Chapter 10: Historical Ecology of the Grand Canyon Terrestrial River Corridor Prior to Glen Canyon Dam

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Introduction

The riparian vegetation along the Colorado River in the Grand Canyon corridor has been dramatically altered in the last century by the building of Glen Canyon Dam (Webb et al 2007). In order to properly understand the extent to which this has occurred requires historical investigation. Scientific studies surveying the riparian vegetation in the Grand Canyon corridor are limited (Jotter and Clover 1944). Historical ecology and reconstruction of past ecosystem dynamics has been used in restoration ecology in order to provide a baseline by which to set management goals. In the past several decades, there has been a growing perception that both Arizona and the American Southwest as a whole have experienced significant declines in riparian wetlands (Arizona State Parks 1989). This report will examine the scientific evidence available for determining what the riparian river corridor may have looked like before the building of Glen Canyon dam and discuss the role of this information in management decisions.

Nationally, since the 1970s, there has been an increase in concern over the destruction of riparian habitat. The decline of riparian habitat is alarming given the number of important ecosystem services riparian vegetation serve in a desert environment. With the increased construction of dams in the American Southwest, concerns have centered on the impact of dams on manipulation of water resources and fluvial processes that may threaten the survival of riparian vegetation. This perception of declines in riparian habitat resulted in the Arizona governor in 1991 to issue an executive order "to actively encourage….restoration of degraded riparian areas" (Webb et al 2007). The scientific evidence for this perception has been traced back to a single study on cottonwood gallery forests adjacent to the lower Colorado River (Webb et al 2007).

Robert Webb and colleagues have extensively examined the historical evidence available to determine if this perception of declines in riparian vegetation applies to several of the major river systems in the American Southwest. In the book Ribbon of Green, Robert Webb and others use repeat photography to address the claim that 90 percent of riparian vegetation has been lost in American Southwest. This report will summarize the scientific evidence discovered by Webb and others for changes in riparian vegetation in the Colorado River corridor through the Grand Canyon. This report will describe the terrestrial river vegetation both along key geomorphic stretches of the river and the vertical distribution along the river edge in the pre-dam environment.

Background

Sources of Scientific Evidence for Changes in Riparian Vegetation

There is limited scientific evidence on pre-dam conditions of riparian vegetation in the Grand Canyon river corridor (Webb et al 2011). Evidence for pre-dam conditions comes from a combination of personal historical accounts by old-time river runners, accounts from historical expeditions, and comparison to undammed rivers in the region such as the section above Glen Canyon Dam (Webb et al 2002). The evidence most influential in determining changes in vegetation prior to the building of Glen Canyon Dam has been repeat photography. Repeat photography since the turn of the 20th century has become a common tool in understanding shifts in plant communities over time. There are a number of benefits and limitations to the use of repeat photography. Images provide a snapshot of the ecosystem in a way plant transects and permanent plots may not capture; however, there are spatial limitations and bias to consider when using photographs taken with a different purpose in mind. Photographs were used on historical expeditions for scientific documentation of the canyon conditions; however perhaps not with the vegetation in mind. Early expeditions were surveying the canyon for potential development for hydroelectric power and to understand the geological formations. Fortunately for the Colorado River in the Grand Canyon, there is a significant amount of photographs that have been taken along major portions of the river corridor and major tributaries.

The story of repeat photography in the Grand Canyon is one of government-funded expeditions. Survey expeditions for potential development of the area started shortly after Arizona became a territory in 1863. The first scientific expedition down the Colorado River was the USGS funded survey to map the Colorado River by Major John Wesley Powell in 1871 and 1872 (Powell 1895). The photographer on the Powell expedition, credited for taking the greatest number of photos was John K. “Jack” Hillers. The greatest number of images used in repeat photography were obtained from the Robert Stanton expedition with a total of 445 photos. The Robert Brewster Stanton’s expedition took numerous photos in order to determine the potential for development of a railroad along the Colorado River in 1889 to 1890. The photographer for the Stanton expedition was Franklin A. Nims. Perhaps the second most noteworthy source of images was from the brothers Ellsworth and Emery Kolb from their expedition in 1911. The Kolb brothers began the tradition of repeat photography, taking pictures in the same locations as the photographers from the Powell expedition. Table one describes the major historic expeditions. Photographs from these expeditions have been matched in 1992 and again in 2001. A total of 1,447 historical photos were matched from notable expeditions discuss above and other sources. Of these photos, 1,391 showed changes in the riparian vegetation (Webb et al 2007).

