The Colorado River Workshop
issues, ideas, and directions

THE ROLE OF SCIENCE IN COLORADO RIVER MANAGEMENT

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THE PROBLEM

No single reach of the Colorado River system, nor the system in its entirety, can possibly meet all the demands (often mutually exclusive) made upon it. The seven Colorado River Basin states and Native American interests compete for water allocations; water diversion projects reduce instream flow; hydropower producers manipulate discharge in response to demand; dams turn flowing water into lakes, trap sediment, and cool downstream water temperatures in the interest of water storage and power production; and sportfishery managers stock nonnative fish species in the man-made lakes and in the cold, clear waters of the transformed rivers. In direct opposition, environmental advocates fight for the preservation of natural river ecosystems (free-flowing, sediment-laden, variable-temperature rivers devoid of nonnative species) where they still exist, and the restoration of such ecosystems where they have been destroyed. Environmentalists are aided in this struggle—and consumptive use is obstructed—by the very costly clout of the Endangered Species Act of 1973. Every interest cannot have its way. Choices must be made. Choices will be made. The problem before us is how this will be done.

The Colorado River system, from its myriad headwaters to the now mostly dry Mexican delta, is one of the most highly regulated, politically controversial, and ecologically altered river systems in the world. With the passage of time, the competing human demands on the Colorado River and its tributaries have grown in complexity and magnitude. Management of this system has often been characterized (and handicapped) by competition and conflict—first, just among the many consumptive users of riverine resources, and more recently, between consumptive users, environmental advocates, and recreationists. In the last 20 years, the single most powerful element in Colorado River management decisions has been the enforcement of the Endangered Species Act (ESA) of 1973, particularly as applied to the preservation and recovery of listed[1] native fish species. But the influence of the ESA may be short lived, because, as its power has grown, so has its attendant social, economic, and political costs. As a result, the level of dissension over Colorado River system management has escalated; pressure to revise, weaken, or even eliminate the ESA has increased; and the direction of future management decisions remains unclear.

No single reach of the Colorado River system, nor the system in its entirety, can possibly meet all the demands (often mutually exclusive) made upon it. Choices must be made. Choices *will* be made. The problem before us is how this will be done. Our options lie along several continuums. One continuum measures the degree of cooperation that will take place among various interests and jurisdictions. Another measures the degree to which choices will be directed by conscious public policy. Yet another measures the competency and wisdom of these choices in light of long-term human needs. This last continuum relates directly to the central theme of this paper: the role of science in Colorado River management.

Our discussion of where Colorado River Basin management is today and where the process might go in the future is based on the following assumptions:

A. *The use of science in Colorado River management has always been driven by social values and socioeconomic and political pressures. This will continue to be the case in the future.*

B. *The role of science in Colorado River management is to better illuminate the arena in which changing social forces operate, thereby facilitating well-informed decisions.*

C. *Neither society in general, nor the scientific community, nor agency personnel currently have a coherent vision to guide river management into the future. Special interest groups may have such visions, but their objectives are by definition narrowly focused, and the vision of one group is often at odds with that of another.*

D. *An integrated, basinwide, long-term vision of what society wants the Colorado River system to be is needed to develop an overarching management philosophy that will minimize conflict among divergent interests and best serve the public good. A holistic view of Colorado River Basin management would acknowledge that the river system has been forever altered and that power and water projects are an integral part of that system. It would also acknowledge that, in the long term, economic stability within human societies is dependent upon sustainable ecosystems.*

E. *A long-term vision and concomitant management philosophy should be based on sound scientific knowledge of how the physical and biological components of the Colorado River system function and interrelate.*

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F. *To most effectively realize long-term goals, evolving management strategies should incorporate scientific processes in a continuous, dynamic, feedback relationship. The widely accepted term for such a relationship is "adaptive management."*

How can the role of science in Colorado River Basin management be intelligently discussed given the ambiguities of larger social, economic, and political forces? Good question. We suggest that those concerned about this issue first step back and play the critic. Try to answer the following questions about recent scientific work in the Colorado River system:

- What has society received for an investment in scientific research and monitoring that now exceeds $60 million?
- What has been accomplished?
- What have been the benefits and to whom?
- What have been the trade-offs and indirect costs?
- Have the resources expended on scientific work been used effectively, and have research opportunities been defined and pursued wisely?

