Chapter Twenty-One

Environmental History of the Colorado River: The Changing Focus of Science

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To quote the authors, the "Colorado River has a plethora of national and local agencies and organizations firmly shackled to it for reasons ranging from preservation to profits." Rather than propose specific actions to protect the river's biological integrity, a task far too complex for a single presentation, Emma Benenati and Joseph Shannon help unravel the issues by outlining the history and changing focus of scientific investigations of the pre-dam (before 1964) and post-dam era in relation to the evolution of human values and our views of the natural world. Along the way, they identify some of the problems of modern river management by stakeholders with conflicting agendas.

Although long appreciated for phenomenal beauty and natural attributes, in recent decades the Grand Canyon and the Colorado River flowing within have become the center of political, economic, and environmental controversy. The heart of this controversy stems from differing views on the best use, or nonuse, of the resource. Factors contributing to controversy include:

- Grand Canyon National Park (GCNP) visitation now approaches five million people annually.
- The number of Colorado River rafters below Lake Powell and in the Grand Canyon exceeds 50,000 annually.
- The river corridor is critical habitat for endangered species, including the humpback chub, razorback sucker, Kanab ambersnail, and southwestern willow flycatcher (Schmidt et al. 1998).
- Rainbow and brown trout, introduced fish that thrive in the cold waters below Glen Canyon Dam, provide a sport-fishing industry for nearby communities, yet are responsible for the decline of native fish through predation and competition for food and habitat.
- The river lies between two of the largest dams and reservoirs in the United States and is part of a regulated system that exports more water out of its basin than any other river basin on earth (Hirsch et al. 1990).

Because of conflicting interests and uses, the Colorado River has a plethora of national and local agencies and organizations firmly shackled to it for reasons ranging from preservation to profits. Examples of the wide range of Grand Canyon "stakeholder" groups include the Bureau of Reclamation (BOR), Western Area Power Administration, Colorado River Energy Distributor Association, Arizona Game and Fish, Grand Canyon Trust, Bureau of Indian Affairs, commercial fishing and rafting companies, boaters' and river runners' organizations, states, and several American Indian tribes.

The nature of scientific investigations on the Colorado River has evolved over time, reflecting prevailing human values in much the same way as changes in management policies and laws. Relationships and influence among scientists, managers, legislators, and the public are convoluted

and dynamic, and as population and resource demands have exploded, "final authority" has fluctuated between these sectors. This is primarily because managing agencies are confused about their mission or have not been allowed to follow it. Years of vague and conflicting legislation combined with political influence within and outside management agencies have made it dangerous to voice an opinion, much less make decisions that benefit the resource.

For example, during the Bridge Canyon Dam controversy in the early 1950s, all Grand Canyon National Park personnel were prohibited from voicing personal opinions after Acting Superintendent Lemuel Garrison expressed anti-dam sentiments in written correspondence. National Park Service (NPS) Region Three Director M. R. Tillotson immediately ordered park personnel to limit comments to "factual data and known Service policies or decisions." A decade later, during hearings on Marble Canyon Dam, NPS Director Conrad Wirth spoke against reclamation projects that involved park lands after having been warned by Secretary of the Interior Stewart Udall not to express his personal opinions (Pearson 1992). Within a year Udall removed Wirth as NPS director.

All too often, responsible government agencies rely on the most powerful voice of the time, a dubious way to manage natural resources. In this paper we will describe the changing focus of scientific investigations of the Colorado River over the past four centuries since Europeans realized its existence. This change in focus is presented in relation to the evolution of human values and our view of the natural world relative to ourselves.

