

**OBSERVATIONS OF ENVIRONMENTAL  
CHANGE IN GRAND CANYON**

ROBERT H. WEBB  
THEODORE S. MELIS

U.S. Geological Survey  
1675 W. Anklam Road  
Tucson, AZ 85745

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# Observations of Environmental Change in Grand Canyon

By Robert H. Webb and Theodore S. Melis

## Abstract

Little scientific data has been collected on pre-dam conditions of the Colorado River corridor through Grand Canyon National Park. Using historical diaries and interviews with long-term river runners, referred to as the Old Timers, we compiled anecdotal information on environmental change in Grand Canyon. The most significant changes are the lowering of water temperature in the river, the lack of heavily sediment-laden flows, the erosion of sand bars, the invasion of non-native tamarisk trees, the reduction in driftwood, the development of marshes, the increase in non-native fish, and the increase in waterbird populations. In addition, few debris flows were observed before closure of Glen Canyon Dam, which suggests that the frequency of debris flows in Grand Canyon has increased. Other possible changes include decreases in bat populations, and increases in swallow and big horn sheep populations, although the evidence is inconclusive. These results provide a perspective on managing the Colorado River that may allow differentiation of the effects of Glen Canyon Dam from other processes of change.

## INTRODUCTION

The Glen Canyon Environmental Studies (GCES) program, has amassed considerable data about the ecology and geomorphology of Grand Canyon (U.S. Department of the Interior, 1989). Until recently, this research has focused entirely on the post-dam Colorado River, mostly the decade after the 1983 flood. This concentration of effort meets many of the management needs of regulatory agencies, but ignores some questions of scientific interest. Ongoing changes in the regulated river were inherited from a free-flowing river that only a few people, and fewer scientists, have experienced.

Initially, our project focused on specific geomorphic questions about the pre-dam river, particularly the frequency of debris flows and their effects on the Colorado River. Debris flows are slurries of water and sediment that transport large

boulders into the Colorado River, forming the rapids (Webb and others, 1988; Melis and others, 1994) and constraining the sites of eddies (Schmidt and Graf, 1990; Melis and others, 1994). In attempting to understand debris-flow frequency in Grand Canyon, we relied on historic photographs taken between 1872 and the 1970s; in matching them (Melis and others, 1994; Webb, 1996), we learned where and when debris flows occurred. The old photographs opened a Pandora's box, yielding far more than just information on debris flows. Insights into longevity of desert plants, invasion of riparian vegetation, effects of burro grazing, changes in rapids, and stability of sand bars were gained from replicated photographs (Webb and Bowers, 1992; Webb and Bowers, 1993; Bowers and others, 1995; Schmidt and others, 1995; Webb, 1996).

Although photographs are an excellent source of unbiased information about the environment of

Grand Canyon, they have limitations in terms of spatial coverage and content. For example, photographs are an excellent source for evaluating the frequency of debris flows but are a poor source of information about wildlife populations or the hydraulics of a particular rapid. To gain a broader perspective, we began to discuss the changes we thought had occurred with river runners who had experienced the unregulated river. In so doing, we realized the discussions would bear greater fruit if they were held in the course of a Grand Canyon trip.

The Old Timer's Trip, from September 8 to 20, 1994, was designed to gain new insights into Grand Canyon history and environmental change along the Colorado River. We sought to record the direct observations of the participants in pre-dam river trips, and to incorporate their journals and photographs in our research. We sought to test our ideas about the magnitude of change with the people who experienced the changes as they occurred. Our intent here is to relate the changes observed by the Old Timers and to briefly discuss any independent verification of changes and their importance to scientific knowledge about Grand Canyon.

## THE OLD TIMERS

The Old Timers on the September 1994 trip were John Cross Sr., John Cross II, Lois Jotter Cutter, Kent Frost, Les Jones, Martin Litton, Garth Marston, Shirley Marston, Tad Nichols, Sandy Nevills Reiff, Woody Reiff, Gene Shoemaker, Joan Nevills Staveley, and Bob Rigg. The following brief biographies show the qualifications of these individuals as observers of environmental change in Grand Canyon.

*John Cross.* After boating in Glen Canyon with Bert Loper, a well-known early river runner (Lavender, 1985), John Cross founded Cross Expeditions, an important river-running company. Much of his experience with Grand Canyon occurred during the first years after closure of Glen Canyon Dam. Most of his experience with the unregulated Colorado River occurred in Glen Canyon.

*John Cross II.* John Cross II ran the Colorado River extensively in the 1960s. He has the distinction of being the first boatman to run the

newly enlarged Crystal Rapid in March 1967, and he wrote extensive notes on the 1966 floods.

*Lois Jotter Cutter.* With Elzada Clover, Lois Jotter Cutter was the first woman to go through Grand Canyon in 1938 (Cook, 1987). She authored several publications on the plants of Grand Canyon (e.g., Clover and Jotter, 1944), and the 1994 trip was her second. She is one of the first 100 river runners through Grand Canyon.

*Kent Frost.* After rowing boats for Norm Nevills in the late 1940s, Kent Frost worked with Mexican Hat Expeditions in the early to mid-1950s. He is one of the first 100 river runners through Grand Canyon. His photographs show the condition of riparian vegetation and sand bars in Grand Canyon.

*Don Harris.* Besides having the distinction of being the second river runner to successfully navigate all Grand Canyon rapids, Harris operated a commercial river-running company until the late 1960s. His 1939 diary is an excellent account of Grand Canyon rapids. He is one of the first river 100 runners through Grand Canyon. His photographs and a movie made of his 1939 trip help document changes in Lava Falls Rapid.

*Les Jones.* Les Jones was one of the first canoeists to traverse Grand Canyon, beginning in 1953. He made the first river guide to Grand Canyon (Jones, 1962) and ran a trip on extremely low water just after closure of Glen Canyon Dam. His photographs show many important rapids at low water, and his scroll map documents historical river trips.

*Martin Litton.* Founder of Grand Canyon Dories, Litton is an outstanding photographer and conservationist. In particular, his photographs document the considerable changes to Lava Falls Rapid. After hiking in at Lava Falls Rapid to meet Mexican Hat Expeditions on several occasions in the early 1950s, Litton rowed the river for the first time in 1955 with P.T. Reilly. Litton is currently the oldest person to have piloted a boat through Grand Canyon.

*Garth Marston.* Son of the river historian Otis "Dock" Marston, Garth Marston first ran the river in 1942. He rowed boats for Norm Nevills in the 1940s and is one of the first 100 river runners through Grand Canyon. Unlike many of the Old Timers, Marston has continued to take trips through

Grand Canyon and has experienced many of the changes directly.

*Tad Nichols.* An outstanding photographer and cinematographer, Nichols recorded scenes of Grand Canyon for Mexican Hat Expeditions in the 1950s. His photography documents a wide variety of changes in Grand Canyon, particularly in sand bars at Badger Rapid and Redwall Cavern.

*Sandy Nevills Reiff and Woody Reiff.* Sandy, a daughter of Norm Nevills, was heavily influenced by her parent's river-running prowess. She has run the Grand Canyon numerous times and possesses the photographic archives of her parents.

*Bob Rigg.* Bob and his brother Jim obtained Mexican Hat Expeditions with Frank Wright in 1950. Bob ran the river numerous times between 1950 and 1965 as an oar boatman and motorboatman. He has a remarkable memory of specific places and documented numerous changes to the canyon.

*Gene Shoemaker.* A world-class scientist, Shoemaker led USGS expeditions to replicate photographs from the second Powell expedition. The 1968 trip resulted in a book (Stephens and Shoemaker, 1987) that documents rivering conditions in Grand Canyon shortly after closure of Glen Canyon Dam. Shoemaker, a geologist, also has considerable field experience in Grand Canyon.

*Joan Nevills Staveley.* The first daughter of Norm and Doris Nevills, Joan first ran the river in 1947. She later acquired Mexican Hat Expeditions with her husband, Gaylord Staveley. Joan has a ongoing voice in the politics of the Grand Canyon region and has an active interest in preservation of river running memorabilia.

In addition to the Old Timers, we had six guides with long experiences in Grand Canyon: Alistair Bleifuss, Ann Cassidy, Brad Dimock, Brian Dierker, Kenton Grua, and Lew Steiger. These guides provided key information on changes in the river during the 1970s and just before and during the 1983 flood.

Additional information was obtained from the diaries of historic river runners (Table 1). The exploits of most of these river runners are documented in Lavender (1985). The diaries of Norman D. Nevills and P.T. Reilly were made available as a result of the Old Timers Trip. Other

diaries — including those of Frank Wright, Georgie Wright, and Otis "Dock" Marston — were obtained from the Marston Collection at the Huntington Library in San Marino, California (Table 1). Many diaries from early river trips are published (Table 1).

Several Old Timers, including several that did not go on the river trip, provided additional information. Bill Beer was interviewed in August 1994; he loaned us photographs and movies for our interpretations. After the trip, several participants sent notes, photographs, and movies for our use. The combination of diaries, photographs, and direct observations of the Old Timers provide considerable information on pre-dam conditions between 1872 and 1963, particularly between 1938 and 1963.

## OUR APPROACH TO THE INTERVIEWS AND INTERPRETATION OF OBSERVATIONS

We listened and tried not to intentionally prompt the Old Timers. After an introduction to debris flows, types of sand bars, and the basic purpose of the trip, we simply recorded their responses to the canyon. We deliberately let many sites pass without discussing some obvious changes that have occurred since 1982. In several cases, places identified as critical camping beaches or habitat for endangered species were passed without comment by either the scientists or the Old Timers.

