NEW TITLE:

Hydrogeomorphic factors influencing the establishment and distribution of *Tamarix* in Grand Canyon National Park

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Geomorphology and hydrology influence the establishment, persistence, and spread of invasive riparian plants. In turn, riparian plant invasions affect hydrogeomorphology by stabilizing river banks and narrowing river channels. We are interested in the present establishment and distribution patterns of *Tamarix* and the hydrogeomorphic factors that favor *Tamarix* over native riparian woody species in Grand Canyon National Park (GCNP). Following the completion of Glen Canyon Dam in 1963, *Tamarix* colonized the newly available habitat adjacent to the river that was now protected from annual floods. However, new germination surfaces have been limited due to decreased flooding and sedimentation. Current conditions appear to favor new *Tamarix* establishment on cobble bars and silty-sand beaches.

In order to elucidate the influence of geomorphology on *Tamarix* distribution patterns, we estimated *Tamarix* density on random 100 m “floating transects” from Lee’s Ferry to Diamond Creek (364 km). The average *Tamarix* density was 0.29 m^{-2}. The maximum (1.65 m^{-2}) and minimum (0 m^{-2}) *Tamarix* densities were sampled in the Upper Granite Gorge geomorphic reach which has the lowest mean reach width of the sampled reaches. We analyzed the influences of distance to nearest upstream tributary, channel sinuosity, geomorphic reach, substrate resistivity, and channel width on *Tamarix* density using multiple linear regression models. In a previous study we found higher cover of *Tamarix* in geomorphic reaches of moderate resistivity. Additionally, straighter channels are more likely to have higher relative *Tamarix* cover due to this shrub’s unique ability to colonize cliffs and rocky channel margins. We hypothesized that transects located closer to tributary mouths would have a higher density of *Tamarix* as a consequence of added sediments. However, initial analyses (scatterplots) reveal no significant effect of distance to major upstream tributary on *Tamarix* density (p=0.39). These findings corroborate earlier research finding no significant difference in vegetation cover one mile above and one mile below the Little Colorado River tributary.

In addition, historical aerial photo analyses were used to explore the importance of tributary sediment input for facilitating *Tamarix* establishment. We used historical aerial photos of the Colorado River in GCNP from 1965, 1973, 1980, 1985, 1988, 1990, 1995, and 2002 to relate intervals of *Tamarix* establishment to the annual hydrograph record. Specifically, we investigated the effect of tributary flooding on the establishment of *Tamarix* by focusing on four debris fan complexes (DFC) located above and below the Little Colorado River (LCR) / Colorado River confluence. The LCR flooded in 1993 causing inundation, scouring, addition of sediments, and creation of new surfaces for establishment of riparian vegetation downstream. We expected to find a higher proportion of young (post 1993) cohorts (i.e. patches) of *Tamarix* at sites below the LCR when compared with sites above the LCR. In the same way, we investigated the potential for *Tamarix* establishment events related to the managed flood of 1996.

Locations of present-day *Tamarix* patches were mapped in the field in spring 2006 and used to identify *Tamarix* patches in historical aerial photos. Orthophotos from 2002 were used to count the total number of *Tamarix* patches or cohorts at each site with a focus below the 1,274 m^2s^{-1} inundation line (defined by the USGS flow stage reconstruction model) that represents maximum post-dam flows. We compared aerial photos from 1990/1995 with 1995/2002 photos at each DFC, and the number of young cohorts (those patches that were absent in earlier photos but present in the later photos) were counted. The majority of *Tamarix* patches below the 1,274 m^2s^{-1} inundation line originated in the 1990s. Between three and seven percent of the identified patches appeared between 1995 and 2002. This suggests that the 1996 flood did not incite major establishment events at the sampled DFCs.

Thus far, our results indicate that long-term *Tamarix* establishment is not influenced by proximity to upstream tributaries. Sediment aggradation from tributary inputs may occur far downstream from tributary confluences. This suggests a possibly minor influence of tributary flooding and sedimentation on vegetation patterns along the main channel. Thus, appropriate management of flow regime from Glen Canyon Dam might be able to prevent further *Tamarix* establishment in GCNP, given knowledge of flows that have favored *Tamarix* establishment in the past. Clearly we need annually precise data to be able to relate particular flow events to establishment events, so we will age trees on varied geomorphic surfaces to obtain the year of establishment. Dendroecological techniques in combination with analysis of historical aerial photography will allow us to precisely correlate specific *Tamarix* establishment events with key aspects of flow regime and geomorphology.