Pre-Dam Investigations

The Grand Canyon and the Colorado River have a long history of human investigations. Recorded history over the past few hundred years shows the slow progression of investigative themes shifting from exploration to exploitation to restoration. Science has been a part of all these themes and has grown in importance, especially in the last few decades. Biological investigations on the river had a rather slow start, largely because the objectives and priorities of early researchers were more physical-based. The most striking features of the Colorado River and the Grand Canyon to most observers are their physical components: rocks, colors, depth, danger, rapids, etc. Moreover, surface appearances did not reveal much "biology" in pre-dam days, with the river corridor generally appearing as a scoured, muddy waterway with little riparian vegetation. Biological features were subtle and required time to be noticed and understood, which is still the case, even after post-dam increases in ecological systems. Today, however, due to the effects of Glen Canyon Dam, the corridor appears to be a biological wonderland with both positive and negative aspects.

One element that has not changed is that the Grand Canyon is both a spectacular and challenging place to conduct scientific investigations. The challenge of travel on the Colorado River often impedes science, and it can be a struggle to keep the research in perspective. Scientists have always had to deal with conditions that confront expeditions in remote settings, such as a lack of outside assistance in the event of illness or equipment loss. Other common problems include collecting data in or beside the river regardless of season or weather conditions. Living in cramped or awkward conditions tests a person's resolve, as does constant packing and unpacking of gear. One hundred and fifty rapids must be negotiated while preventing loss or damage to equipment and workers. Despite these challenges, however, most of us gladly accept the inconveniences and danger just to work in the Grand Canyon.

Explorations in the canyon region from the 1500s through the early 1800s were primarily land based and not "scientific" as we define the term today. During these years, Spaniards dominated the investigative landscape, searching for gold, silver, and other immediate economic opportunities (Spicer 1962). Science became a part of exploration in the mid-1800s, when a series of government surveys scoured the Colorado Plateau; at that time, scientific objectives changed to more in-depth examination of land resources, mapping, and wagon-road and railroad surveys. Natural-history observations of plants and animals were also documented, usually by physicians who served as the collectors and naturalists in addition to their medical duties. Professional geologists such as John Newberry and Grove Karl Gilbert were often employed to study rock strata and construct geologic cross sections of explored areas. These expeditions were led by military officers, including John C. Frémont, Lorenzo Sitgreaves, John Gunnison, and Amiel Whipple, and usually assisted by civilian specialists such as the trapper-guide Antoine Leroux and artist-cartographer Richard Kern (Wallace and Lubick 1991). Two of the first Colorado River surveys were accomplished by Lieutenant Joseph Ives in 1857–58, and by Lieutenant George Wheeler in 1871–72, both of whom concentrated on the lower river. Ives determined the lower river's navigability by steaming upstream from the Gulf of California as far as Black Canyon, the present site of Hoover Dam. Wheeler undertook the more difficult task of exploring the river within the Grand Canyon itself, rowing, towing, and portaging rowboats upriver from Camp Mohave near today's Needles, California, to Diamond Creek.

The earliest systematic research was a geographical and geological survey conducted by John Wesley Powell during two river trips in 1869 and 1871–72 (Powell 1895). Although Powell's research comprised a predominantly physical examination of the largely unknown river drainage, he also documented some plant species. He later proved instrumental in ushering in the age of reclamation, a decade before the 1902 Reclamation Act. As head of the U.S. Geological Survey in 1889, entrusted with management of the new Irrigation Survey project, Powell directed numerous survey trips on western rivers to map potential dam sites (Aton 1988). Based on his research, Powell developed a democratic and science-based reclamation plan for the West that logically organized water districts based on watershed boundaries and available water. His plan explicitly excluded government interference, and instead proposed that the support, labor, and control of western water development remain with local cooperative associations after initial government surveys for dam sites. His ideas were never implemented, however, due to opposition by members of Congress who stood to gain personally through governmental development of western water (Worster 1994). Powell appreciated the beauty of the rivers and canyons, as his romantic descriptions attest; however, he supported the control and damming of western waters, in particular, large rivers such as the Colorado and Rio Grande (Aton 1988). One can only speculate what his opinion would be of monopolistic policies practiced by today's BOR and Western Area Power Administration.