We devised some simple tests of the veracity of the Old Timers' memories. For example, we asked whether Bedrock and Dubendorff Rapids had changed, knowing full well that Bedrock had and Dubendorff had not. The Old Timers correctly recognized the changes in Bedrock Rapid and the lack of change in Dubendorff. By listening to the answers, we established the credibility of the Old Timers as very high in remembering specific and detailed information about changes in Grand Canyon. We also established that differences in water level between the pre-dam era and the Old Timer's Trip was extremely important to their memory of specific sites. Several did not remember the debris bars at Vaseys Paradise and the mouth of

**Table 1. Diaries from historical river trips in Grand Canyon used in this study.**

Date of Trip	Author	Part of Canyon	Source of Material
1869	Powell expedition	All	Cooley, 1988
1872	F. S. Dellenbaugh	Lees Ferry to Kanab Creek	Dellenbaugh, 1908
1872	J. K. Hillers	Lees Ferry to Kanab Creek	Fowler, 1972
1890	R. B. Stanton	All	Smith and Crampton, 1987
1890	W. H. Edwards	All	Unpublished diary
1896	G. Flavell	All	Flavell, 1987
1909	J. Stone	All	Stone, 1932
1911	E. Kolb	All	Kolb, 1914
1911	B. Lauzon	Phantom to Grand Wash Cliffs	Unpublished diary
1923	USGS Expedition	All	Unpublished diary
1927	C. Eddy	All	Eddy, 1929
1928	J. Harbin	Phantom to Diamond Creek	Unpublished interview
1937	I. Campbell	All	Unpublished diary
1937	B. Sharp	All	Unpublished diary
1938	N. Nevills	All	Unpublished diary
1938	L. Jotter	Lees Ferry to Granite Rapid	Unpublished diary
1938	E. Clover	All	Unpublished diary
1938	A. Burg	All	Unpublished postcards
1938	B. Holmstrom	All	Unpublished postcards
1938	W. Johnson	All	Unpublished narrative
1940	N. Nevills	All	Unpublished diary
1940	B. Goldwater	All	Goldwater, 1940
1940	M. Baker	All	Unpublished diary
1941	N. Nevills	All	Unpublished diary
1942	N. Nevills	All	Unpublished diary
1942	O. Marston	All	Unpublished diary
1947	N. Nevills	All	Unpublished diary
1948	N. Nevills	All	Unpublished diary
1948	F. Masland	All	Masland, 1948
1948	J. Doerr	Phantom to Grand Wash Cliffs	Unpublished diary
1948	O. Marston	All	Unpublished diary
1948	G. Marston	Lees Ferry to Bedrock Rapid	Unpublished diary
1949	P.T. Reilly	All	Unpublished diary
1949	F. Wright	All	Unpublished diary
1949	H. Welty	Lees Ferry to Phantom	Unpublished diary
1950	F. Wright	All	Unpublished diary
1950	S. Reilly	Phantom to Grand Wash Cliffs	Unpublished diary
1951	Harris	All	Unpublished diary
1951	F. Wright	All	Unpublished diary
1951	DesLoge	All	Unpublished diary
1951	S. Reilly	Lees Ferry to Phantom	Unpublished diary
1952	F. Wright	All	Unpublished diary
1953	P.T. Reilly	All	Unpublished diary
1953	F. Wright	All	Unpublished diary
1953	G. White	All	Unpublished diary
1954	O. Marston	All	Unpublished diary
1954	G. White	All	Unpublished diary
1955	P.T. Reilly	All	Unpublished diary
1955	F. Wright	All	Unpublished diary
1956	P.T. Reilly	All	Unpublished diary
1956	F. Wright	All	Unpublished diary
1957	P.T. Reilly	Lees Ferry to Phantom	Unpublished diary
1957	F. Wright	All	Unpublished diary
1958	P.T. Reilly	Phantom to Lava Falls	Unpublished diary
1959	P.T. Reilly	Lees Ferry to Pipe Creek	Unpublished diary
1962	P.T. Reilly	All	Unpublished diary
1964	P.T. Reilly	All	Unpublished diary

the Little Colorado River. These bars may have changed significantly, but both bars may have been covered with water when some of the Old Timers passed them.

Some observations may seem trivial or unremarkable; for example, the large invasion of non-native tamarisk is generally recognized by scientists and river runners alike (Turner and Karpiscak, 1980). On the other hand, tamarisk was advancing its distribution before the dam was built and its spread is little known (see Graf, 1978). Because of such subtleties, we include the full set of observations. Other changes noted by the Old Timers, particularly those concerning wildlife, are probably inconclusive, a consequence of limited observations and lack of independent scientific verification. We include them anyway, albeit with appropriate caveats, to spur discussion.

## **SPECIFIC OBSERVATIONS OR CHANGES NOTED BY THE OLD TIMERS**

### **AESTHETICS**

The aesthetics of river trips were a common theme among the Old Timers. The cold water released from the bottom of Lake Powell was a very noticeable change to most. Some, particularly Sandy Nevills-Reiff and Joan Nevills-Staveley, commented on how clean the canyon is now. Their most recent canyon experiences were just before the current policy of cleaning up trash and hauling human waste from campsites. Others noted the oppressive noise of aircraft overflights compared to the rare airplane in the pre-dam era.

Several Old Timers missed the effects of a silt-laden river on the quality of the river trip; they missed the sound of sand scraping on the sides and bottoms of boats. Nevills-Staveley was impressed with the high degree of cooperation among guides now, instead of the competitive atmosphere that prevailed on her last trip. Rigg and Nevills-Staveley noted the deterioration of air quality as a major change; Rigg stated that the sky was much hazier now than when he ran the river and that it

significantly degraded the experience. He also lamented the loss of the Bass cableway.

### **GEOMORPHOLOGY**

*Debris flows and floods.* Because of their ability to transport large boulders into the Colorado River, debris flows have an important effect on many environmental features along the Colorado River. Debris flows deposit characteristic sediments that are poorly sorted; most debris-flow deposits have particles that range in size from clay to boulders. Streamflow floods, which occur more commonly in Grand Canyon tributaries, typically transport mostly sand and gravel with few larger particles (except during very rare floods). The distinction between these two geomorphic processes was an important point with the Old Timers, who saw evidence of both types of flash floods.

The Old Timers remember few new debris-flow deposits, and only a few debris flows are recorded in diaries. We showed the Old Timers the 1994 debris-flow deposits at Badger Creek Rapid (mile 7.9) and asked them if they had seen any similar deposits along the river during their experience. Rigg remembered when the debris fan of Boucher Creek (mile 96.7) changed radically in 1951 or 1952. When he first saw it, mud was still oozing out from between the boulders. Using Robert Brewster Stanton's photographs from 1890, we had identified the Boucher Creek debris flow as one of the largest in the last century in Grand Canyon but had not known when it had occurred (Webb, 1996).

The highest frequency of debris flows in Grand Canyon occurs at Lava Falls Rapid (mile 179.3) from Prospect Canyon. A total of 6 debris flows have occurred in the last century — in 1939, 1954, 1955, 1963, 1966, and 1995 (Webb and others, in prep.). In 1954, Georgie White arrived at Lava Falls on July 24 and saw Prospect Creek running at "full force." Large boulders were entering the river in a manner White likened to a "big black lava flow." White's observations are only the second eyewitness account of a Grand Canyon debris flow, after Robert Brewster Stanton's account of a debris flow in South Canyon (Smith and Crampton, 1987).

Jones remembered that the debris fan of Prospect Canyon was paved with fine gravel on his trip in early October 1963; it made his portage of Lava Falls Rapid much easier. Our photographic evidence of this debris flow suggested that it occurred between August and September 22, 1963; Jones' recollection corroborates our independent estimate. Reilly observed the effects of the debris flow of 1955 in Prospect Canyon. He wrote that the 1956 high water had sliced into the newly deposited debris fan, leaving a 15-foot-high bank.

Other river runners do not observe or record debris-flow deposits. Frank Wright wrote detailed trip logs (Table 1), yet he failed to record either the Boucher Creek deposition or the two debris flows at Prospect Canyon, despite the fact that others on his trip either remembered them, wrote about them, or photographed them.

P.T. Reilly meticulously noted the signs of recent flooding in tributary canyons. Most of what he observed can be attributed to streamflow floods, not debris flows. He observed new mud and silt in the mouth of Shinumo Creek (mile 108.6) in 1949. In 1954-1955, a flood removed large redbud trees from the mouth of an unnamed canyon at mile 38.7-R, and a "heavy flood" down Red Canyon (mile 76.7) cut a channel 5-feet deep and 40-feet wide. Also in 1955, a flood cut a large swath through a sand bar at Spring Canyon (mile 204.3). A flood in Deer Creek (mile 136.2) in 1956 filled the pool with sediment and rearranged boulders in the mouth, and a Diamond Creek (mile 225.5) flood changed the channel at its mouth. Reilly was particularly impressed with the effects of tributary flooding in 1961; a new deposit filled much of the pool beneath Deer Creek Falls and the mouth of Tapeats Creek (mile 133.8) shifted downstream. Although he accurately described changes he saw in the 1950s, he made additional observations on dam-related and other changes during trips in 1982 and 1984. A few of the later observations were inaccurate; for example, Reilly erroneously thought that the Quigley grave at President Harding Rapid (mile 43.2) was removed by a flood between 1964 and 1982. The grave is still present.

The lack of observations of debris-flow deposits before Glen Canyon Dam is significant. Before the Old Timer's Trip, we already knew from repeat photography and historical records that many debris flows had occurred in the last 15 years and

that few could be identified from the pre-dam era (Figure 1). It is unlikely that Colorado River floods completely removed the evidence before the Old Timers could see the changes. Most pre-dam river trips occurred in the summer months, when debris flows are most likely to occur, or in the fall, before the spring floods could rework the deposits. In fact, Reilly and Nevills each saw evidence of streamflow floods, not debris flows.

Both Litton and Cross II commented on the extensive channel changes associated with the 1966 flood in Bright Angel Creek (mile 87.8). Historical photographs had suggested that the initial phase of the flood was a debris flow because of the new debris fan that was created. We already knew from repeat photography that changes in the debris fan under the Silver Bridge were among the most extensive of the last century in Grand Canyon, but Litton and Cross II reinforced the hypothesis that the early stage of the 1966 flood was a debris flow followed by higher flood waters bearing less sediment.

Most of the Old Timers, particularly Jones, were impressed by the large number of recent debris-flow deposits along the river. Some Old Timers did not remember evidence of debris flows specifically, but they recognized small changes in places they had previously visited. Frost knew that the mouth of South Canyon (mile 31.6) had changed since his last visit. We previously had documented the occurrence of the debris flow using matched photographs from 1890 and those of Goldwater (1940) and Bill Fahrni (1934). The year of the debris flow causing the change is still unknown but it occurred between 1940 and 1965.

The Old Timers have contributed greatly to our knowledge of debris-flow frequency with their photographs and memories. For example, Nichols consistently took photographs of Badger Creek Rapid from the left canyon rim (Figure 2). His photographs document changes in the sand bars and tamarisk and provides the basis for determining whether any debris flows had occurred prior to one in August, 1994 (Melis and others, 1994). We also used many of Reilly's photographs to document debris-flow frequency in Grand Canyon, particularly at Lava Falls Rapid.

The Old Timers recognized the large change at the mouth of Tapeats Creek, where many of them had spent considerable time. The channel mouth

shifted upstream during a 1961 flood. They also noted a large decrease in the amount of sand present (see below), which in part was related to channel change at the mouth. The 1961 flood may have had a small debris-flow component to it; the rapid was filled in on the top right side.