Then look to the future and consider the following questions:

- Should the public continue to support scientific work in the Colorado River Basin? If so, to meet what objectives?
- To what degree is Basinwide coordination of management and scientific efforts necessary, desirable, or possible? Is it possible for society to reach a consensus on what the Colorado River system should look like in the foreseeable and long-term future?
- How should science relate to ongoing management? How should priorities be set and by whom? Who should direct, fund, and perform the work?
- How do we determine if and when the work (e.g., species recovery) is a) completed or b) abandoned as impossible? Should there be a "sunset clause" on expenditures in endangered species recovery programs?

Suggesting possible answers to all these questions is beyond the scope of this paper; we are simply presenting the questions as a framework for consideration and debate. To aid the discussion, we organized the paper as follows. First we explore some of the conceptual underpinnings of the problem, specifically the relationship of science, social values, socioeconomic and political pressures, and resources management. We then sketch the historical evolution of this relationship in the Colorado River Basin leading up to the existing situation and provide some examples. We end by looking at some options for the future, focusing on the concept of adaptive management and on the possibilities offered by a basinwide scientific perspective, particularly as it relates to recovery possibilities for the system's endangered native fish.

RELATIONSHIP OF SCIENCE, SOCIAL VALUES, SOCIOECONOMIC AND POLITICAL PRESSURES, AND RESOURCES MANAGEMENT

Assumption A: *The use of science in Colorado River management has always been driven by social values and socioeconomic and political pressures. This will continue to be the case in the future.*

Today it is convenient for contending parties to blame the failure to establish basinwide economic and ecological goals on insufficient scientific understanding of system components and interactions. While sound and compatible economic and ecological goals must be based on good scientific knowledge, science has never governed how human societies have chosen to manage natural resources. Rather, science has served (or been used to justify) the objectives of larger socioeconomic and political forces. These forces, in turn, have been functions of changing social values. The extent to which growing knowledge about how our ecosystem works can influence social values and associated socioeconomic and political forces is an open question.

Assumption B: *The role of science is to better illuminate the environment in which changing social forces operate.*

Scientific work can be seen as a process of illumination; it casts a light on the world around us so that we can better "see," or understand, our environment and ourselves. How we go about casting that light and what we do with the information revealed is variable and depends on a plethora of limiting factors that fall outside the realm of science.

HISTORICAL PERSPECTIVES ON COLORADO RIVER MANAGEMENT

MAKING THE DESERT BLOOM

For most of this century, development of water and power resources monopolized management decisions. Decisions affecting the region were forged from the communally held belief that arid lands have no intrinsic value and making the "desert bloom" is an incontestable social goal. Proponents of Colorado River Basin water development encouraged the assumption that land and water were in unlimited supply. From the earliest scientific exploration of the region with the historic river-trips of John Wesley Powell, major water projects, especially irrigation projects, were seen as prerequisites to significant settlement. Interestingly, Powell, a principal force behind the founding of the Bureau of Reclamation (Reclamation), as early as 1878 advocated treating aridland water development differently from the approaches used in the eastern United States. In 1893, he made the following prophetic statement to a most unreceptive audience:

> *Gentlemen, it may be unpleasant for me to give you these facts. I hesitated a good deal but finally concluded to do so. I tell you gentlemen, you are piling up a heritage of conflict and litigation over water rights, for there is not sufficient water to supply the land.*
>
> —John Wesley Powell to the National Irrigation Congress, Los Angeles, 1893

Powell's concept of organizing development of the West into specific watersheds and his recognition that both land and water were in limited supply were ignored almost from the start. But even Powell, with his warnings about the limited potential and vulnerability of arid land, had no concept of the pressures that ultimately would be put on water resources in the Colorado River Basin or of the resulting effect that development would have on its natural ecological communities.

Significant alteration of the Colorado River drainage ecosystems began in 1892 with construction of the 16.7-mile Colorado Rocky Mountain Grand Ditch, a hand-dug water conveyance designed to transfer water across the Continental Divide. In 1928, with the enactment of the Boulder Canyon Project Act (authorization for Hoover Dam), a program that would eventually lead to major changes in Colorado River ecosystems was launched. Legislative mandates which would inadvertently lead to what are essentially permanent changes in riverine environments reached their pinnacle in 1956 with the enactment of the Colorado River Storage Project (CRSP) Act. Triumphantly hailed as a victory of mankind over nature, the CRSP Act proved

to be an unwitting, but clear prescription for the reduction, and in some cases, removal, of the Colorado River Basin's native fishes and their habitats.