Coincident with Powell's years of governmental service, a national environmental movement began to flourish. The 1890 census revealed an end to the American "frontier," and concerns regarding land use continued to grow in two directions. One view held that there was an increasing and justified need for use of land and resources for national progress and growth. The opposite view held that land and natural-resource consumption was occurring too quickly and carelessly, requiring immediate conservation. While Americans struggled with these ideas from the middle 1800s to the early 1900s (Merchant 1993), a national conservation movement began, a movement split between those who would preserve the land and those who would conserve it. Preservationists, ideologically associated with Henry David Thoreau and John Muir, believed that the best in life could be found in nature and that land development did not necessarily lead to progress. Conservationists, led by Theodore Roosevelt, defined their policy as the "use of natural resources for the greatest good of the greatest number for the longest time." Many citizens were caught between these opposing ideologies, wanting to preserve the qualities of wilderness yet desiring the advantages and conveniences afforded by development of wild lands. While preservationists were often viewed as radicals and romantics, conservationists considered their position to be based in science.

The roots of conflict between the use and preservation of the Colorado River date to the early-twentieth-century conservation movement and its scientific base. More than two decades of controversy preceded the passage of legislation creating Grand Canyon National Park in 1919; unfortunately, thanks to Arizona Senator Carl Hayden, the same law allowed for reclamation projects within park boundaries. When questioned on his position, Hayden responded that reservoirs for water storage and irrigation would be built only when "consistent with the primary purposes of the park" (Pearson 1992). Since the primary purpose of national parks, to paraphrase the National Park Service Organic Act of 1916, is to conserve the scenery, the natural and historic objects, and the wildlife therein, and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations, it is clear that human-induced additions or "impairment" of the Grand Canyon and its wildlife are inconsistent with the "primary purposes of the park." The problem that scientists as well as managers, politicians, and environmentalists grapple with today, however, is that although nearly two thousand miles of the river and its tributaries are legally protected as national parklands or are designated critical habitat, water has become the lifeblood of the Southwest (Carothers and Brown 1991).

Theodore Roosevelt illustrated early on the conflict and political contradiction between conservation and preservation. In 1903 he spoke at the canyon's South Rim and asked its residents and, by implication, the nation, "to keep this great wonder of nature as it is now . . . Leave it as it is. You cannot improve on it" (quoted in Hughes 1978). Five years later, in his White House speech formally inaugurating the conservation movement, Roosevelt proclaimed the virtue of using our national resources in such a manner not only as to leave them undiminished, but to "actually be improved by wise use." He added that "men can improve on nature by compelling the resources to renew and even reconstruct themselves to serve increasingly beneficial uses—while the living waters can be so controlled as to multiply their benefits" (Merchant 1993). He must have forgotten his visit to the Grand Canyon.

Back on the Colorado River, the general theme of investigation changed from exploratory-based expeditions to exploitation using the physical sciences but still very little biology. In 1889–90, Frank Brown, president of the Denver, Colorado Cañon, and Pacific Railroad Company, and his engineer Robert Brewster Stanton surveyed the

river through the Grand Canyon for a water-level railway that would run from Grand Junction, Colorado, to San Diego, California (Smith and Crampton 1987). The expedition incidentally gathered information on plant life. In August 1923 Claude Birdseye led a U.S. Geological Survey trip that produced a topographical map of the canyon bottom and, more importantly, twenty-one potential dam sites within the Grand Canyon. They called this survey the "conquest of the Colorado," an excellent reflection of the sentiment of contemporary citizens and government.

By the 1930s biological research was on the rise. Between 1933 and 1938 a series of trips sponsored by the Museum of Northern Arizona floated the San Juan and Colorado rivers as far as Lees Ferry. Although archaeology was their main purpose, researchers also pursued biological studies of mammals, birds, reptiles, insects, and plants. In 1938 Norm Nevills guided the first biological research trip through the canyon. Professor Elzada Clover and her graduate student, Lois Jotter, of the University of Michigan—the first women to float all the way through the Grand Canyon—studied botany on this trip. Nevills himself used the publicity to launch a commercial river-running business. Angus Woodbury of the University of Utah conducted biological studies on the river in the late 1950s (Woodbury 1959), although he worked above the later site of Glen Canyon Dam.