Table 1: Description of major historic expeditions indicating their major contributions and number of photos made available for repeat photography .

Year	Expedition	Major Findings and Contributions
1869/1871	Powell Expedition	First scientific expedition funded by the USGS with the objective to map the Colorado River or “the great unknown”. Trip produced number of photographs
1890	Rob Brewster Stanton Expedition	Survey of potential for building a railroad along the Grand Canyon corridor. Survey was completed taking numerous photographs leaving 445 Images used to examine changes in vegetation.
1911	Kolb Brothers	First to take repeated images of those taken on Powell Expedition. First motion picture; Second greatest number of images used for repeat photography.
1923	Birdseye USGS Expedition	Surveying locations for construction of Dam. Significant number of photographs taken.
1949 & 1964	P. T. Reilly	Photos of the river from boats and aircraft
1938	Clover and Jotter	First survey of grand canyon flora by pair of female botanists

Historic Botany Survey

The first expeditions down the Grand Canyon focused largely on either the geology of the region or surveying the area for potential development. The first and only systematic botanical survey of the Colorado River in pre-dam conditions was in June of 1938 by Dr. Elzada Clover of the University of Michigan with graduate student assistant Lois Jotter. These two woman botanist, were also the first woman to successfully raft through the Grand Canyon with the famous river runner Norman Nevills. The lack of pre-dam plant surveys is perhaps in part because of the lack of riparian vegetation in the pre-dammed Colorado River. While Clover and Jotter's survey found a significant amount of diversity to exist in some of the tributaries, waterfalls, and seeps or springs in the canyon, they also made the following conclusions:

> "Owing to constantly changing conditions of the talus caused by landslides, and the river's edge in consequence of periodic floods, there is little climax vegetation in the Canyon of the Colorado. However, vegetation may remain undisturbed for years, chiefly at springs and on stabilized portions of the lower talus."

The pre-dammed riparian vegetation of the Colorado River was thus one constantly shifting in response to frequent disturbance events and the environmental stresses of desert climate.

Clover and Jotter classified five habitat types within the river corridor. The botanists observed the zone they named "the margin of moist sand" near the river edge to be rather devoid of any plants with establishment of dense clusters of shrubs in a zone called "dry sandy shore". These two zones noted by Clover and Jotter is now known as the flood scouring zone and the old high water zone. Dr. Paul S. Martin in the 1960s from University of Arizona collected plants along the river corridor for a study doing paleo-environmental reconstructions, and noted that in just 5 years after Glen Canyon Dam was opened for use, the zone Clover and Jotter had declared as devoid of vegetation now had been aggressively colonized (Webb et al 2007). The three other major vegetation classes declared by Jotter and Clover was vegetation associated with springs and waterfalls, Rubble and Boulder area, and Talus Slopes. Within these habitats Clover and Jotter noted the diversity and distribution of vegetation in the canyon being controlled not just by moisture but also altitude, light (north or south side of canyon wall), and temperature, more so than the underlying geological formation.

Historic Flow Regime and Sediment Supply

The most dramatic impact of the Glen Canyon Dam on riparian vegetation is the changes in flow regime both in seasonal and diurnal frequency and timing (see Chapter Three, Burley) as well as changes in sediment supply (see Chapter Four, Gibbson). The pre-dam river was characterized by having highly variable flows with frequent spring floods scouring the riverbanks. Historic floods could be as great as 500,000 ft^3/s^2 but were on average 100,000 ft^3/s^2. This dramatically contrasts to the regulated flows seen today (see Chapter Three, Burley). The diurnal pattern of flow has also changed from one of relatively minor fluctuations to a highly regulated daily fluctuating, thus providing less scouring of riparian habitat by the river and less variable water supply to riparian plants. As a result, the two zones described by Clover and Jotter has been replaced with a new high water zone. Glen Canyon Dam has also dramatically altered the sediment load of the river (see Chapter Four, Gibson) with only 5% of the pre-dam sediment concentrations being released from the dam (Webb et al 2007). Changes in sediment load have altered the successful germination and successful competition of native riparian vegetation (see Chapter 11, Kelso).