*Rockfalls.* Rockfalls were rarely noted or observed in the pre-dam era. Reilly noted any rockfalls he observed; he particularly mentions a 1,500-pound boulder falling at Diamond Creek in 1949. On one of his last river trips in 1982, Reilly noted that many rockfalls had occurred since his previous trip in 1964. Rigg also mentioned the lack of rockfalls when he ran the river. This was thought to be significant because we witnessed a rockfall at Eminence Camp (mile 44) on the Old Timers Trip, and many recent rockfalls were pointed out by trip participants.

*Rapids.* The Old Timers recognized some obvious and some subtle changes in rapids. The change in Crystal Rapid (mile 98.3), which many of the Old Timers had not seen before, is the most dramatic of any noted, although Rigg was also impressed with the changes in Lava Falls Rapid. Cross II had a wealth of information on changes to rapids in the first decade after closure of Glen Canyon Dam and shared his notes with us of what he saw during the first river trip after the December 1966 storm. Lava Falls Rapid changed on the left side in 1966 owing to many large boulders being deposited in a former "sneak" run; we subsequently identified the cause as a debris flow from Prospect Canyon. Bright Angel Rapid also changed slightly in 1966.

Although the Old Timers could not agree when House Rock Rapid (mile 16.8) changed, the body of observations points to more than one event. Litton associated the change with the 1966 storm, but had no specific evidence to support the observation. Dierker claims the largest change occurred before 1969, when he started working in Grand Canyon, and that subsequent floods constricted the river further. Rigg remembered small changes between 1959 and 1965, but thought the constriction was much worse now. Taken together, these observations indicate a typical pattern of several, closely-timed debris flows in one tributary, with little change before or after. The same course of events unfolded in other tributaries, including Prospect Canyon, where five debris flows and

several other floods altered Lava Falls Rapid between 1939 and 1966.

Dimock provided photographs and observations about the 1984 debris flow in Monument Creek (mile 93.5). His trip photographed an enormous wave that formed briefly just after the event. After successfully photographing (and running) the wave, Dimock said he never saw it or anything like it again in Granite Rapid. Dimock also noted changes on the left side of Soap Creek Rapid (mile 11.2), which he attributed to a rockfall, and the reworking of the right side of House Rock Rapid by the 1983 flood.

One of the most perceptive observations came from Reilly. He noted changes caused by the 1955 debris flow at Lava Falls, such as fewer holes and smoothing of the rapid as the spaces behind the large boulders were filled with smaller ones. Sediment eroded from the fan filled in much of the eddy downstream to the Warm Springs, making the lining operation easier.

*Sand bars.* Our work with repeat photography, particularly with the Stanton photography of 1889-1890, suggests that sand bar erosion was severe and decreases with distance downstream from Glen Canyon Dam (Schmidt and others, 1995; Webb, 1996). We wanted the Old Timers' opinion of that conclusion. Most of the Old Timers lamented the current status of sand bars in Grand Canyon, particularly in Marble Canyon. They often pointed to sand bars and noted how small they were. The Old Timers noted severe beach erosion in the reach downstream from Nankoweap Rapid (mile 53-54) and at the mouth of the Little Colorado River (mile 61.5), Elves Chasm (mile 116.5), Stone Creek (mile 131.9), Tapeats Creek (Figure 3), Deer Creek Falls, and the mouth of Kanab Creek (mile 143.5).

Comments about beach erosion decreased downstream of Havasu Creek (mile 156.9), which may or may not be significant. They either continued to see eroded bars and felt it not worth additional comment, or the bars may not have been as eroded as upstream. Most of their comments came at heavily used sites, not generic sand bars. In no case did the Old Timers specifically contradict our interpretations of historic photographs.

Both Reilly and Beer lamented the loss of camping beaches during trips they made in the 1980s. During a 1984 trip, Reilly noted erosion of sand bars at Tuckup Canyon (mile 164.5), National

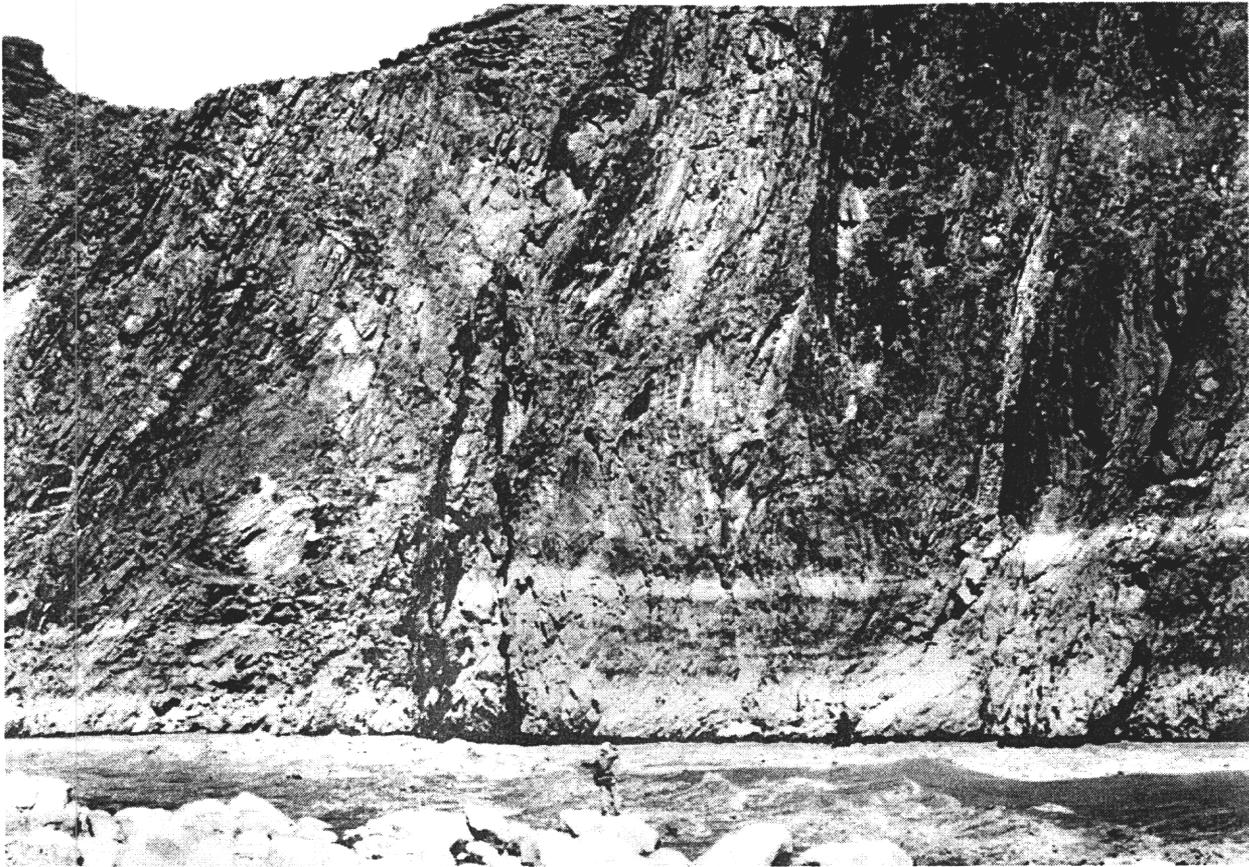


Fig. 1. The debris fan at Specter Chasm (mile 129.0), a tributary of the Colorado River.

A. The original view, which is downstream and across the river, shows the debris fan and rapid at the mouth of Specter Chasm as it appeared on July 27, 1927 (Clyde Eddy, photograph 76, Huntington Library).

Canyon (mile 166.4), and Fern Glen (mile 168.0). Beer, in particular, remembers the sound of sand bars calving off into the river as he swam by in 1955. Rigg noted several sand bars he had camped on were either reduced or eliminated. Nichols, in particular, noted that reductions in sand bars at the mouth of the Little Colorado River, Elves Chasm, and Deer Creek Falls. Cross II pointed out a large reduction in the sand bar at the mouth of Stone Creek as an example of extreme erosion.

Reilly observed the relation between sand bar erosion, tributary flows, and pre-dam river flows. He observed bank caving during a 3-4 foot rise in the river in 1956 that resulted from storm runoff. At Tapeats Creek in 1962, Reilly watched as the river eroded the sand bar below the rapid. He saw large channels cut through sand bars during storm runoff in 1953. These incidents were mentioned primarily because Reilly considered sand bar erosion a hazard

to sleeping boatmen, not because he was concerned that sand bars were diminishing.

Cross II, who ran the river frequently in the years after closure of Glen Canyon Dam, described the slow, progressive loss of sand bars in Marble Canyon. He believed that wind erosion and human impacts, not large clearwater releases such as the 1965 flood, were the dominant reasons for sand bar erosion between 1963 and about the mid-1970s. He used the separation bar at Soap Creek Rapid as an example of a campsite that gradually eroded away.

Rigg thought that the sand-bar erosion downstream from Nankoweap was probably the greatest of any place in Grand Canyon. What formerly was a sand-lined channel is now a reach lined with gravel bars. We had previously recognized the magnitude of sand-bar erosion in this reach.

*Channel bars.* The Old Timers were impressed with changes in three debris-bar-controlled rapids.



Fig. 1. The debris fan at Specter Chasm.

B. The replicate view was taken on September 25, 1993 (Ted Melis, U.S. Geological Survey, stake 2624). The debris flow of 1989 has deposited large boulders on the debris fan and in the rapid. Note that the discharge is about the same as in 1927, but the waves are much larger. This aggradation of boulders at the mouth of a side canyon is observed for about half of the tributary canyons in Grand Canyon (Melis and others, 1994).

The Rock Garden at Crystal Rapid is a consequence of the 1966 debris flow and subsequent reworking by the Colorado River. No pre-dam river runners (or their photographs) noted the debris bar below Crystal Rapid. Shoemaker, Rigg, and Nichols felt that the debris bars at the mouth of the Little Colorado and Vaseys Paradise are significantly bigger, although the changes could be attributed to differences in water level. Pre-dam river runners, particularly Reilly, ran left of the island at the mouth of the Little Colorado River; such a run today is more difficult although possible at discharges above 20,000 ft<sup>3</sup>/s in the Colorado River.

There are subtle implications to these observations. The 1973 flood in the Little Colorado River changed the bar at the mouth significantly; Shoemaker specifically asked us to match his 1968

photograph (if., Stephens and Shoemaker, 1987) to verify this. The debris flow out of South Canyon, which occurred between 1940 and 1965, could have added significantly to the material in the debris bar opposite Vaseys Paradise. This relation between debris bars and the parent debris fan represents another documented case of the relation between debris flows and the course of the Colorado River.