Despite the rise in scientific interest, very little information was obtained on the Colorado River prior to the completion of Glen Canyon Dam in 1963. Immediately thereafter, the physical and biological condition of the river corridor began to change dramatically (Carothers and Brown 1991; Webb et al. 1999). It took years for managers to realize the dam's effects. Some were immediate and obvious, but many developed over time and are still developing today. Although the river and corridor appears to be "improved" to many people, with its clear water, lucrative trout fishery, abundance of riparian life, and absence of scouring floods, a tremendous part of the natural ecosystem has been lost.

Research conducted since the gates of Glen Canyon Dam closed has revealed that the ecosystem today is completely altered above and below the dam (Stanford and Ward 1986; Blinn and Cole 1991). One of the changes is river water temperature, which remains in a narrow range between forty-six and fifty degrees Fahrenheit. Therefore, the macroinvertebrate community is dominated by alien cold-adapted species that also have a narrow range of temperature tolerance (Oberlin et al. 1999; Blinn and Cole 1991). The dam as barrier has reduced the former carbon source of "externally produced" upland woody vegetation that used to wash in and serve as the base of the food web (Haden et al. 1999, 2003). The loss of sediment, at least 80 percent less today, results in greater water clarity and exposed cobble substrate on the river bottom, which allows sunlight to penetrate the water column and promotes photosynthesis and growth of aquatic plants such as algae and macrophytes that now serve as an "internally produced" base of the food web (Blinn et al. 1998; Benenati et al. 2000). Finally, due to the lack of seasonal floods, discharge has changed to a narrow range of flows on an annual basis; however, due to the production of hydropower, there is now a daily tide that influences physical and biological aspects of the river channel (Benenati et al. 1998).

Post-Dam Investigations

The 1970s ushered in an era of long-term research on the Colorado River. The 1960s wave of national environmental awareness gained momentum due to proposed dams within the Grand Canyon. Congress passed environmental legislation, such as the Endangered Species Act in 1973 and the National Environmental Policy Act in 1969, which mandated improved management of national resources (Carothers and Brown 1991). Science commissions under the Department of the Interior called for the NPS to manage in accordance with the original intent of the NPS Organic Act of 1916 and to use scientific research as a basis for NPS policies (National Research Council 1992).

Meanwhile, greater numbers of people were rafting through the Grand Canyon, both creating and publicizing problems on the river. Campsites were trashed, vegetation was trampled, and human feces and toilet paper permeated beaches. As many as 5,000 unregulated potty dumps occurred every season along the corridor; favorite beaches could receive more than 150 potty dumps per year (Phillips and Lynch 1977). Waterfalls, side canyons, and other scenic spots were polluted with urine, feces, and garbage. These problems of overuse prompted the Colorado River Research Program in the early 1970s, combining the efforts of Grand Canyon National Park, the BOR, and the Museum of Northern Arizona (Grand Canyon National Park 1979). The Colorado River Research Program was "reactive science" that addressed well-established recreational use problems from the previous decade. Participants studied conditions and assisted in the development of the 1979 Colorado River Management Plan to mitigate recreational impacts, but little thought was given to the effects of dam operations. Implementation of the river plan did result in better camping and cooking procedures and portable toilets, however, and studies did include the effects of feral burros and how to remove them, as well as the issue

of motor use. Research in the later 1970s also produced a flora and fauna survey, documentation on native and nonnative fishes, and some attention to the effects of dam operations on riverine resources.