RIPARIAN VEGETATION

Vertical Distribution of Riparian Vegetation

Available evidence overwhelmingly points to the fact that the vegetation in the Grand Canyon river corridor was sparse. As described by botanists Jotter and Clover, the riparian plant community consisting of short-lived annuals and young perennials prone to frequent disturbance by annual spring floods (Clover and Jotter, 1944). The spring floods of the Colorado River prior to Glen Canyon Dam resulted in a significantly difference in the zones of vegetation along the banks of the river. Historically, spring floods would create a scouring zone were not even the hardiest vegetation could survive the enormous spring floods. This area was temporarily devoid of vegetation, until the spring floods started to decline, at which point annual vegetation re-colonized this barren alluvial substrate, only to be removed in the coming spring by scouring floods. Photographs before 1900, for the most part, show no perennial vegetation establishing below the old high water zone (Webb et al 2007).

At the old high flood zone is an area that supports important riparian vegetation. In this zone, vegetation is left relatively undisturbed by the destructive forces of the annual spring floods, yet also benefit from the spring floods creating water saturated sediments. Species growing in the high flood zone often have taproots that can access the water table as the spring floods subside and are facultative riparian species such as mesquite, catclaw, netleaf hackberry, and Apache plum. Obligate riparian species, such as cottonwood, Arizona ash, and Arizona sycamore, require water-saturated soils year-round and thus are rarely found along the river corridor prior to the operation of Glen Canyon dam. Notable exceptions were obligate riparian species establishing in areas with extensive flood plains such as at the end of tributaries with extensive deltas, areas the river widened, or in areas being spring feed. Even areas, such as deltas of major tributaries, have experienced increases in vegetation with the regulation of flows.

The regulation in flow created by Glen Canyon dam has resulted in the creation of a new high water zone, with the old high water zone becoming degraded. The old high water zone no longer receives annual saturation of sediments and as a result vegetation in the old high water zone has had significant declines in available water. The germination of mesquite, for example, is now infrequent at the old high water zone (Webb et al 2011) and significant die back of mesquite and cat claw are occurring at the old high water line. Since the regulation of flows by the dam, the 100,000 ft^3/s^2 mark has been approached only once (in 1983) (Webb et al 2007). Vegetation at the old high water mark is slowly dying and being replaced by the xeric desert species found farther upslope, such as prickly pear, ocotillo**,** and other cacti. The new high water zone is now 20 to 50 feet closer to the river edge. Figure 2 and 3 illustrate the shift in the high water line being closer to the river edge, and switch at the old high water zone to more xeric species. Figure 5 and 6 illustrates the shift in the high water line being much lower than it was in the past.

Mosaic of Habitats along the river corridor

Robert Webb and colleagues have evaluated 2724 sets of repeat photographs taken prior to the building of Glen Canyon dam and afterwards, both in 1992 and again in 2000s. In these photographs, it was found that 73% of the views showed an increase in biomass density of vegetation and in 15% of the photos, no change was observed. In very few cases were declines in vegetation observed. Reaches shown to have declines in vegetation were generally areas now inundated by either Lake Powell or Lake Mead (Webb et al 2007). Increase in vegetation has occurred throughout the river corridor in large part because of the notable invasive specie, Tamarisk (see Chapter 12, Eskra). Figures 2 – 6 illustrate the rather consistent conclusion of repeat photography of the Grand Canyon corridor being an increase in vegetation and a change in the composition of species at the old high water zone.

At the high water zone, where the majority of vegetation exists, there are slight shifts in composition along the river reaches. In the narrow gorges from Glen Canyon Dam to mile 38, the high water zone is not distinct with limited establishment of vegetation. Below mile 38, catclaw is the most common species and is typically the only species in the narrow and steep Inner Gorge. Between miles 40 to 77 and miles 167 and 225, mesquite and catclaw form assemblage at the high water zone. In some historic images, netleaf hackberry and coyote willow are also abundant along these river reaches. In the western reaches of the Colorado, species at the high water mark begin to transition to more xeric species (such as California Barral Cactus, Octillo, and other cacti) that are common species found in the Mojave versus Sonoran desert (Webb et al 2007).

Figure One: Schematic cross section of the Colorado River in Grand Canyon before and after completion of Glen Canyon Dam (Webb et al 2007).