## DRIFTWOOD

Before closure of Glen Canyon Dam, fires were set in the enormous driftwood piles lining the river corridor at the request of the National Park Service and the Bureau of Reclamation, who were concerned about the effect of driftwood on navigation in Lake Mead. These fires caused a



**Fig. 2.** Badger Creek Rapid, the downstream sand bars, and riparian vegetation.  
A. Photograph taken August 1964 (Tad Nichols, stake 2862) of Badger Creek Rapid from the left canyon rim.

considerable reduction in the amount of dead biomass below the old high-water zone. Driftwood accumulated over a thousand years (Ferguson, 1971), and its destruction over a few decades, represents a huge acceleration in the release of nutrients into the atmosphere and in the sands adjacent to the river.

The magnitude and number of fires set along the river corridor by pre-dam river runners was large (Table 2). The effects could be seen for years; for example, signs of the 1940 fire at the mouth of Saddle Canyon were still prominent in 1942. The reduction in driftwood was substantial owing to the deliberately set fires and subsequent use of firewood for cooking fires. Rigg remembers seeing huge piles of driftwood on every debris bar below Lava Falls Rapid; now, there is little driftwood on these bars. Many Old Timers indicate the decrease in driftwood is one of the major changes in the river corridor. The number of pre-dam fires may have

been largely responsible for the current state of depleted firewood in the canyon.

Another contributing factor to the reduction in driftwood could have been its use in campfires just after closure of Glen Canyon Dam. During the first decade of river running on the regulated river, wood was the primary fuel for cooking. It seems improbable that the large piles of driftwood could have been diminished by typical kitchen use, but Grua remembers large piles that were depleted between 1969 and 1980. As early as 1967, Cross II noted the abundance of new driftwood during the 1966 floods, adding that "firewood would not be a problem" during the 1967 river season.

Nevills-Reiff thought there was more driftwood now than when she last was on the river in 1972. She also felt the ban on summer wood fires has had a major effect on increasing the amount of driftwood, which now is added only during tributary floods.

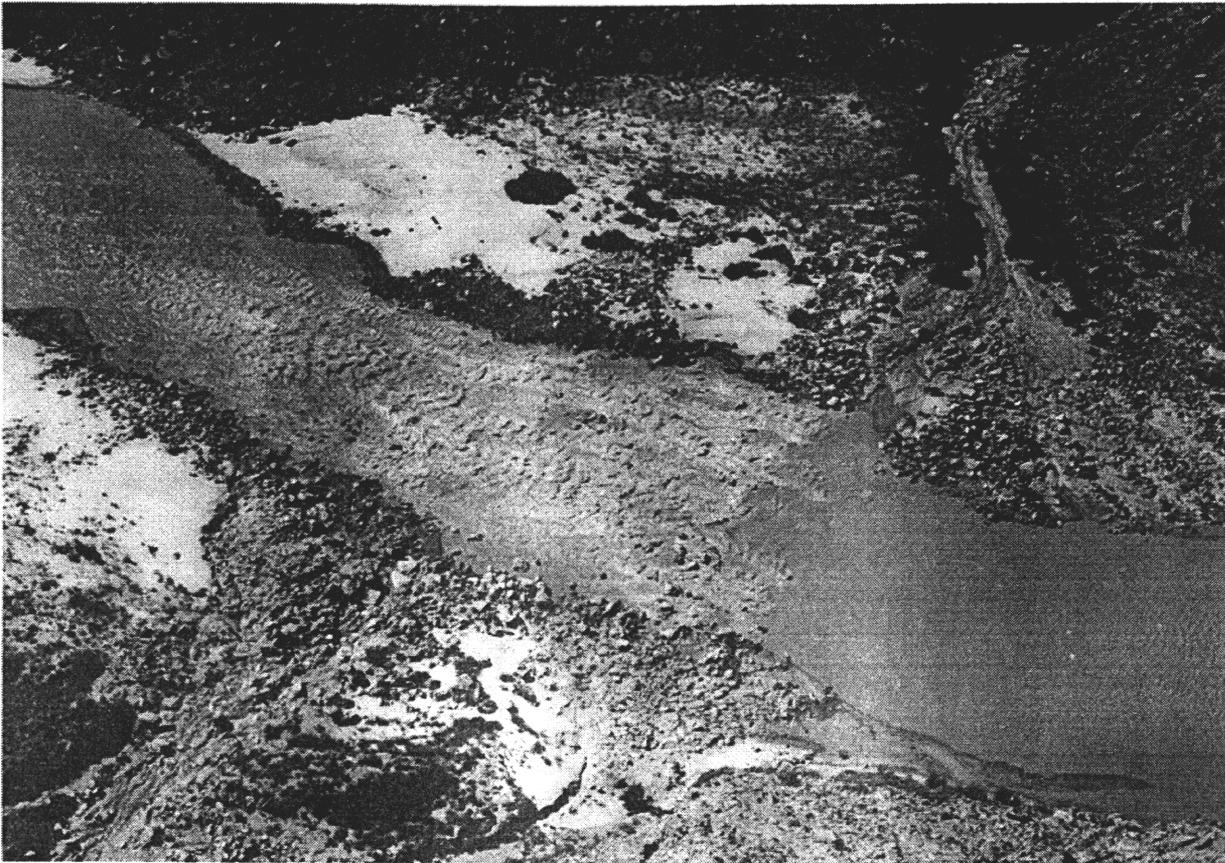


Fig. 2. Badger Creek Rapid, the downstream sand bars, and riparian vegetation.  
B. This replicate photograph, taken in October 1968 (Tad Nichols) documents changes in the sand bars and tamarisk growth. No debris flows occurred between 1964 and 1968.

## PLANTS

*Riparian vegetation.* All the Old Timers noted the huge increase in riparian vegetation along the Colorado River. The change was considered both good and bad: good for shade and wildlife, bad for environmental aesthetics and camping space. The Old Timers recognized tamarisk as the major contributor to the increase. A good example is Lees Ferry: Cutter spent considerable time there in 1938 amid extensive media coverage. She remembered some willows where the boats landed, but not the extensive stands of tamarisk that now are present. Other places, such as the mouth of the Little Colorado River, were devoid of tamarisk before Glen Canyon Dam. Rigg and Nichols stated they did not recognize the mouth of the Little Colorado River, in part because of the dense stand of tamarisk and willows, the eroded sand bars, and the low stage of the Colorado River.

Tamarisk was rare enough in the pre-dam era that its presence along the unregulated river was noted in diaries (Table 3). In 1938, tamarisk was very sparse. By the 1950s, tamarisk was present at places where it was not noted in 1938 (for example, Spring Canyon). Tributary floods played a role in limiting its spread; the willows and tamarisk that had invaded the mouth of Spring Canyon were damaged by a flash flood in 1955 and tamarisk on the Lake Mead delta was periodically destroyed by rises in the elevation of the lake.

Large native trees were rare (Table 3). Bob Sharp noted an increase in native willow trees downstream of Lava Falls in 1937, implying that few trees were present upstream. Others, particularly Dock Marston, had similar observations in later years (1948). Shade was eagerly sought but rarely found under trees during the Nevills' expeditions, and the locations of large trees were specifically noted in diaries. By the

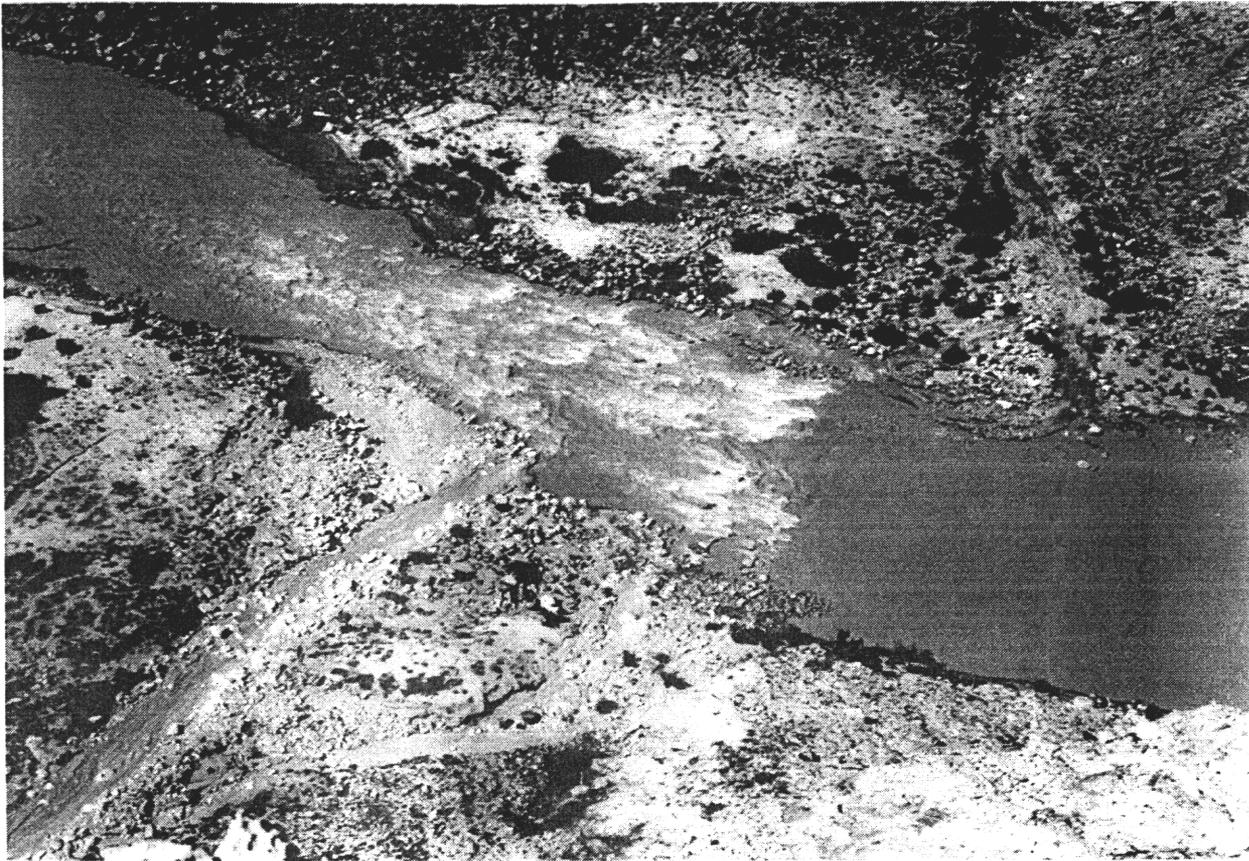


Fig. 2. Badger Creek Rapid, the downstream sand bars, and riparian vegetation.

C. This replicate view of Badger Creek Rapid, taken on September 5, 1994, shows marked erosion of the sand bar, invasion of riparian vegetation, and aggradation of the debris fan by a debris flow. The debris flow occurred on August 19, 1994.

