhile, however, to experimentally reduce tamarisk numbers in some selected areas, along with the planting of cottonwoods and willows, in order to see how animal life responds to the change.

Marsh Management Options

Marshes were not present before Glen Canyon Dam because of the fluctuating, scouring water flows. Stevens et al. (1995) believe that the Colorado River is a 'bottom-up' system dependent on sediment movement. The Colorado River used to carry sediment that scoured all vegetation and reworked sandbars providing diverse aquatic habitat (Booth 2005, this volume) required by the native invertebrate (Purdy 2005, this volume) and fish species (Campos 2005, this volume). When sediment becomes trapped by stable marsh vegetation, both aquatic and terrestrial systems are altered. At the cost of decreasing aquatic habitat diversity, terrestrial habitat has increased, along with the abundance of terrestrial organisms An objective of the current flow management is to put sediment back into this system.

High sediment capacity, relatively low magnitude, short duration pulse flooding will not remove marshes, as seen by the results of the 1996 flood attempt. If the management goal is to maintain or expand marshes, short duration flooding (three day duration) is ideal (Kearsley and Ayers 1999). If the objective is to remove marshes, seasonal, long duration, high intensity floods would be required. The peak intensity of floods would have to be nearly double the 1996 peak discharge of 45000 cfs to scour established vegetation (Stevens et al. 2001). Long duration flooding decreased the area of marshes after several years of high flows due to the 1983 flood (Stevens et al. 1995). Depending on the human management values, marshes can be considered a benefit or a problem to the Colorado River system. Depending on which viewpoint prevails, flood management can increase or decrease marsh habitat.

Overall Conclusions

Forty-two years after the completion of Glen Canyon Dam, the riparian communities of the lower Colorado River have dramatically changed. The future of the two exotic communities discussed here depends on management goals. If the main goal is to restore the system to pre-dam conditions, larger and longer floods will be required. However, more vegetation has increased bank stability and woody vegetation has more resistance to flood damage, indicating an even greater flood magnitude would be required to reset the system to historic conditions (Shafroth et al. 2001). If nothing is done to curtail present vegetation trends, I believe that tamarisk is likely to expand to a near monopoly over this system, including crowding out the marshes. Marshes will eventually be confined along the immediate river's edge where they are more susceptible to flood mortality. Riparian vegetation (tamarisk) will expand its range until no backwater habitat remains. Presumably this will result in a decrease (from present conditions) of the diversity and abundance of terrestrial animals, although this hypothesis would have to be tested if large-scale tamarisk control programs are instituted. Aquatic systems must be considered in management options so that terrestrial vegetation is not allowed to completely dominate riparian areas.

REFERENCES

Baker, V.R. 1984. Flood sedimentation in bedrock fluvial systems. Pages 387-390 *in* E.H. Koster and R.J. Steel, editors. Sedimentology of gravels and conglomerates. *Canadian Society of Petroleum Geologists Memoir* 10.

Busch, D.E., N.L. Ingraham, and S.D. Smith. 1992. Water uptake in woody riparian phreatophytes of the Southwestern United States: a stable isotope study. *Ecological Applications* 2: 450-459.

Carothers, S.W., and B.T. Brown. 1991. The Colorado River Through the Grand Canyon. The University of Arizona Press, Tucson.

Clover E.U. and L. Jotter. 1944. Floristic studies in the canyon of the Colorado and tributaries. *American Midland Naturalist* 32:591-642.

Conway, K., J. Sirota, and S. Rose. 2003. Tamarisk (*Tamarix* spp.). http://www.coopext.colostate.edu/TRA/PLANTS/index.html#http://www.colostate.edu/Depts/CoopExt/TRA/PLANTS/tamarisk.html *In* University of Colorado Cooperative extension. date assessed: 3/1/2005.

Gladwin, D.N. and J.E. Roelle. 1998. Survival of plains cottonwood (*Populus deltoides* sub. *Monilifera*) and saltcedar (*Tamarix ramosissima*) seedlings in response to flooding. *Wetlands* 18*:669-674.*

Horton, J.S. F.C. Mounts, and J.M. Kraft. 1960. Seed germination and seedling establishment of phreatophyte species: United Sates Department of Agriculture, Rocky Mountain Forest and Range Experiment Station, Ft. Collins, CO, USA. Paper No. 48.

Jansson, R., C. Nilsson, M. Dynesius, and E. Andersson. 2000. Effects of river regulation on river-margin vegetation: A comparison of eight boreal rivers. *Ecological Applications* 10:203-224.

Johnson, R.R. 1991. Historic changes in vegetation along the Colorado River in the Grand Canyon. Colorado River Ecology and Dam Management, Proceedings of a Symposium, May 24-25, 1990, Santa Fe, New Mexico. National Academy Press, Washington D.C.

Kearsley, M.J.C. and T.J. Ayers. 1999. Riparian Vegetation Responses: Snatching Defeat from the Jaws of Victory and Vice Versa. *In* The Controlled Flood in Grand Canyon. Eds. R.H. Webb, J.C. Schmidt, G.R. Marzolf, and R.A. Valdez. Washington D.C., American Geophysical Union.

Levine, C.M. and J.C. Stromberg. 2001. Effects of flooding on native and exotic plant seedlings: implications for restoring south-western riparian forests by manipulating water and sediment flows. *Journal of Arid Environments* 49:111-131.