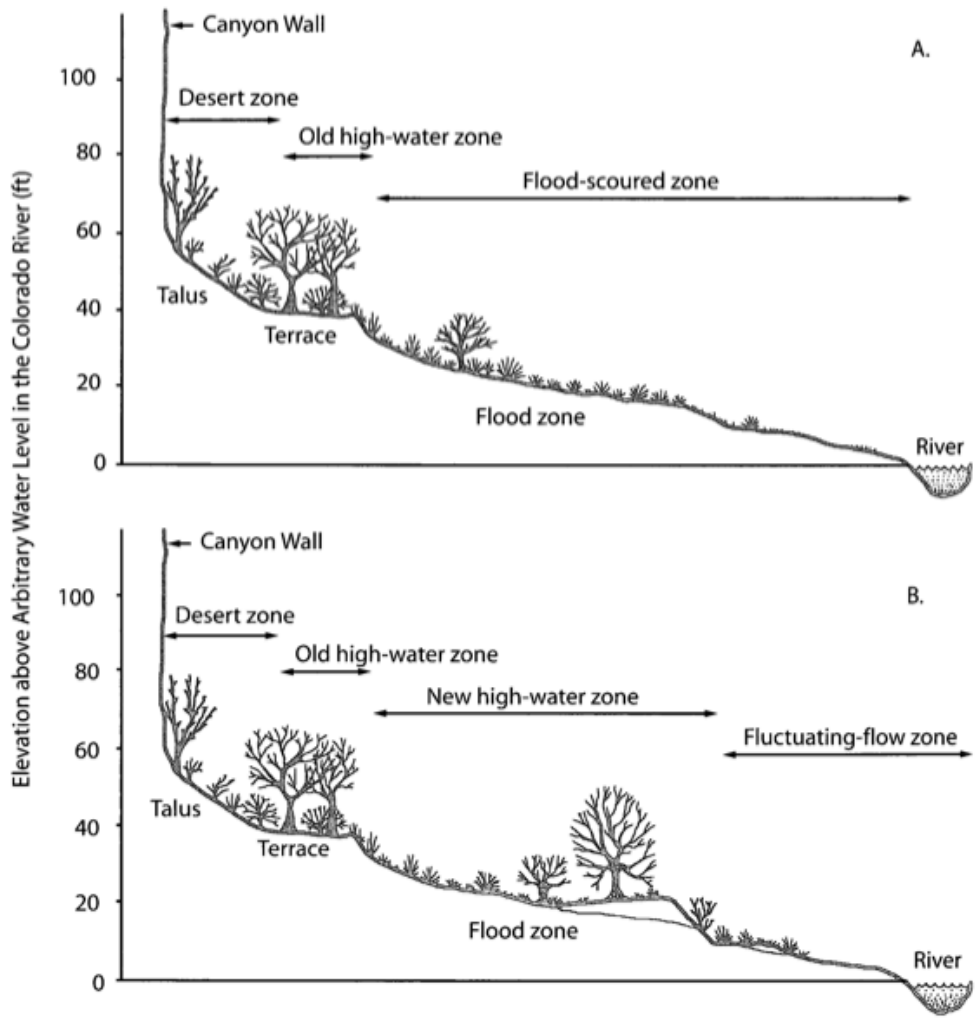
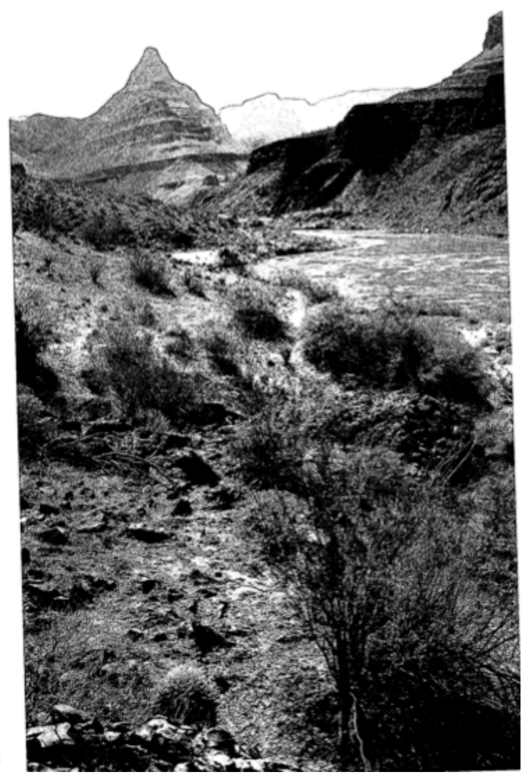


Figure Two : Image above Diamond Peak mile 222.5 pre-dam (A) and post-dam (B).