1950s, native trees were rarely mentioned. With the exception of a large catclaw tree (now gone) at the mouth of Nankoweap Creek, no leguminous trees or hackberry trees were specifically noted by the Old Timers. These trees were common along the river in 1890 (Webb, 1996).

Early river runners rarely noted exotics other than tamarisk. None of the Old Timers remembered seeing camelthorn during their river running experiences. Clover and Jotter found Bermuda grass in the Lake Mead delta, and Reilly observed it at Tapeats Creek and “several other places in the canyon” in 1956. The Bermuda grass in western Grand Canyon may have originated from the sacks of seed lost in the 1910 flood in Havasu Creek (Webb, 1996).

*Marshes.* Cutter confirmed the photographic evidence that no marshes were present along the river (Figure 4) that were not fed by perennial tributaries or springs. The known marshes—for

example, the warm springs below Lava Falls and Three Springs Canyon (mile 215.7) — were observed and collected by Clover and Jotter (1944). Reilly observed that the marsh in the mouth of Three Springs Canyon had a patch of cane 100 feet across; it also contained willows, tamarisk, and cattails. This marsh is still present.

Riparian vegetation surrounding the springs at Deer Creek Falls, Vaseys Paradise (mile 31.8), and on the right side of Hance Rapid (mile 76.7) shows prominently in historic photographs. Rigg and Nichols stopped at Cardenas Creek (mile 70.9) before Glen Canyon Dam and agreed that the area now supporting a marsh was sand and rocks. Reilly saw willows at Cardenas Creek but did not specifically mention tamarisk, which he saw elsewhere. Cutter noted the current large amount of reeds along the river corridor as not resembling anything she saw in 1938.

**Table 2. List of known driftwood fires in Grand Canyon, 1937-1964**

Year	Date	Diarist	Location	Relative Size
1937	Nov 9	I. Campbell	Dubendorff Rapid	Large
1937	Nov 15	I. Campbell	Gateway Rapid	Large
1937	Nov 16	I. Campbell	Lava Falls Rapid	Large
1938	Jul 11	N. Nevills	Tanner Canyon	Large signal fire
1938	Oct 20	W. Johnson	Above Lava Canyon	Large
1940	Aug 5	N. Nevills	Boulder Narrows	Large
1940	Aug 7	N. Nevills	Vaseys Paradise	Small
1940	Aug 8	N. Nevills	Saddle Canyon	Large
1940	Aug 8-20	N. Nevills	All scouts of rapids	Small but many
1940	Aug 20	N. Nevills	Diamond Creek	Large (cabins)
1941	Jul 17	N. Nevills	Nankoweap Canyon	Large
1941	Jul 18	N. Nevills	Nankoweap Canyon	Large
1942	Jul 14	O. Marston	North Canyon	Unknown
1942	Jul 16	N. Nevills	Vaseys Paradise	Unknown
1942	Jul 17	N. Nevills	Nankoweap Canyon	Large
1942	Jul 19	N. Nevills	Tanner Canyon	Signal fire
1942	Jul 27	N. Nevills	Fern Glen Canyon	Large
1947	Jul 12	N. Nevills	Navajo Bridge	Unknown
1947	Jul 15	N. Nevills	Nankoweap Canyon	Unknown
1947	Jul 17	N. Nevills	Palisades Creek	Brush fire
1947	Jul 17	N. Nevills	Lava Canyon	Small
1947	Jul 17	N. Nevills	Tanner Canon	Large signal fire
1947	Jul 18	N. Nevills	Unkar Creek	Large
1948	Jul 14	O. Marston	mile 35	Small
1948	Jul 14	N. Nevills	mile 40	Unknown
1948	Jul 14	N. Nevills	Buck Farm Canyon	Unknown
1948	Jul 15	N. Nevills	Nankoweap Canyon	Unknown
1948	Jul 16	N. Nevills	Tanner Canyon	Large signal fire
1948	Jul 23	O. Marston	Elves Chasm	Small
1948	Jul 23	N. Nevills	Mile 118	Unknown
1949	Jul 14	P.T. Reilly	President Harding Rapid	Large
1949	Jul 15	P.T. Reilly	Nankoweap Canyon	Unknown
1949	Jul 16	P.T. Reilly	Nankoweap Canyon	Unknown
1950	Jul 14	F. Wright	President Harding Rapid	Large
1951	Jul 15	S. Reilly	Bert's Canyon	Unknown
1951	Jul 15	S. Reilly	Nankoweap Canyon	Large
1951	Jul 16	S. Reilly	Tanner Canyon	Large signal fire
1951	Jul 25	F. Wright	mile 180.5	Unknown
1952	Jul 23	F. Wright	mile 137	Unknown
1952	Jul 26	F. Wright	Whitmore Wash	Unknown
1953	Jul 12	F. Wright	Salt Water Wash	Unknown
1953	Jul 14	F. Wright	Nankoweap Canyon	Unknown
1955	Jul 2	P.T. Reilly	Fern Glen Canyon	Unknown
1955	Jul 4	P.T. Reilly	Spring Canyon	Large
1955	Jul 5	P.T. Reilly	Spring Canyon	Large
1955	Jul 13	F. Wright	Hance Rapid	Signal fire
1956	Jun 19	P.T. Reilly	24 1/2-Mile Rapid	Unknown
1956	Jun 20	P.T. Reilly	President Harding Rapid	Unknown
1956	Jun 30	P.T. Reilly	Fern Glen Canyon	Large
1956	Jul 13	F. Wright	Hance Rapid	Signal fire



Fig. 3. The sand bar downstream from Tapeats Creek.

A. This photograph of Tapeats Creek (mile 133.9) was taken in 1952 by Kent Frost. The large sandy beach has few rocks or boulders exposed.

*Desert vegetation.* Cutter thought the desert above the river appeared greener in 1995 than in 1938. Both years had relatively wet winters and normal summers. From replication of the Stanton photographs, we attribute the difference to a large increase in brittlebush. Jotter stated that she and Clover would certainly have listed now-common species such as snakeweed and tamarisk if they had been present at any of their sampling locations. This allows us to use their plant lists (Clover and Jotter, 1944) as a baseline for evaluating invasions or increases of common species. At the site where the type specimen of *Opuntia basilaris* var. *longiaureolata* was collected in 1938, we could find nothing that matched the original plant, which has not been recollected. We believe the variety was yet another *Opuntia* hybrid.

## ANIMALS

*Insects.* Various types of insects were bothersome to pre-dam river runners. Stanton had problems with bugs at Hance Rapid in 1890; he described “flies, millers, and moths flying about.” Goldwater noted his body was covered with welts from nocturnal bug bites at the end of his 1940 trip. Nevills and Goldwater mention “deer flies” at mile 68 that were so bad that they kept the river party up all night in 1940, Mildred Baker also mentions mayflies at Tanner at the same time. Reilly discusses “many large black flies” that pestered their trip at mile 80 in 1964; he wrote about the “hum of everpresent flies” in 1956. In some years (1942), Nevills complained vehemently about flies at Diamond Creek; in others (1947), he observed no



Fig. 3. The sand bar downstream from Tapeats Creek.

B. Large rocks and boulders are now exposed because of severe beach erosion. This photograph was taken on March 1, 1995.

flies. Nevills blamed their abundance on the presence of livestock.

Red ants were particularly bothersome all throughout the river corridor. Both Nevills and Reilly complained about them in 1942 and 1957, respectively. In particular, Nevills found that "bugs and red ants are a nuisance" at Spring Canyon. Reilly notes aphids on plants at Hermit Rapid in 1958, and scorpions are routinely mentioned in the diaries. Baker noted velvet ants at Diamond Creek in 1940 but did not indicate if they were bothersome.

The frequency of complaints about obnoxious bugs increases in diaries of trips taken after low-water runoff in the Colorado River with some notable exceptions, particularly red ants. This could explain why some pre-dam river runners (e.g., Nichols) do not remember pestilent insects, whereas others (e.g., Reilly) complained vehemently about them.

*Fish.* Few of the currently listed endangered fish in the Colorado River were noted by pre-dam river runners (Table 4). The Stanton expedition (1889-1890) caught Colorado River squawfish and the Kolb brothers (1911) caught 23 bonytail chub and one squawfish. In 1923, Emory Kolb caught a "bonytail fish" near Mohawk Canyon. In 1940, Goldwater mentions catching "salmon" (squawfish) in the mouth of Shinumo Creek in addition to catfish. Nevills observed 4-inch suckers and 2 inch minnows in Shinumo Creek 2.5 miles upstream from the Colorado River. Humpback chub were not specifically mentioned, but "humpbacked suckers" were caught in Shinumo Creek and near Gueiss Canyon Rapid (Table 4). Although most fishermen caught trout in Tapeats Creek, John Doerr, the chief naturalist at Grand Canyon National Park, caught squawfish there in 1948.

**Table 3. Pre-dam locations of tamarisk and native trees in Grand Canyon.**

Year	Notes
1869	Few native trees are noted. The canyon is described as barren.
1872	Few native trees are noted.
1890	Several trees are noted and photographed. No tamarisk is visible (Webb, 1996).
1923	USGS expedition photographs show no tamarisk, nor do the diaries mention it. They photographed the Goodding willow at Granite Park and large cottonwoods at mile 196 and 222.
1937	Sharp notes large increase in native willow trees downstream from Lava Falls Rapid.
1938	Clover observed "some tamarisk coming in now on sandbars" in the vicinity of Saddle Canyon (mile 47). Otherwise, she specifically noted few tamarisk trees between Lees Ferry and Lake Mead. She notes "weedy baccharis" but no tamarisk at Spring Canyon (mile 204).
1938	Huge cottonwood trees were reported at President Harding Rapid (Cook, 1987) and the expedition slept under a "huge willow" at mile 194. Nevills observed the deltaic deposits at the head of Lake Mead were covered with tamarisk.
1940	Goldwater notes a large cottonwood tree was present at mile 220.
1942-47	Nevills observed invasion of tamarisk at the mouth of Spring Canyon.
1947	Nevills expedition finds shade under tamarisk trees at Kanab Creek in 1947.
1948	Nevills expedition finds shade under tamarisk trees at Whitmore Wash (mile 185); Doerr notes that willow trees were also present. Marston notes that "willows decorate wide sandy beaches" near mile 190. Doerr and Nevills report that a large willow across from Pumpkin Spring (mile 213) was being gnawed by beavers. Masland rested under a large willow tree at Diamond Creek. Doerr reports canyon mouths on Lake Mead supported dense stands of young tamarisks and willows.
1951	S. Reilly noted "beautiful green tamarisks" at Badger Rapid. The camp at Salt Water Wash had "many tamarisks" as well as the debris fan at President Harding Rapid. S. Reilly especially noted "the smell of tamarisks" in the vicinity of Tanner Rapid.
1950s	P.T. Reilly notes tamarisk at Bridge (mile 237) and Spring Canyons. Tamarisk was noted at Beamer's Cabin up the Little Colorado. He does not note cottonwood or other native trees.
1955	P.T. Reilly notes the willows and tamarisk at Spring Canyon were damaged by a flash flood. 1955 Beer photographs show widespread tamarisk.
Early 1960s	Litton observed that tamarisk on the Lake Mead delta was periodically destroyed by rises in the elevation of the lake; he photographed the barren delta.
Early 1960s	Frost remembers a cottonwood tree at the mouth of Kanab Creek.
1970	Martin (1971) notes huge increase in tamarisk.
1977	J.N. Staveley remembers seeing the cottonwood tree at mile 220.

