Documenting Riparian Vegetation Changes along the Colorado River through Replication of Historical Photographs

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This presentation describes an ongoing project of the US Geological Survey's Grand Canyon Monitoring and Research Center (GCMRC) that is documenting changes to riparian vegetation along the Colorado River by analyzing matched photographic images taken prior to construction of Glen Canyon Dam with the same view as it appears today. The purpose of this repeat photography study is not only to assess how the riparian terrestrial environment has changed since closure of Glen Canyon Dam, but also to evaluate how changes in the riparian environment have affected the abundance and distribution of plants of cultural importance to Native American tribes as well as how growth of riparian vegetation has impacted upland dunes and the archaeological sites that occur in and immediately adjacent to the riparian zone.

In February 2015, the USGS's Grand Canyon Monitoring and Research Center (GCMRC) hosted a workshop with representatives from the five tribes that actively participate in the Glen Canyon Dam Adaptive Management Program: Hopi, Hualapai, Kaibab Band of Paiute Indians, Navajo, and Zuni. During this workshop, riparian plant species of mutual interest to multiple tribes were identified as the focus of the current study (Table 1). In 2015 and continuing in 2016, we began assembling historical imagery that could be analyzed for changes in vegetation through time. In addition to working with an existing collection of matched images from the USGS Desert Laboratory Repeat Photography collection, several hundred high-resolution digital scans of photographs from the 1923 USGS Birdseye expedition were obtained from the USGS library archives in Denver, CO. Other data sources that supplement the photographic images include Glen Canyon Environmental Studies-era reports, GCMRC and tribal monitoring data, and historical river runner journals. .

To date, most of the emphasis has been placed on matching panoramic images taken by Eugene C. La Rue during the 1923 USGS dam site survey in Grand Canyon. In the course of working with the 1923 photographs, in 2016, we became aware of some previous attempts at matching the1923 images. One of these efforts was documented in a publication (Baars and others, 1994); however, another attempt in the early 1990s was never completed or reported, due in part to the complexity of accurately matching La Rue's panoramic images (T. Melis, personal comm., 2016). Although the latter attempt at matching La Rue panoramas was only partially completed, numerous prints resulted from this earlier effort that are curated in the Desert Laboratory Repeat Photography collection currently housed at the Southwest Biological Science Center in Flagstaff, AZ. In 2017, we began exploring ways to incorporate these earlier matches as part of our current project to provide a more complete diachronic picture of riparian vegetation change along the Colorado River downstream of Glen Canyon Dam, since implementation of the 1996 record of decision for operating Glen Canyon Dam (Figures 1-2)..

So far, we have matched a total of 120 individual images along the Colorado River (and some images were matched more than once to improve the quality of the final match). We apply analytical methods previously developed by USGS hydrogeologist Robert H. Webb (Webb 1996; Webb and others, 2011) to evaluate post-dam vegetation changes by comparing the 1923 La Rue photos with replicates taken in 1975-1994 and then comparing these post-dam matches with the more recent duplicate images obtained in 2016 and 2017. This qualitative analysis began in late summer of 2017 and is ongoing. While still a work in progress, preliminary analysis reveals patterns and trends generally similar to those identified from a similar analysis conducted with Stanton photos (Scott and others, *in press*), i.e., while riparian vegetation clearly increased dramatically below the level of pre-dam spring flood elevations during the first 10-20 years following emplacement of Glen Canyon Dam, riparian vegetation has continued to increase in subsequent decades within the new high-water zone (Figures 1-2). Since initiation of interim and post-1996 EIS Record-of-Decision modified low fluctuating flows in the early-mid 1990s, most of the formerly open space between tamarisk trees has become infilled with other woody shrubs, primarily *Baccharis* sp., while the fluctuating flow zone below the 25,000 $ft^3/2$ stage elevation, which was only sparsely vegetated in the early 1990s, has become densely colonized with riparian wetland species such as *Phragmites australis, Equisetum* sp., *Juncus* sp., and other water-loving plants.. .Meanwhile, flood-adapted

species such as Gooddings Willow and cottonwood trees have been largely extirpated from the river corridor since completion of Glen Canyon Dam.

In 2018, we plan to continue to collect matches of 1923 images in conjunction with other planned field work and complete the species-specific analysis using these repeat photographs. In collaboration with volunteers Dr. Michael Scott and Alan Fairley, we intend to report the results of this project in a future USGS publication. This report will include numerous sets of matched images and will expand upon initial conclusions reached from analyzing a sample of the Stanton photographs in FY 2016 (Scott and others, *in press*), with emphasis placed on documenting changes in abundance and distribution of each of the species identified in the FY 2015 workshop, so as to provide a more comprehensive assessment of the changes in the distribution and abundance of culturally-valued riparian species along the Colorado River corridor.

Table 1. Species of cultural value to tribes and their changes in abundance, 1923-2018

Plant name/species	Hopi	Hualapai	Navajo	Paiute	Zuni	Change in Abundance				
						--	-	0	+	++
Goodding's willow (*Salix gooddingii*)	X	X		X	X	X				
Cottonwood (*Populus fremontii*)	X	X	X	X	X	X				
Netleaf Hackberry (*Celtis reticulata*)	X	X		X	X				X	
Honey Mesquite (*Prosopis glandulosa*)	X	X		X					X	
Coyote willow (*Salix exigua*)	X	X	X	X	X			?		
Seep-willow (*Baccharis emoryi, B.salicifolia*)	X	X		X						X
Apache plume (*Fallugia paradoxa*)	X	X		X			X			
Prince's plume (*Stanleya pinnata*)	X						?			
Arrow-weed (*Pluchea sericea*)	X	X								X
Common reed (*Phragmites australis*)	X	X	X	X	X					X
Cattail (*Typha sp.*)	X	X	X	X	X				?	
Horsetail (*Equisetum sp.*)	X	X	X	X	X					X
Dropseed (*Sporobolus sp.*)	X				X		?			
Indian Rice Grass (*Achnatherum hymenoids*)	X			X	X		?			