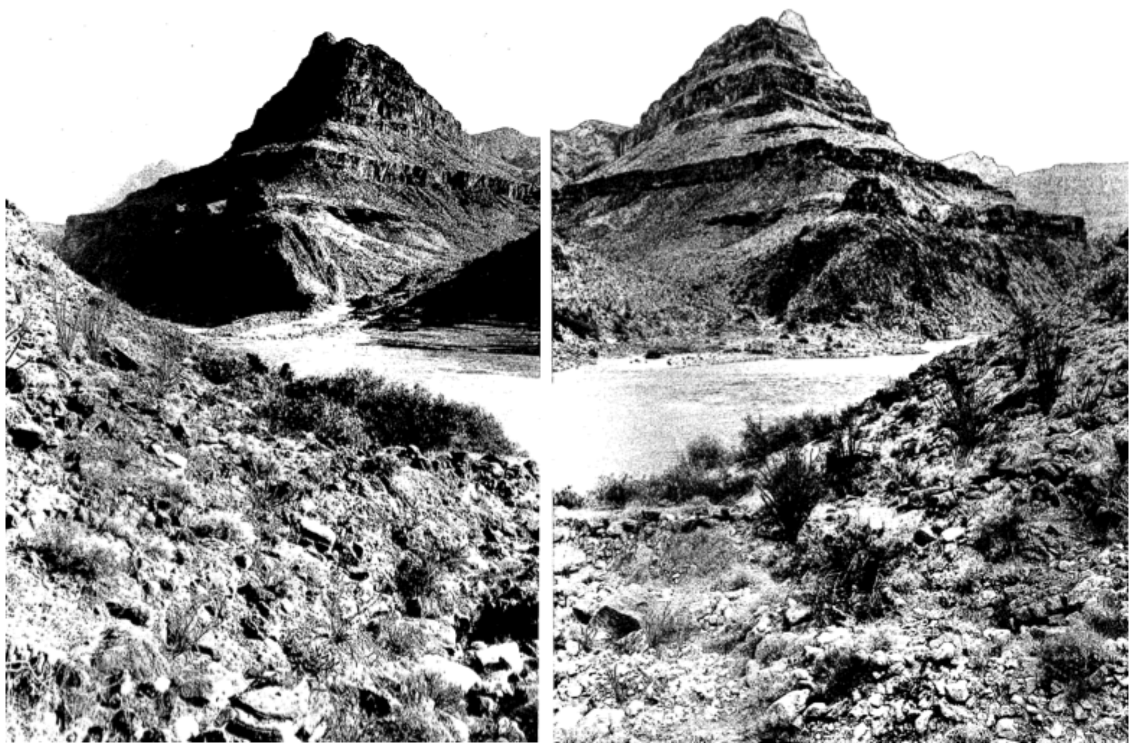
Images illustrate the sparse vegetation that existed on dunes and the shoreline, which is now partially overgrown and stabilized by vegetation. In the foreground can be seen ocotillo in the lower center part of the image, which has since died, and its skeletal remains are now obscured by new vegetation growth. This illustrates the dying off of riparian species in the old high water zone. (Image from Baars and Buchanan 1994)

A.