Some Old Timers remember seeing fishermen along the river, particularly in its first 32 miles. Sharp saw a flat-bottomed boat near Hermit Rapid in 1937; Nevills observed a fishing boat pulled up on the bank at mile 187 in 1947. Many trips included fishermen, which led to many observations about the kinds of fish in the river. Cross Sr. talked with Bert Loper about fishing in Glen Canyon in the 1940s; dynamiting earlier in the century yielded Colorado River squawfish, whereas later dynamiting yielded only catfish. Nevills found a cache of dynamite at the mouth of Parashant Wash (mile 198.5) in 1942 that he thought was used for fishing. Rigg and Nichols saw

dynamite being used to fish for catfish at Whitmore Wash in the 1950s.

Catfish were extremely common and are mentioned in every fishing reference after 1938 except most years at Tapeats Creek. Before 1938, no fisherman reported catching catfish despite occasionally intensive efforts. In 1938, Johnson reports "thousands of fish" in Lake Mead where the water turned blue; these likely were catfish and/or carp, but may have been "humpbacked suckers." Nevills observed catfish jumping in the mouth of Havasu Creek in 1942. Goldwater observed catfish in Tapeats Creek and speculated they spawned in the side canyons. In 1955, Reilly observed 3-in.

**Table 4. Anecdotal accounts of native and non-native fishes in the Colorado River in Grand Canyon**

<b>Date</b>	<b>Expedition (Diarist)</b>	<b>Notes</b>
1869	J.W. Powell	No fishes noted.
1872	F.S. Dellenbaugh	No fishes noted.
1890	R.B. Stanton	Colorado River squawfish caught in Cataract Canyon, no fishes noted in Grand Canyon.
1896	G. Flavell	No fishes noted.
1909	J. Stone	No fishes noted.
1911	E. Kolb	Caught 14-16 "salmon" (Colorado River squawfish) downstream from Lava Falls.
1923	USGS	No sign of fish in Tapeats Creek. Kolb caught a "bonytail fish" near Mohawk Canyon. Despite regular fishing, no catfish were caught.
1927	C. Eddy	No fishes noted.
1938	N. Nevills	No fishes noted.
1940	N. Nevills (B. Goldwater)	"Large salmon (Colorado River squawfish)" and catfish abound in Shinumo Creek. Catfish appeared to be spawning in Tapeats Creek.
1942	N. Nevills	They caught catfish at Shinumo Creek. The trout in Tapeats Creek were 10-14 in., and catfish were jumping in the mouth of Havasu Creek.
1942	N. Nevills (O. Marston)	Small fish observed in Hermit Creek. No fish were observed in Shinumo Creek above the waterfall, but he caught 15 channel catfish, a 2 lb. "humpbacked sucker", and 2 Colorado River squawfish below the waterfall. He caught 10 rainbow trout in Tapeats Creek. Catfish was observed 3/4 mile upstream in Diamond Creek. Near Gneiss Canyon Rapid, they caught "2 ft humpbacked suckers" with bare hands. The water was "alive with fish". Trout appeared to grow 1 in. per year in Tapeats Creek.
1942-1948	N. Nevills (G. Marston)	
1947	N. Nevills	They caught catfish at Lava Creek. No trout were seen in Shinumo Creek, but 4 in. "suckers" and 2 in. "minnows" were observed 2.5 miles up Shinumo Creek. A dozen trout were caught in Tapeats Creek.
1948	N. Nevills	They caught 11 rainbow trout in Tapeats Creek.
1948	N. Nevills (J. Doerr)	Squawfish 9 in. long caught in Tapeats Creek with 6 rainbow trout. Catfish were seen in Havasu Creek.
1948	N. Nevills (O. Marston)	Carp and catfish were observed under the waterfall near the mouth of Shinumo Creek. Catfish were observed in the mouth of Havasu Creek.
1949	N. Nevills (F. Wright)	No fishes noted.
1949	N. Nevills (P.T. Reilly)	Caught catfish at Elves Chasm and 12 in. trout in Tapeats Creek.
1951	P.T. Reilly (S. Reilly)	Two catfish were caught at Vaseys Paradise.
1954	O. Marston	Rainbow trout caught in Tapeats Creek.
1955	P.T. Reilly	Observed 2-3 in. fish in Nankoweap Creek and thought they were catfish. Shinumo Creek had 8 in. fish of an unknown species in its mouth. They caught trout in Tapeats Creek and saw 8 in. catfish in Diamond Creek 400 ft from the Colorado River. Bluegill and crappie were in Separation Creek in the mouth.
1956	P.T. Reilly	They caught catfish at President Harding Rapid.
1959	P.T. Reilly	Found rainbow trout on a rock at mile 38.5. These must have come from the Colorado River.
1962	P.T. Reilly	He observed trout in Lava Creek and caught catfish at Elves Chasm. He caught rainbow trout at Spencer Canyon.

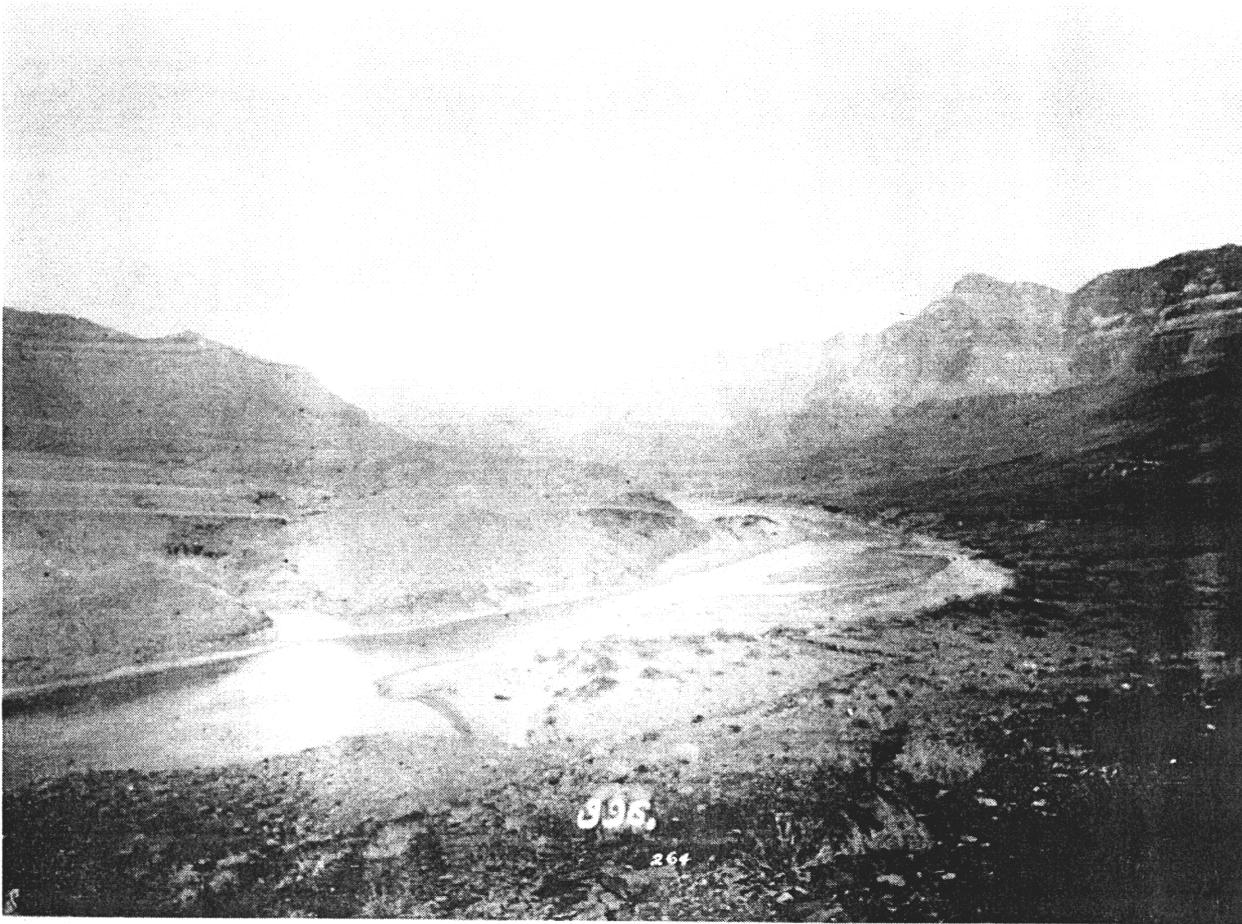


Fig. 4. The marsh at Cardenas Creek.

A. On January 23, 1890, Robert Brewster Stanton took this upstream view at 3:00 PM during the climb to what is now called Cardenas Hilltop Ruin. Except for scattered mesquite and what appears to be clumps of willows, little riparian vegetation is present along the Colorado River (Webb, 1996).

fish he thought were catfish in Nankoweap Creek. Carp were commonly observed in Shinumo Creek near the waterfall and large individuals were caught in the river.

Rainbow trout were commonly caught in Tapeats Creek. Garth Marston remembered that they increased in size about 1 in. per year in the 1940s. Reilly notes that trout were caught and left by a river party at mile 38.5-L in 1959; these could have only come from the Colorado. On two consecutive days in 1962, Reilly observed trout in Lava Canyon (mile 65.5); trout were never planted in Lava Canyon. Reilly also observed bluegill and crappie in the backwaters of Separation Canyon (mile 239) in 1955 and rainbow trout at Spencer Canyon (mile 246) in 1962. Cross Sr. remembers catching blue gill in tributaries of Glen Canyon in the 1950s.

Most tributaries had water backed up into their mouths during high water. Reilly, who took many

high-water trips, saw water backed up into Rider Canyon, South Canyon, Nankoweap, the Little Colorado River, Shinumo Creek, Kanab Creek, and Havasu Creek. Fish occasionally were observed in these pools. In the dry years of the 1950s, Reilly noted the width and depth of perennial streams. Nankoweap dried up 0.5 mile from the river, stranding fish in the channel upstream; flow in Nankoweap Creek decreased between 1949 and 1955, or the early period of drought on the Colorado Plateau.