Marler, R.J., J.C. Stromberg, and D.T. Patten. 2002. Growth response of *Populus fremontii*, and *Salix gooddingii*, and *Tamarix ramosissima* seedlings under different nitrogen and phosphorous concentrations. ???

Merritt, D.M. and D.J. Cooper. 2000. Riparian vegetation channel changes in response to river regulation: a comparative study of regulated versus unregulated streams in the Green River Basin, USA. *Regulated Rivers: Research Mangement.* 16:543-564.

Mitsch, W.J. and J.G. Gosselink. 2000. Wetlands. 3rd ed. New York, John Wiley and Sons, Inc.

Nagler, P.L., E.P. Glenn, and T.L. Thompson. 2003. Comparison of transpiration rates among saltcedar, cottonwood, and willow trees by sap flow and canopy temperature methods. *Agriculture and Forest Meteorology* 116:73-89.

Nature Conservancy. 2000. Element Steward Abstract: Tamarix species (Saltcedar, Tamarisk). http://tncweeds.ucdavis.edu/esadocs/tamaramo.html Invasive Species Inititiave. Date accessed: 3-1-2005.

Parnell, R.A., Jr., J. Bennett, and L. Stevens. 1999. Mineralization of riparian vegetation buried by the 1996 controlled flood. Pages 225-240 *in* R. H. Webb, J.S. Schmidt, G.R. Marzolf, and R.A. Valdez, editors. *In* The Controlled Flood in the Grand Canyon. Washington, D.C., American Geophysical Union Geophysical Monograph 110.

Randall, J.M. 2004. Invasive Species inititive: dense tamarisk photo. The Nature Conservancy. 3/08/2005. http://tncweeds.ucdavis.edu/photos/tamsp06.jpg

Ranswell, D.S. 1963. Spartina salt marsh in southern England, III: Rates of establishment, succession and nutrient supply at Bridgewater Bay, Somerset. *Journal of Ecology* **52**:95-106.

Schmidt, J.C., R.A. Parnell, P.E. Grams, J.E. Hazel, M.A. Kaplinski, L.E. Stevens, and T.L. Hoffnagle. 2001. The 1996 Controlled Food in the Grand Canyon: Flow Sediment Transport and Geomorphic Change. *Ecological Applications* 11:657-671.

Shafroth, P.B., J.C. Stromberg, and D.T. Patten. 2001. Riparian vegetation responses to altered disturbance and stress regimes. *Ecological Applications*. 12:107-123.

Sher, A.A., D.I. Marshall, and S.A. Gilbert. 2000. Competition between native *Populus deltoides* and invasive *Tamarix ramosissima* and the implications for reestablishing flooding disturbance. *Conservation Biology* 14:1744-1754.

Sher, A.A., D.L. Marshall, and J.P. Taylor. 2001. Establishment patterns of native *Populus* and *Salix* in the presence of invasive nonnative *Tamarix*. *Ecological Applications* 12:760-772.
Stevens, L.E. Exotic Tamarisk on the Colorado Plateau: Saltcedar or Tamarisk (Tamaraceae: *Tamarix ramosissma* Deneb). www.cpluhna.nau.edu/ Biota/tamarisk.htm Colorado Plateau: Land Use History of North America. date accessed: 3-1-2005.

Stevens, L.E., T.J. Ayers, J.B. Bennett, K. Christensen, M.J.C. Kearsley, V.J. Meretsky, A.M. Phillips, III, R.A. Parnell, J. Spence, M.K. Sogge, A.E. Springer, and D.L. Wegner. 2001. Planned flooding and Colorado riparian trade-offs downstream from Glen Canyon Dam, Arizona. *Ecological Applications* 11:701-710.

Stevens, L.E., J.C. Schmidt, T.J. Ayers, and B.T. Brown. 1995. Flow regulation, geomorphology, and Colorado River marsh development in the Grand Canyon, Arizona. *Ecological Applications* 5:1025-1039.

Stromberg, J., S. Lite, and V. Beauchamp. 2003. Presentation Abstract. *In* 2003 *Tamarix* Symposium – Oct 22-24, 2003: Colorado State University Cooperative Extension. Two Rivers Convention Center, Grand Junction, Colorado.

Taylor, J.P. and K.C. McDaniel. 1998. Restoration of saltcedar (*Tamarix* spp.)-infested floodplains on the Bosque del Apache National Wildlife Refuge. *Weed Technolgoy* 12:345-352.

Tallent-Halsell, N.G. and L.R. Walker. 2002. Responses of *Salix gooddingii* and *Tamarix ramosissima* to flooding. *Wetlands* 22:776-785.

United States Fish and Wildlife Service. 1997. Endangered and threatened wildlife and plants: final determination of critical habitat for Southwestern Willow Flycatcher; correction. *Federal Register* 62: 44228.

Webb R.H. 1996. Grand Canyon - A Century of Change. The University of Arizona Press, Tucson, AZ.

Warren, D.K., and R.M. Turner. 1975. Saltcedar seed production, seedling establishment, and response to inundation. Arizona Academy. *Science Journal* 10:131-144.

Young, J.A., C.D. Clements, and D. Harmon. 2004. Germination of seeds of *Tamarix ramosissima*. *Journal of Range Management* 57:475-481.

Zimmerman, R.L. 1969. Plant ecology of an arid basin, Tres Alamos-Redington Area. U.S. Geological Survey Professional Paper 485-D.