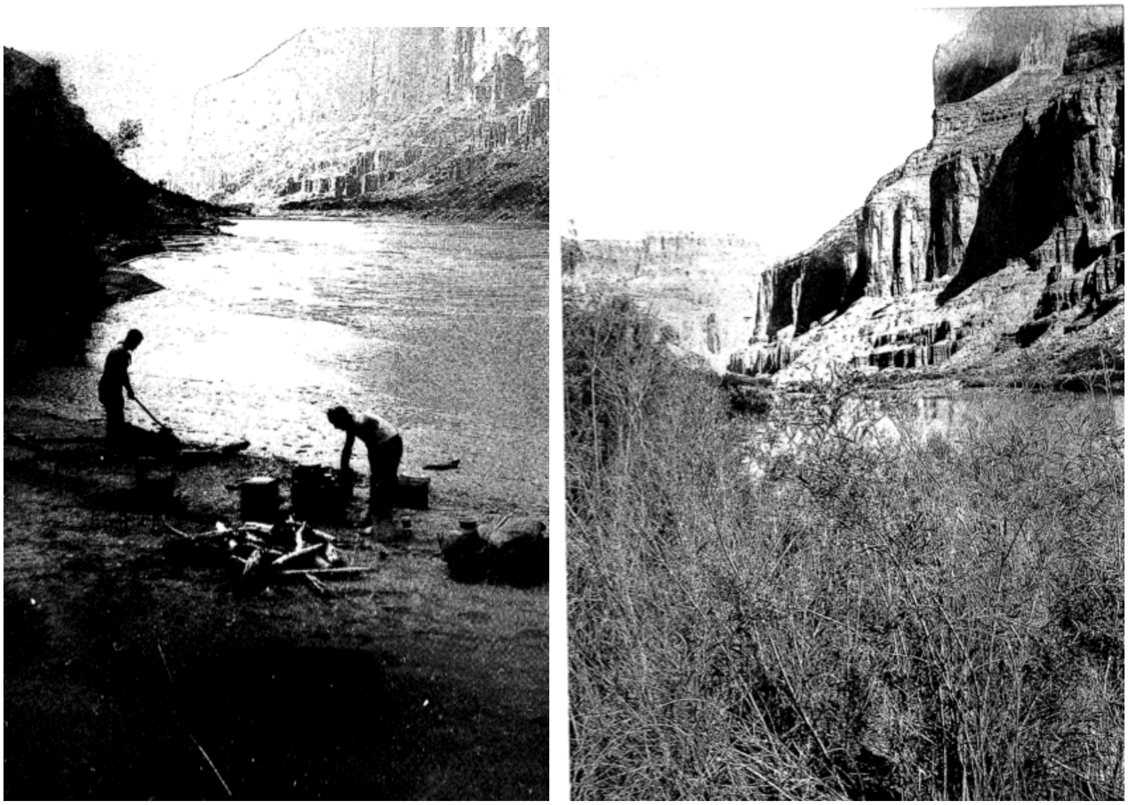
B.

Figure Three: Image of pre-dam (A) and post-dam (B) conditions at 224 mile rapid. Image illustrates a reduction in vegetation in the foreground with the variation in plants changing to more xeric species and with already established xeric species such as the ocotillos in the older photo are still thriving in the newer image. The image illustrates that the vegetation at the high water line has changed to more xeric dominated vegetation. (Image from Baars and Buchanan 1994)



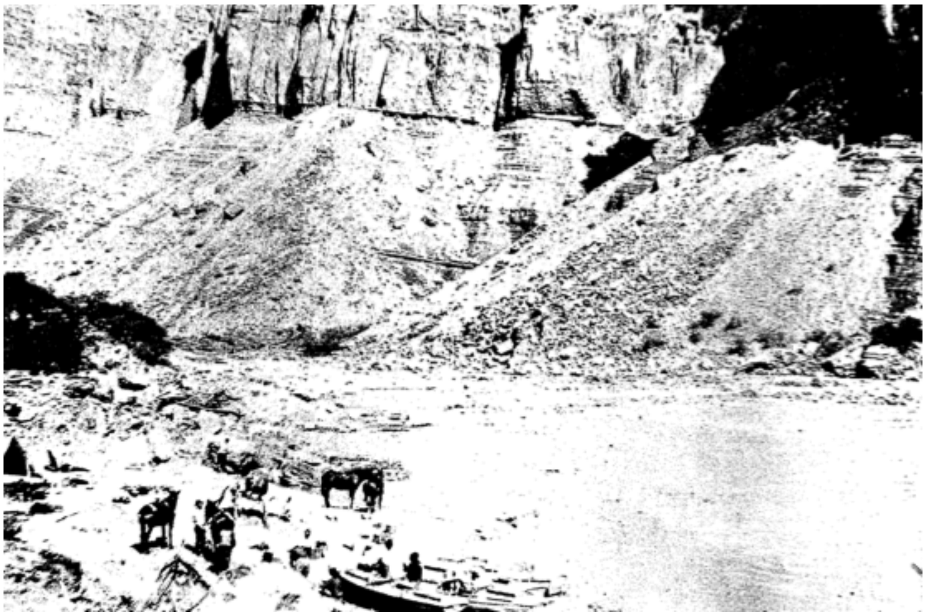
A. B.