*Beavers.* Beavers were commonly observed in the pre-dam river, as they are today. For example, McKee noted the presence of beaver sign at four sites downstream from Phantom Ranch in 1937; on the same trip, Sharp observed beaver sign at sites throughout Grand Canyon. The presence of beavers typically resulted in a note in Reilly's diary, so sightings could be cataloged. Even more notes were made on beaver effects on riparian vegetation.



Fig. 4. The marsh at Cardenas Creek.

B. Marshes, prime riparian habitat in Grand Canyon and elsewhere, provide habitat to native fishes and wildlife, particularly birds. Young native fish use the backwaters as protection from predators, and birds frequently nest in the dense vegetation. The marsh at Cardenas Creek, for example, is nesting habitat for southwestern willow fly catchers, which is a proposed endangered species. But marshes were not present in 1890; they exist solely because of the flood control by Glen Canyon Dam. Most of the increased riparian vegetation in the view is tamarisk, although willow, arrowweed, and other native species also have increased. Tom Wise replicated this view on February 26, 1993, at 10:06 AM.

The exception is the experience of George Flavell (Flavell, 1987), who found no beaver to trap in 1896.

*Otters.* Sightings of river otters were common on some historic river trips. Edwards observed two otters at Turquoise Rapid (mile 102) on February 14, 1890. He expressed surprise and noted he had never seen otters before. Stone (1932) reported otter tracks at about every camp down to Waltenberg Rapid (mile 112.2). In 1911, Lauzon "scared up an otter" near Serpentine Rapid (mile 106) and nearly shot one on the lower Colorado River. McKee (1937) reported otter tracks at the mouth of Tapeats Creek and again at mile 190. A member of Reilly's 1959 trip saw an otter at mile 19. Otters are now absent from Grand Canyon.

*Birds and Bats.* Waterbirds were commonly observed on early river trips (Table 5). Even as

early as 1890, Edwards noted the presence of "lots of ducks" downstream from Lava Falls Rapid. In 1937, Sharp noted many duck sightings (Table 5). Goldwater may have summed up the frequency of observance: "Ducks and geese are constantly rising from the water ahead of us." Species mentioned by name include Red-Breasted Mergansers, Mallards, and Blue-Wing Teal. Snowy Egrets commonly were seen near or with other waterbirds. Great Blue Heron were commonly seen, particularly in western Grand Canyon. Waterbirds have greatly increased along the river since closure of Glen Canyon Dam (Stevens and others, in press). The Old Timers with us on the 1994 trip found nothing unusual in the current waterbird population along the river, with the exception of Great Blue Herons, which they felt had decreased in numbers.

**Table 5. Waterbird sightings in Grand Canyon compiled from selected historic diaries.**

Year	Diarist	Date	Notes
1869	J.W. Powell		No waterbirds noted (summer).
1872	F.S. Dellenbaugh		No waterbirds noted (summer).
1890	R.B. Stanton	Feb 26	Shot at a duck near Cove Canyon.
		Feb 28	Shot a duck at 205 Mile Rapid.
1890	W.H. Edwards	Feb 14	Shot a duck, saw two others at Turquoise Rapid.
		Feb 28	"Lots of ducks" near 205 Mile Rapid.
1896	G. Flavell		No waterbirds noted (fall).
1909	J. Stone		No waterbirds noted (fall).
1911	E. Kolb		No mention of waterbirds (fall/winter).
1923	USGS Expedition		They caught a duck, which was sick or wounded, at Kanab Creek.
		Sep 24	Great Blue Heron at about Parashant.
		Sep 25	"Saw a few ducks today - the first for a few days." Just above Spring Canyon.
			Later, just before exiting the canyon, they mention they want to shoot a few ducks to supplement their food supply.
		Oct 15	Shot four ducks at the Grand Wash Cliffs.
		Oct 16	Shot five more ducks near Smiths Ranch (outside of the canyon).
1927	C. Eddy		No mention of waterbirds (summer).
1937	B. Sharp	Oct 11	Duck seen in upper part of Roaring Twenties, duck seen below Vaseys. 7 ducks were seen at Lava Canyon Rapid, another flock of 15-20 ducks, and another duck near Horn Creek. Downstream, they saw several Great Blue Heron.
1937	I. Campbell	Oct 18	"Flight of Redwing Blackbirds" near Kwagunt Rapid.
1938-1949	N. Nevills		No mention of waterbirds in the Nevills diaries.
1938	E. Clover		No mention of waterbirds.
1938	L. Jotter		No mention of wildlife.
1938	B. Holmstrom		No mention of wildlife sightings.
1938	A. Burg	Oct 16	Shot a duck between Badger and Soap Creek Rapids.
1938	W. Johnson		Ducks and geese were seen on the Green River but not Grand Canyon.
1940	B. Goldwater		Pretty sparse on wildlife, but does contain the following statement:
		Aug 19	"Ducks and geese are constantly rising from the water in front of us." He specifically notes Red-Breasted Mergansers.
1940	M. Baker	Aug 7	Kassin's Kingbirds at Vaseys Paradise.
		Aug 9	Nine American Egrets between Sockdolager and Grapevine Rapids; saw many Red Breasted Mergansers and a flock of Blue-Winged Teal.
		Aug 12	Immature Black Crowned Night Heron, five Cinnamon Teal near Horn Creek; American Egret near Shinumo Creek.
		Aug 14	Curlew seen above Waltenberg Rapid.
		Aug 17	Gadwalls, Red-Breasted Mergansers, and Great Blue Herons were "plentiful."
		Aug 18	Two Avocets near Whitmore Wash. Black Phoebe and White-Faced Glossy Ibis at Diamond Creek.
1942	O. Marston	Jul 24	Two ducks and a Great Blue Heron at Shinumo Creek.
		Jul 26	Four ducks at the mouth of Tapeats Creek.
		Jul 28	Great Blue Heron near Lava Falls Rapid.
		Jul 30	Several Great Blue Herons near Diamond Creek.
		Jul 31	Heard geese flying by during the night at Diamond Creek.

**Table 5. Waterbird sightings in Grand Canyon compiled from selected historic diaries.—Continued**

Year	Diarist	Date	Notes
1948	F. Masland	Jul 13	Blue-Winged Teal at Vaseys Paradise.
1948	O. Marston	Jul 13	Blue-Winged Teal at Vaseys Paradise.
1948	J. Doerr	Jul 20	Two Great Blue Herons between Granite and Hermit Rapids.
		Jul 22	Great Blue Heron at Tapeats Creek.
		Jul 28	Great Blue Herons at mile 214.
1949	P.T. Reilly		No mention of waterbirds.
1953	P.T. Reilly		No mention of waterbirds.
1954	O. Marston	Jun 14	Two Snowy Egrets near Lava Falls.
1955	P.T. Reilly	Jul 2	Two Blue-Winged Teal at mile 155.4.
		Jul 5	Great Blue Heron between 205 and 217-Mile Rapids.
		Jul 6	Blue-Winged Teal at Separation Canyon.
1956	P.T. Reilly	Jun 27	Two Mallards at Tapeats Creek.
1957	P.T. Reilly		No mention of waterbirds.
1958	P.T. Reilly	May 21	Two ducks at Crystal.
		May 21	Three Mallards at Hakatai.
1959	P.T. Reilly	Jun 22	Three ducks above Soap Creek.
		Jun 23	Duck at mile 14.
1962	P.T. Reilly	Jul 9	Two ducks at mile 152.
1964	P.T. Reilly	Apr 28	Five Blue-Wing Teal at mile 17.4.
		May 10	Snowy Egret below Kanab Creek.
		May 11	Snowy Egret at mile 160 and two above National; Blue Wing Teal at mile 163; four ducks above National.
		May 12	Two Great Blue Heron above Lava Falls.
		May 13	Two egrets at mile 214; two Blue-Winged Teal at mile 221; Great Blue Heron and Snowy Egret at 225.4.

Hummingbirds also occasionally were observed, sometimes flying about the drifting boats. Reilly specifically mentions seeing a Ruby-Throated Hummingbird at mile 155.8 and a Black-Chinned Hummingbird between Hermit and Boucher in 1956. Bats were commonly observed, particularly in the early morning hours. Nevills saw many bats at the mouth of Havasu Creek; Reilly noted bats at Spring Canyon. Fresh bat guano was seen by early visitors to Christmas Tree Cave. The Old Timers specifically noted a decrease in bats.

Cutter, Nevills-Reiff, and Nevills-Steveley noted a large increase in swallows in the Furnace Flats area. The change was attributed to an increase in insects using tamarisk. Litton thinks the swallows are a different species from the one that typically lived next to the unregulated river. Although Cliff Swallows were common before Glen Canyon Dam, Violet-Green Swallows are common now. Litton attributes the change to leadoff mud along the river that Cliff Swallows need for nest construction.

Dock Marston and P.T. Reilly occasionally saw eagles (most likely Golden Eagles). Masland (1948) mentions two Golden Eagles in western Grand Canyon. On the Old Timers Trip, several participants noted the peregrine falcons and mentioned that as something they had not seen before along the river corridor. Most Old Timers were surprised when we saw several turkeys on the 1994 trip. Cross II, however, remembered seeing turkeys at the mouth of Boucher Creek in the early 1960s.

*Large Mammals.* Bighorn sheep may have increased along the river corridor since the first river runners (Table 6). Beginning with the first Powell expedition (Cooley, 1988), few river trips saw large mammals along the river corridor. Trips before the turn of the century saw the largest numbers. The most common sightings of bighorn sheep were between Elves Chasm and mile 126, in the vicinity of Havasu Creek, and occasionally in western Grand Canyon.