Preliminary Data: Please do not cite.

References

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Webb, R.H., Belnap, J., Scott, M.L., and Esque, T.C., 2011, Long-term change in perennial vegetation along the Colorado River in Grand Canyon National Park (1889-2010). Park Science v. 28, no. 2, p. 83-87.

Figure 1. Matched view at river mile 65.95 (mouth of Palisades Creek), left bank, looking across and downstream (Stake No. 1707a). Top photograph by E.C. La Rue, August 14, 1923. Middle photograph by E. Hymans, February 24,. 1993. Bottom photograph by A. H. Fairley, May 10, 2017. Note how the growth of tamarisk and mesquite trees and increase in other riparian species such as *Pluchea sericea* obscures the view of the Colorado River in 2017.

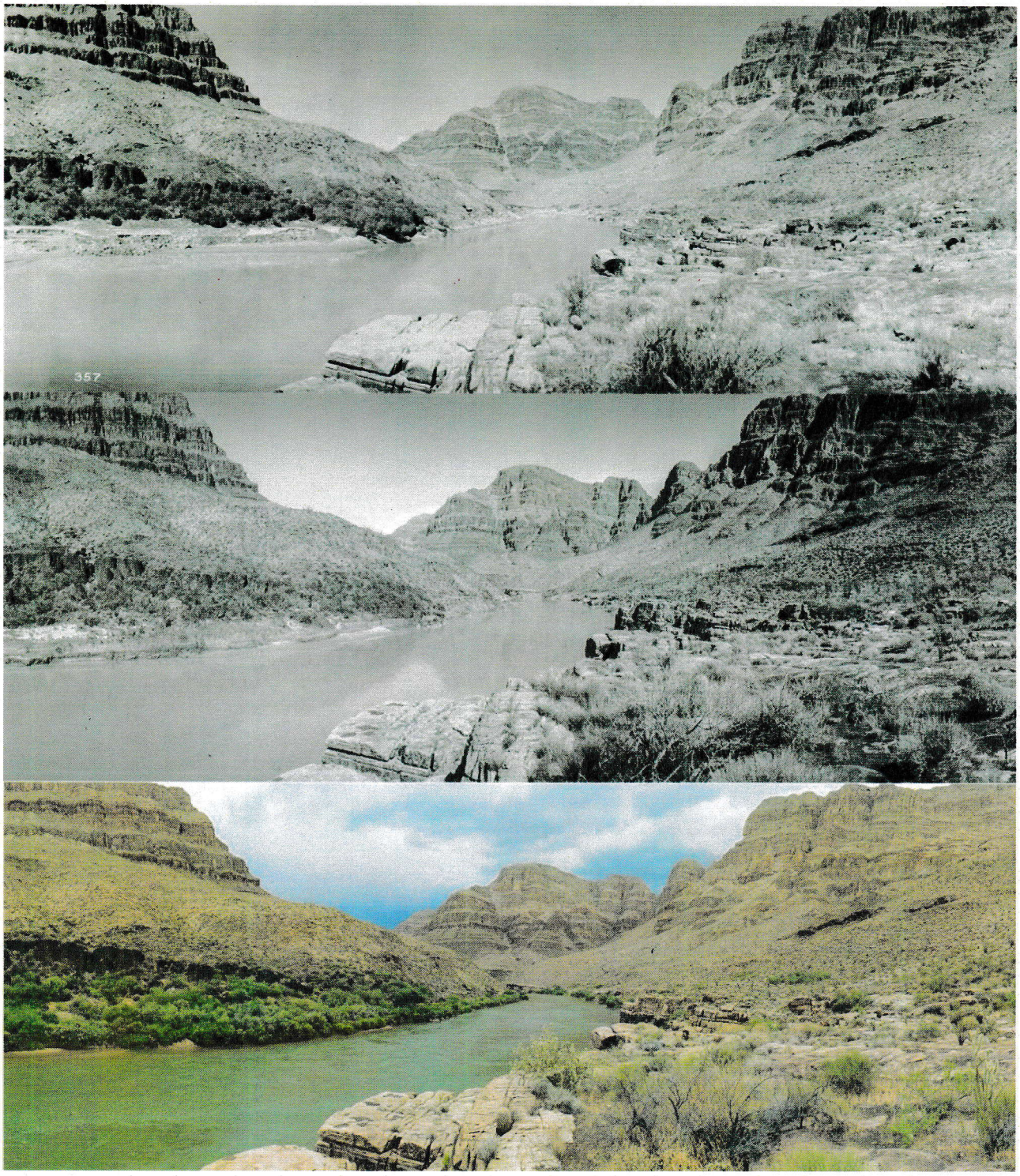

Figure 2. Matched view at river mile 215.7, left bank, looking upstream (Stake No. 701). Top photograph by E.C. La Rue, September 30, 1923. Middle photograph by E. Hymans, March 13, 1993. Bottom photograph by A. H. Fairley, May 17, 2017. Note how 2017 riparian vegetation has filled in previously open sand areas since 1993, including the formerly exposed sandy strip at water's edge.