Figure Four : Image of pre-dam (A) and post-dam (B) conditions near Kwagunt Rapid mile 55.8. Image illustrates the significant increase in vegetation on previously barren sandy beaches. (Image from Baars and Buchanan 1994)

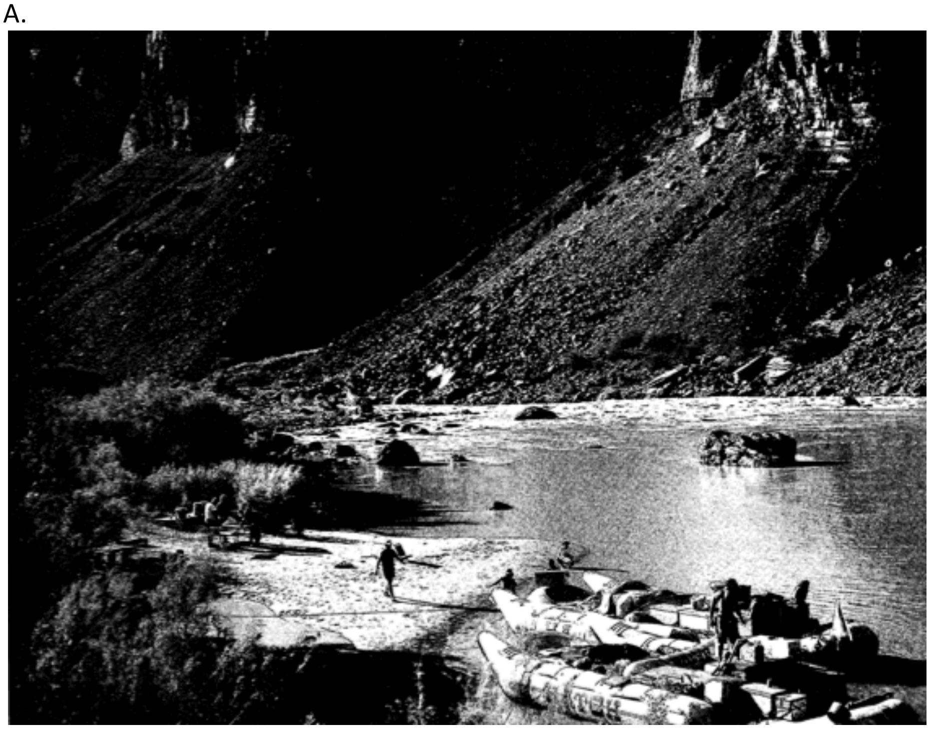


A. B.

Figure Five: **Image of pre-dam (A) and post-dam (B) conditions at the top of Hance Rapid mile 76.5. Image illustrates a significant increase in vegetation with the new high flood zone being at a lower elevation than in image A. In Image A, the high water zone can be seen with the cluster of shrubs, mostly mesquite, above the pre-dam high water line. (Image from Baars and Buchanan 1994)**



A.



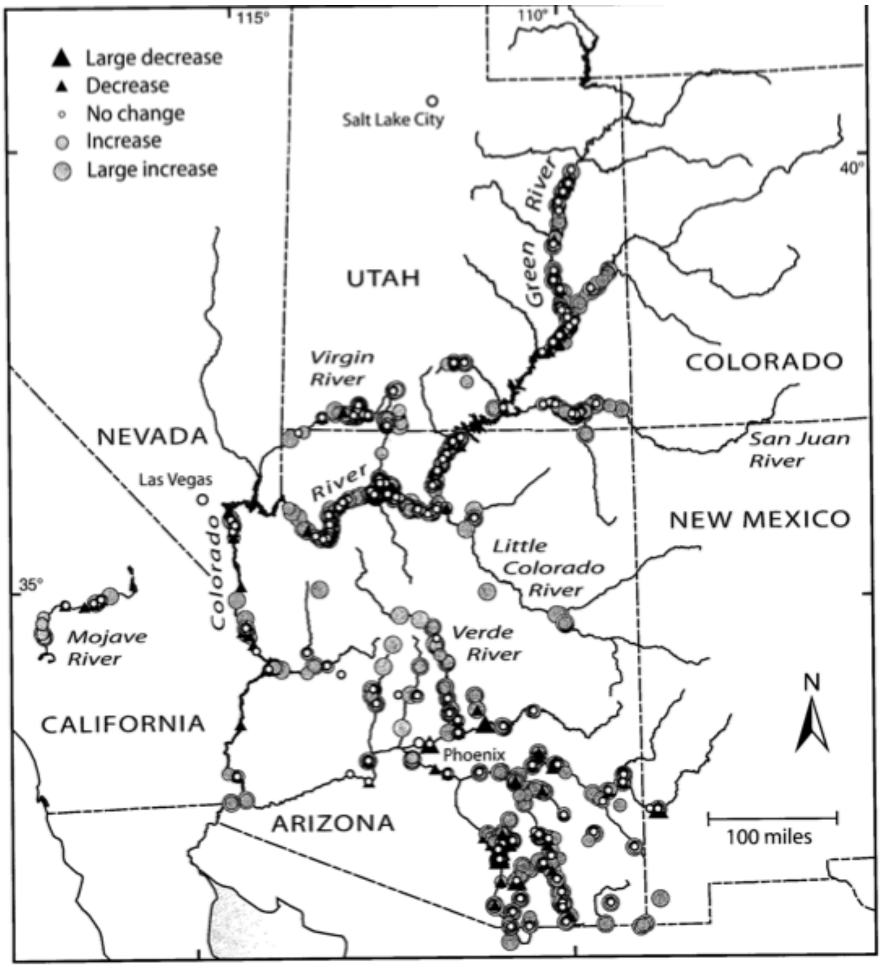
B.