**Table 6. Sightings of bighorn sheep in Grand Canyon during pre-dam river trips.**

Year	Date	Trip	Location	Number of Sheep	Source
1869	Aug-Sep	Powell	Grand Canyon	0	Cooley, 1988
1872	Aug 27	Powell	Near Cardenas Creek	2	Dellenbaugh, 1908
1890	Feb 5	Stanton	Bright Angel Creek	tracks	Unpublished diary
	Feb 27	Stanton	Whitmore Wash	15	Unpublished diary
1896	Oct 25	Flavell	near Fossil Canyon	1	Flavell, 1987
	Oct 25	Flavell	near Deer Creek	2	Flavell, 1987
1909	Nov 9	Stone	Above Havasu Creek	5	Stone, 1932
	Nov 10	Stone	National/Mohawk Canyons	1	Stone, 1932
1911	Dec 28	Kolb	Deer Creek	1	Unpublished diary
	Jan 12	Kolb	About mile 265	5	Unpublished diary
1923	Sep 6	USGS	Specter Chasm	tracks	Unpublished diary
	Sep 8	USGS	mile 133	1	Unpublished diary
	Sep 13	USGS	mile 152	2	Unpublished diary
	Oct 1	USGS	Granite Springs Canyon	1	Unpublished diary
1937	Oct-Nov	Campbell	Grand Canyon	0	Unpublished diary
1938	Jul 29	Nevills	Diamond Creek	1	Unpublished diary
1938	Oct	Holmstrom	Grand Canyon	0	Unpublished diary
		Johnson	Grand Canyon	0	Unpublished diary
1940	Aug	Nevills	Grand Canyon	0	Goldwater, 1940
1941	Jul	Nevills	Grand Canyon	0	Unpublished diary
1942	Jul 27	Nevills	National Canyon	7	Unpublished diary
	Jul 27	Marston	Fern Glen Canyon	7-8	Unpublished diary
	Jul 28	Nevills	Whitmore Wash	5	Unpublished diary
	Jul 28	Marston	Whitmore Wash	5	Unpublished diary
	Jul 29	Marston	Spring Canyon	1	Unpublished diary
	Jul	Nevills	Grand Canyon	0	Unpublished diary
1948	Jul	Nevills	Grand Canyon	0	Unpublished diary
	Jul 24	Doerr	Surprise Valley	dung	Unpublished diary
1949	Jul 26	Doerr	mile 190	1	Unpublished diary
	Jul 23	Nevills	Mile 122	9	Unpublished diary
1950	Jul	Wright	Grand Canyon	0	Unpublished diary
1951	Jul 23	Wright	mile 144	several	Unpublished diary
1952	Jul	Wright	Grand Canyon	0	Unpublished diary
1953	Jul	Wright	Grand Canyon	0	Unpublished diary
1954	June	Marston	Grand Canyon	0	Unpublished diary
1955	Jun 28	Reilly	Elves Chasm	4	Unpublished diary
	Jul 15	Wright	Elves Chasm	3	Unpublished diary
1956	Jun-Jul	Reilly	Grand Canyon	0	Unpublished diary
	Jul	Wright	Grand Canyon	0	Unpublished diary
1957	Jun	Reilly	Grand Canyon	0	Unpublished diary
	Jul	Wright	Grand Canyon	0	Unpublished diary
1958	May 22	Reilly	Forster and Stone Creek	tracks	Unpublished diary
1959	Jun	Reilly	Grand Canyon	0	Unpublished diary
1962	Jul 4	Reilly	Boucher Creek	10	Unpublished diary
	Jul 4	Reilly	Elves Chasm	2	Unpublished diary
1964	May 8	Reilly	near Elves Chasm	2	Unpublished diary

Bighorn sheep sightings now are more common. Nevills-Staveley was surprised to see bighorn sheep near Navajo Bridge; no historic river trips ever saw them so far up canyon. According to Grua, these sheep were introduced onto the Paria Plateau in 1980, and they subsequently migrated into Marble Canyon. Several people indicated they saw more bighorn sheep on the Old Timers Trip than on any other. From our experience, we felt we saw very few.

Burro sightings became more common through the 1940s and 1950s, but burros are only rarely mentioned in diaries. The sightings followed the known distribution of the animals. In 1938, Clover and Jotter observed burros on both sides of the river at Diamond Creek. Reilly observed burros at the mouth of Hermit Creek in 1962. The most apparent populations of burros along the river were downstream of Whitmore Wash. Nevills saw a domestic sheep at Spring Canyon in 1942; the Stone Expedition killed domestic sheep near Salt Water Wash (mile 11.8) in 1909 (Stone, 1932).

Deer sign was observed, particularly from about mile 35 to Phantom Ranch. Jotter and Clover saw a deer at the mouth of Kwagunt Creek (mile 56.0) in 1938. Nevills saw a large buck at mile 71-L in 1947. Reilly saw tracks at Buck Farm Wash (mile 41.0) and Kwagunt Rapid, and saw a doe at Tanner Canyon (mile 68.5). "Dock" Marston saw many deer in Lava Canyon in 1948. Several Old Timers mentioned deer swimming in front of the boats in the 1950s; Cross II stated he observed deer swimming 6 times on his trips in the 1960s. The most downstream report of deer was by McKee, who noted the presence of "weathered" antlers on ledges 600 feet above the river at Tapeats Creek.

Mountain lions were observed on a Nevills trip in 1947 (mile 215) and a Reilly trip in 1956 (mile 177). Reilly commonly mentioned seeing bobcats or bobcat tracks. He saw a bobcat at mile 200 and bobcat tracks at Unkar Creek (mile 72), Lava Canyon, Nankoweap Creek, Kwagunt Creek, Stone Creek, Fern Glen, Whitmore Wash, and Gneiss Canyon (mile 135). McKee saw sign of bobcats at the foot of the Bass Trail (mile 107) and at mile 176. Frost had a special memory of seeing a bobcat in the vicinity of Three Springs Canyon.

Ringtail cats were also seen during pre-dam river trips, but only one of the Old Timers remembered food thefts by ringtails. Several Old

Timers mentioned they did not cause problems. McKee noted the presence of ringtail tracks at six sites between Bright Angel Creek and Diamond Creek in 1937, and Reilly also recorded their presence in the 1950s.

## CONCLUSIONS

The strongest conclusion from the Old Timers Trip is that people who travelled the pre-dam river have vivid, and typically accurate, memories of the environment of Grand Canyon. Few early river runners observed or remembered all aspects of the environment; most noted or remembered specific details about certain changes, such as distribution of sand bars, while not noticing other aspects, such as changes in wildlife populations. These observations must be taken in aggregate to provide an accurate accounting of environmental changes in Grand Canyon. Much has changed along the Colorado River since most of the Old Timers and other historic river runners were in Grand Canyon. The following changes, many of which are supported using photographic or other evidence, are probably significant:

- The low water temperature, lack of substantial sediment in the river, noise from aircraft, and deteriorated air quality are considered the largest changes in Grand Canyon.

- The largest changes, other than rapids, were observed just downstream from Nankoweap Creek and at the mouth of the Little Colorado River, Elves Chasm, and Tapeats Creek.

- The Old Timers saw little evidence of debris flows before closure of Glen Canyon Dam. The frequency of debris flows apparently increased after the early 1960s.

- Certain rapids — such as Crystal, Bedrock, and House Rock — are now more difficult than in the pre-dam era. Other rapids are unchanged or are less difficult.

- Erosion of camping beaches used by pre-dam river runners is severe. Now, some formerly popular camping sites are not easily used for camping.

- Fires had a significant impact on the amount of driftwood along the river corridor. Fires were set randomly and specifically at certain popular places,

particularly the mouth of Nankoweap Creek and Tanner Rapid.

- Riparian vegetation, mostly tamarisk, is much denser along the river, whereas cottonwoods and tree-form willows decreased in the post-dam era. Tamarisk slowly increased, particularly in the 1940s and 1950s, but accelerated after 1963.

- Perennial marsh vegetation was not observed or photographed along the pre-dam river except near springs.

- Catfish were the most common fish caught in the pre-dam river, although rainbow trout were also present. Some of the Old Timers caught native fish, mostly before about 1950, and the species they observed could not be accurately determined.

- Ducks and other waterbirds were commonly observed along the unregulated river, but they were not as abundant as they are now.

Other changes may or may not be significant, if in fact changes even occurred:

- Bats and some species of birds may have decreased along the river, whereas swallows may have increased.

- Bighorn sheep possibly are more numerous: they certainly are observed more often now. No changes can be inferred in the population of deer or other large mammals along the river.

- It is uncertain whether the population of beavers has changed, although otters are no longer present.

- Bothersome insects were common before Glen Canyon Dam. It is unknown if species or abundances may have changed.

Some of the issues raised in this report have significant implications for dam management. The increase in frequency of debris flows will hasten a long-postulated change in the longitudinal profile of the river; without dam releases significantly higher than powerplant capacity, the river will eventually attain an exaggerated pool-drop configuration. Tamarisk was increasing despite pre-dam flooding. Although dam releases could be used to thin some of the population, tamarisk would have become a common, although exotic, resident of Grand Canyon even if the dam had not been built. Marshes are an artifact of flow regulation, not a natural feature of the pre-dam environment (Webb, 1996). Native fish may have declined precipitously

before Glen Canyon Dam was built possibly owing to invasion by predatory non-native species such as catfish and trout.

Much remains unknown about the pre-dam river and its environment. Ultimately, we may never determine whether changes reported in wildlife populations are in fact significant or merely the result of limited observation. The observations of the Old Timers suggest that monitoring of bighorn sheep and bat populations may be warranted. Regardless of whether hard, scientific conclusions can be reached on all of their observations, one thing is certain: we should listen to the historical experiences of the Old Timers and attempt to independently and scientifically test their ideas about the timing and causes of change along the Colorado River.

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13. ABSTRACT (Maximum 200 words)  <p style="margin: 0;">Little scientific data has been collected on pre-dam conditions of the Colorado River corridor through Grand Canyon National Park. Using historical diaries and interviews with long-term river runners, referred to as the Old Timers, we compiled anecdotal information on environmental change in Grand Canyon. The most significant changes are the lowering of water temperature in the river, the lack of heavily sediment-laden flows, the erosion of sand bars, the invasion of non-native tamarisk trees, the reduction in driftwood, the development of marshes, the increase in non-native fish, and the increase in waterbird populations. In addition, few debris flows were observed before closure of Glen Canyon Dam, which suggests that the frequency of debris flows in Grand Canyon has increased. Other possible changes include decreases in bat populations, and increases in swallow and big horn sheep populations, although the evidence is inconclusive. These results provide a perspective on managing the Colorado River that may allow differentiation of the effects of Glen Canyon Dam from other processes of change.</p>
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**16. Abstract (Limit: 200 words)**  
Recent flooding exerted significant impacts on riparian substrates, plant communities, and invertebrate herbivore populations in the Colorado River corridor in Grand Canyon. Substrates were scoured and leached by flooding in 1983. Base cation concentrations, percent organic matter, and percent silt+clay decreased relative to the substrate surface level following flooding, while pH remained unchanged. Increased percent sand implies increased rates of erosion, leaching, and desiccation; conditions which represent a significant decline in habitat quality. Flood-induced plant mortality was significant in this system and reduced riparian plant abundance by more than 50% below the flood stage. Sources of mortality include removal, drowning/thrashing, and burial by deposited sediments. Mortality of four riparian plant species was strongly differential. Flooding promoted germination but recruitment is uncertain. Flooding negatively affected invertebrate herbivore populations and terrestrial and fossorial invertebrate populations. Trophic relationships between terrestrial and aquatic components are described in relation to suggested changes in operating criteria of Glen Canyon Dam.

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