ERA OF THE ENVIRONMENTAL ETHIC

As the socioeconomic environment of the western United States changed from the budding growth of the 1930s to the continued development and near-full utilization of land and water resources that exist today, environmental conflicts and questions relating to the long-term ecological health of the region have increasingly demanded attention and resolution. Resource management and the role of science in this evolving socioeconomic and political context have changed as well.

Concern for environmental protection in this country was expressed by a few citizens as early as the late 1800s when the passenger pigeon (*Ectopistes migratorius*) was hunted into extinction. Early efforts to stem the destruction of habitats and wildlife were evidenced in federal legislation like the River and Harbors Act (1899), and sporadic efforts continued through the first half of the twentieth century; most notably the Fish and Wildlife Coordination Act in 1934 (amended and strengthened in 1958). For the most part, however, the assumption that natural resources are limitless and exist solely for human exploitation permeated American social values and dominated management strategies into the second half of this century. Concern for deteriorating natural habitats, wildlife, and other environmental resources did not receive broad public attention and an effective constituency until well into the 1960s. Beginning then, the United States Congress responded to shifting public values by passing four pieces of environmental legislation: the Wilderness Act (1964), Wild and Scenic Rivers Act (1968), National Environmental Policy Act (1969), and Clean Water Act (1972). The legislative mandates in these laws clearly had a positive impact on environmental conditions, but they were especially instrumental in sharpening the focus of public awareness on disruptions in the nation's natural resource base.

This was particularly true for rapidly declining, high-profile species (e.g., grizzly bear, bald eagle, peregrine falcon, California condor etc.). In 1973, Congress made a national commitment to protect and recover all endangered species in the United States by passing the Endangered Species Act (ESA). Their intention is stated in Section 2(b):

> *The purposes of this Act are to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved, to provide a program for the conservation of such endangered species and threatened species, and to take such steps as may be appropriate to achieve the purposes of the treaties and conventions set forth in subsection (a) of this section...*

Subsection (a) cited above references a variety of international treaties all pledging to protect wildlife and habitats. One of the more interesting provisions of the Act, Section 2(c)(2), is directly pertinent to Colorado River Basin water development projects:

> *It is further declared to be the policy of Congress that Federal Agencies shall cooperate with State and local agencies to resolve water resource issues in concert with conservation of endangered species.*

As a result of these changing social values and the consequent political actions, federal management policy and practices in the Colorado River Basin changed as well. Agencies could no longer manage almost exclusively for water use, hydropower production, and sportfisheries. They had to take into account the impacts of their actions on the environment (per the National Environmental Policy Act [NEPA]), especially on listed species (per the ESA). These compliance needs opened the door to a far more active role for scientific investigation.

THE CHANGING ROLE OF SCIENCE IN THE COLORADO RIVER BASIN REFLECTS CHANGING SOCIAL VALUES AND THE EVOLUTION OF MANAGEMENT ISSUES

SCIENCE USED TO IMPLEMENT ALREADY-CONCEIVED MANAGEMENT STRATEGIES

From the earliest stages of Colorado River Basin development to the implementation of the CRSP Act in the 1960s, science served as the handmaiden of water and hydroelectric power projects. Its function was to help implement already-conceived management strategies. Scientists were asked to provide specific, limited-vision responses to narrowly framed questions. For example, dam builders would need information about a potential damsite that only geologists could provide: Is this rock structurally sound? How much water from a proposed reservoir would be lost through cracks or by absorption? What would happen if the rock becomes saturated? What are the chances of an earthquake occurring?

The illumination provided by scientific inquiry of this nature tended to be a narrow, sharply focused beam, revealing little about the interconnectedness of natural processes. As a result, management actions often resulted in unanticipated consequences. Searching for remedies would then dictate new narrowly framed questions, and the cycle would repeat itself. Both managers and scientists found themselves operating in a reactive mode. This pattern tended to reinforce short-term management strategies.