A research program known as the Glen Canyon Environmental Studies (GCES) followed the Colorado River Research Program from 1982 through 1996. GCES was envisioned as a multiagency, multibureau effort to study the dam's effects on downstream aquatic and terrestrial resources. The scope was wider than previous projects of the 1970s, although still something less than a total ecosystem approach due to program restrictions and lack of direction from responsible agencies; the underlying assumption of some scientists outside the GCES was that no useful information would be obtained (Wegner 1991). Initially, the main areas of study included sediment, biology, and recreation, with additional studies in river temperature modification and hydrology. The BOR established this program in response to public pressure regarding concerns for the overall effects of Glen Canyon Dam on the river. Listing of the humpback chub as an endangered species in 1978 and concern for other native species served as catalysts. Two primary triggers for the GCES were concerns regarding the "peaking power program," which resulted in large, erratic fluctuations in daily water discharge (for the purpose of instantaneous electricity production and revenues), and the BOR's proposed "uprate and rewind project" on dam generators to increase hydropower production.

Although resigned to an environmental study mandated by the National Environmental Policy Act, the BOR wanted to avoid an Environmental Impact Statement (EIS) that would have entailed a full-scope examination of dam operations (National Research Council 1996). The Department of the Interior decided that the bureau would instead proceed with an Environmental Assessment, a scaled down version of an EIS requiring no new data collection, and at the same time proceed with the generator upgrade. The GCES, originally envisioned to be a two-year project, was intended to provide data that would support the BOR's decision not to conduct an EIS (National Research Council 1996). This was essentially the root of most problems that would plague research for years. Because GCES was created and funded by the BOR essentially to minimize environmental compliance and support their water-development mission, the program and program manager would remain subject to BOR control and authority for the duration of the program.

Aside from limited direction, the GCES research scope was constrained both geographically and conceptually. Studies were initially limited to only the Glen Canyon reach of the Colorado River, hence the name, Glen Canyon Environmental Studies. Any analysis that might result in reduced hydropower revenues was prohibited, as were investigations of cultural and aesthetic values, referred to as "non-use values," a term still used today. The BOR also limited research to agency scientists, precluding more objective academic and outside scientists. Even before these constraints became known, BOR administrators had been criticized for conflict of interest because of their close association with the Western Area Power Administration, which marketed power, and because both agencies provided the funds and management of the research program and both stood to benefit from the status quo of dam operations (National Research Council 1996).

In 1986, to maintain credibility for conducting its own environmental studies, the BOR asked the National Research Council to review the science of the GCES. The National Research Council reviewers, who are outside professionals and scientists charged with ensuring quality and objectivity in federal research, addressed many of the problems hampering the research program. Research scope and scientific expertise were expanded, economic (power) and cultural aspects were added, and an ecosystem emphasis was incorporated into the program. By 1989, GCES had gathered considerable evidence of the dam's negative environmental impacts that enabled Secretary of the Interior Manuel Lujan to order an EIS to be completed by 1994. Under the direction of program manager Dave Wegner, the GCES project became the database for analysis of potential management alternatives for the EIS process (Wegner 1991).

Although conflicts with the BOR continued through the GCES years, the program contributed significant environmental knowledge regarding the Colorado's ecosystem and management specifically as well as large regulated rivers in general. The EIS supplied a wide range of dam management options to Secretary of the Interior Bruce Babbitt's Record of Decision announced in 1996. The secretary's decision authorized a "Modified Low Fluctuating Flow Alternative" that would somewhat reduce the daily change in discharge volume and ramping rates (speed of increasing or decreasing water discharge). In addition, GCES devised a long-term research and monitoring plan to be implemented following the EIS called the Glen Canyon Dam Adaptive Management Program (GCD-AMP). Another benefit of the GCES program was an informed and involved general public, and the growth of numerous environmental watchdog organizations.