Figure Six: Image of pre-dam (A) and post-dam (B) conditions at Camp at President Harding Rapid, mile 43.6 of pre-dam (A) and post-dam (B) conditions. Image illustrates the significant increase in vegetation with thick growth of mostly tamarisks hiding the beach used for campsite in 1923 image (A). (Image from Baars and Buchanan 1994)

A.

Figure Seven: Map illustrate the change in vegetation in the southwestern United States (A) and the change in cottonwoods within the Grand Canyon (B). Note the increases in cottonwoods have occurred at the delta of the little Colorado and within tributaries of the Grand Canyon with otherwise absents of Cottonwood in the Grand Canyon river corridor. Image from Webb et al 2007.

A.



B.

Springs and Major Tributaries

While occupying 0.0003% of the Grand Canyon area, tributaries account for 36% of the total riparian flora in the Grand Canyon state park (Fairley 2003). The Colorado River has numerous tributaries feeding into the main stem, however the most notable ones are the Little Colorado and Paria Rivers, and the Havasu and Kanab Creeks. Historically, the tributaries of the Grand Canyon do not experience the same stand replacing spring floods experienced in the mainstem of the river. This allows for the establishment of lush vegetation including cottonwoods, box elders, good-ding willows, seep willow, arrow weed and other riparian shrubs and herbaceous plants. This vegetation provides important habitat for wildlife (see Chapter 13, Hartman). According to image comparisons and old-timer accounts, there has been an increase in debris flows from tributaries (Webb et al 2002). This increase could result in historical declines in vegetation of tributaries.

The Kanab and Havasu Creek are two examples of the extremes in the influence of frequent flooding on the degree of riparian vegetation. The Kanab Creek is rather barren while the Havasu Creek supports lush vegetation. Repeat photography of the Kanab creek indicates the creek was nearly devoid of any vegetation due to arroyo down cutting and widening of the creek. In contrast Havasu Creek has sustained and seen increases in vegetation. Most well documented increases in vegetation have been along the waterfalls in the creek such as at Havasu Falls, Mooney Falls, and Navajo Falls (Webb et al 2007).

SUMMARY

The building of Glen Canyon Dam in the Grand Canyon is one of the greatest ecosystem experiments of the 20th century. Since the start of Glen Canyon dam's operations in 1963, there has been a significant effort to conduct scientific studies on the impacts of the Glen Canyon Dam on the riparian vegetation. Unfortunately, scientific efforts taken prior to building the dam are not matched by extensive studies of post-dam conditions. While some impacts of the dam were quickly apparent within a decade of the dam being built, other less obvious changes will never be completely understood. We lack the baseline data to truly understand the impact of Glen Canyon dam on the riparian ecosystems of the Grand Canyon river corridor. We are left with piecing together evidence from old-timer accounts and historic expeditions. The best scientific evidence available is from repeat photography using images taken on historic expeditions, most notably the Stanton expedition, and matching them with present images

The evidence provided from repeat photography demonstrates that vegetation in the river corridor of the Grand Canyon has dramatically increased since the building of Glen Canyon Dam. The dam has forever altered the environment of the Grand Canyon river corridor. For better or for worse, the current riparian ecosystem is dynamic and is continuing to change.

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