A TALE OF UNANTICIPATED CONSEQUENCES

The story of unanticipated consequences and reactive management decisions in the Colorado River Basin is long and convoluted. Note, for example, one series of events related to the construction of Hoover Dam.

During the 1930s, when Hoover Dam was built, the unchallenged social ethic toward a natural resource like the Colorado River was to harness and utilize it. States were competing for water to develop agricultural industries and support burgeoning urban growth. Communities on the Lower Colorado River wanted a flood control structure upstream, developing cities and towns wanted a source of electrical power, and recreationists wanted a lake for water-related activities (including fishing). For decades after construction of the dam, fisheries biologists working for state agencies diligently stocked Lake Mead with many nonnative species of sportfish and, indeed, the lake became a successful fishery.

Managers realized their immediate objectives, but over the years they have had to deal with several unexpected developments as well. For example, as the reservoir filled, it became apparent that it was silting in at a totally unpredicted rate. Sedimentologists were called in to study the situation, and they determined that the life expectancy of Lake Mead could be as short as two hundred years. Alarmed, river managers turned their attention toward prolonging the life of the reservoir by building a sediment trap upstream, thus adding impetus for the authorization and construction of Glen Canyon Dam. (Of course, Glen Canyon Dam and other components of the Colorado River Storage Project were already under consideration for altogether different reasons.)

Building the second dam did indeed slow sediment accumulation in Lake Mead, but it also contributed to another management problem in Lake Mead. By the late 1970s, wildlife managers were aware that Lake Mead's sportfishery was in steep decline. Academic biologists called in to study the situation determined that the problem stemmed from low levels of phosphorus and nitrogen (vital nutrients) in the lake. The problem was primarily a consequence of the natural "aging" of Lake Mead, but was exacerbated by a reduction of nutrient inflow due to presence of Glen Canyon Dam upstream. Eventually, the sportfishery was improved by the artificial introduction of phosphorus.

But managing Lake Mead for sportfishing has itself contributed to a different kind of management problem upstream in the Grand Canyon. The Lake was stocked with nonnative species of fish, some of which have seriously contributed to the decline of native fish species by competition and predation. Today, fisheries biologists and managers working on the Colorado River in Grand Canyon watch with dismay as nonnative fish predators from Lake Mead advance upstream, seemingly farther and farther each year. Voracious picivores, like striped bass present a threat to the Little Colorado River population of humpback chub, the largest population of this endangered native fish remaining in existence. Preserving and recovering listed native species like the humpback chub is currently one of the highest management priorities in the Colorado River system.

Perhaps the best known example of an unanticipated consequence of a management action was the transformation of the Colorado River ecosystem in Grand Canyon that resulted from the construction of Glen Canyon Dam. The dam was authorized and built without any thought given to its effects on the environment of the national park downstream, even though the park had been created in 1919 precisely to preserve that environment. The complexity of changes wrought in the Grand Canyon and their consequences for riparian and aquatic resources over the short and the long term are just beginning to be understood. We do know that the legacy left by the action of building that dam in a scientific vacuum has resulted in the resources conflicts we struggle with today.

CLEANSING THE GREEN RIVER OF TRASH FISH

The most stunning example of a short-sighted use of science in the service of a limited management goal in the Colorado River system took place on the Green River in 1962. The actions that occurred that year epitomize the lack of understanding early wildlife managers had for the concepts of systems ecology and the consequences their actions would have on populations of endemic[2] species.

A phenomenon that seems astonishing to us today was common practice just three decades ago. Managers and biologists collaborated to "improve" (a value judgment, not a scientific designation) fisheries by eliminating native species and introducing man-preferred, nonnative species. In the Colorado River Basin, preferred species were usually trout, but the legacy of basinwide introductions includes catfish, carp, and striped bass (all predators on young fish and eggs) and a host of tiny "baitfish," now infamous for their ability, once present in a system, to frustrate attempts to reintroduce or recover declining native species.

The pervasiveness of management's early assault on the native fish of the Colorado River Basin was frighteningly sophisticated. From 1952 to 1962, the U.S. Bureau of Sport Fisheries Wildlife (later renamed U.S.