In 1997 GCES was reorganized into the Grand Canyon Monitoring and Research Center (GCMRC) under the GCD-AMP. The GCMRC's purpose is to coordinate scientific studies suggested by designated work

groups of the AMP that address requirements of the Grand Canyon Protection Act of 1992. The purpose of the GCD-AMP is to use data from ongoing, long-term monitoring and experiments as a basis for change or "adaptation" in management policy in order to better manage the ecosystem and ensure compliance with the Grand Canyon Protection Act (National Research Council 1999). In the AMP hierarchy, GCMRC is on the bottom tier along with a technical advising work group (TWG) and an independent review panel. These three groups report to the second tier, the Adaptive Management Work Group (AMWG), which has the authority to vote for or against science studies and experiments as well as recommend implementation of certain operational policies to the secretary of the interior's designee. The secretary's designee sits on the third tier, and after receiving the recommendations of the AMWG, reports them to the secretary for a decision.

The science advisory groups TWG and AMWG are composed of representatives of "stakeholders" who have an interest related to the Grand Canyon or the Colorado River. Stakeholders include the BOR, Western Area Power Association, Colorado River Energy Distributor Association, each of the seven basin states that receive water or electricity benefits of the Colorado River, commercial recreation groups, Arizona Game and Fish, U.S. Fish and Wildlife Service, Grand Canyon National Park, seven southwestern American Indian tribes, and two environmental organizations: Grand Canyon Trust and Southwest Rivers. The large number of stakeholders with their own interests and infrequent meetings often result in stalemates and a lack of measurable progress for months or years at a time; such delays benefit the agendas of water and power interests.

The organizational structure of the GCD-AMP appears well-planned, but a critical problem that hampers environmental successes is a lack of scientific expertise at all levels. Representatives of TWG and AMWG are largely administrators who are far removed from science. The National Research Council has made several unheeded recommendations to GCMRC for an outside senior scientist to serve as an advisory and interpretive liaison between the science work groups and the secretary of the interior (National Research Council 1999). In addition, GCMRC administrators do not recruit outside objective researchers, but instead use their own agency technicians for research projects—a continuing problem from the GCES era. The National Research Council has also identified conflicts within GCMRC in executing its role of science coordination versus expending considerable effort performing administrative tasks requested by AMP stakeholders.

The GCD-AMP has not attained an integrated ecosystem approach to Colorado River scientific research. In reality, the program appears to be following the historical pattern, with physical resources, especially sediment retention, continuing to dominate research funding and effort over biological and cultural studies (Fritzinger et al. 2001). Sediment loss, movement, and retention remain primary investigation objectives, despite the fact that no data exist to show a positive relationship between biological resources and the amount of sediment in or along the river. The impacts of Glen Canyon Dam encompass a wide range of interconnected biological and ecological effects, yet biological research since the inception of this program in 1997 remains unfocused and single-species directed.

To its credit the AMP has taken on a complex, controversial task and at least posits the need for a worldwide river-resource-management plan. Although the concept of adaptive management is good, adaptive-management programs of the past have been criticized for being all talk and no action and for failing to change management policies (Moir and Block 2001). A major drawback is the anticipation of quick environmental fixes, an unrealistic hope that leads to a loss of commitment, effort, and funding to continue long-term studies to truly understand the ecosystem (Hardin 1985).

Recent events indicate that the public is once again awakening to the issues. A missing link in the GCD-AMP identified by the National Research Council was public outreach and education (National Research Council 1999). The AMP finally added public outreach to its 2002 Monitoring and Research Plan (Fritzinger et al. 2001). In addition, since 1997, environmental organizations have been informing the public of their views of GCD-AMP progress toward compliance with the Grand Canyon Protection Act. Several prominent environmental groups, including the Center for Biological Diversity, Living Rivers, Sierra Club, and Audubon Society, joined in an early 2002 effort to pressure the AMP to show progress in their charge to protect the Grand Canyon ecosystem (Living Rivers 2002). Although the AMWG voted not to acknowledge receipt of the written challenge (per David Orr, Living Rivers), a revised AMP operational plan complete with a series of experimental flows and nonnative fish eradication efforts was announced to the public several months later. Perhaps through the combined efforts of long-term science and an involved society, future management decisions and legislation will reflect human values as well as protect our natural treasures great and small while they still exist.

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