[2] *Endemic species are those that evolve in a specific area and are found nowhere else in nature.*

Fish and Wildlife Service), in conjunction with the state wildlife management agencies of Wyoming, Colorado, New Mexico, Utah, and Arizona, aggressively fostered a program of poisoning streams. Their published intention was to remove all the native "trash" fish and then restock "cleansed" streams with "desirable" species. Implementation of the management decision to remove native fishes was aided by the best available scientific information on how to eliminate fish, but science was not asked to determine the short- or long-term consequences of fish elimination measures on the larger ecosystem.

This program reached its apogee in a concerted effort to eliminate native fish from vast stretches of the Green River and its tributaries. From September 4 through 8, 1962, over one hundred men, positioned at strategic locations throughout more than 500 miles of the Green River drainage, dumped 20,000 gallons of a poison, rotenone,[3] into the river and its tributaries. The poison was applied simultaneously at dozens of streamside locations in Wyoming, Utah, and Colorado in order to subject the 500-mile stretch of river and its tributaries to a continuous flow of water containing a lethal concentration of poison for no less than seventy-two hours. To ensure the desired effect, officials applied the poison in concentrations four to five times the dilution known to kill the most resistant of species. Given the magnitude of direct reduction efforts, combined with Colorado River Basin development, it is a wonder any of these "trash" fish persist today, even as endangered species.

While some fisheries scientists supported this action, and even participated in it, many did not. A group led by Dr. Robert Rush Miller and Carl Leavitt Hubbs, who had studied fishes of the Colorado River Basin for many years, fought to stop the project but failed. They were successful, however, in bringing scientific and political attention to the plight of native fish that were already beginning to decline in Colorado River Basin habitats. There is no question that the efforts of Miller and Hubbs and their supporters in the scientific community, particularly the American Society of Ichthyologists and Herpetologists, were instrumental in focusing the Nation's interest on the fact that native species were declining.

In the above examples, the traditional management approach and the role of science in that approach are evident. Federal and state management agencies *knew* that building Hoover Dam was a good thing to do; all they needed scientists for was to tell them where and how to build it. Later on, managers *knew* that slowing silt accumulation in Lake Mead was a good thing to do; all they needed scientists for was to tell them how severe the problem was and how to solve it. The same was true for building Glen Canyon Dam and for establishing a sportfishery in Lake Mead. Scientists were employed to help managers implement policies that arose from socioeconomic and political goals by providing specific technical solutions to immediate problems. They were not asked to predict possible short- and long-term consequences of management actions over a broad, interconnected system.

SCIENCE USED TO HELP DEVELOP MANAGEMENT STRATEGIES

Today, the demand for scientific studies is driven primarily by the desire to reverse, or at least slow or stop, the trend of degrading "natural" ecological communities and dwindling endangered species populations.

[3] *Rotenone is a powerful toxic chemical that acts by interfering with gill functions. When fish are subjected to water containing even minute amounts of rotenone, death by suffocation results.*

Scientific processes are increasingly being used in the Colorado River Basin to illuminate the components and workings of biological, physical, and chemical processes of ecosystems, which are much more complex than previously imagined.

This came about because managers and private stakeholders, when faced with the need to understand the consequences of particular actions on highly complex ecosystems, quickly realized that they knew little about these systems and how their components interact. They found themselves turning to the scientific community for information on a vastly wider scale. Gone was the "flashlight" approach, where scientists were asked to cast a limited, sharply focused beam to find specific answers to narrowly defined questions. Instead, the trend has been toward a "floodlight" approach, where interdisciplinary teams of scientists are asked to design scientific inquiries that illuminate large segments of ecosystems. This approach allows scientists and managers to better predict the effects of management actions, thus reducing the likelihood of unanticipated and undesirable consequences. As a result, scientists have more control over framing future scientific questions, and managers are able to plan strategies that more effectively achieve their objectives. The most significant outcome of this change is the increasing use of science to help *develop* management strategies, rather than just *implement* them.

The dominant example of intensively involving scientific research in Colorado River Basin management is Reclamation's Glen Canyon Environmental Studies (GCES). Their investigations began in 1982 with studies to evaluate the influence of the operation of Glen Canyon Dam on downstream natural components and recreational resources in Glen and Grand Canyons. Eventually, their scope of interest broadened to include archaeology and economics. Divided into two phases, the first from 1982 to 1987 and the second from 1988 to 1995, the studies coordinated and integrated research projects conducted by several federal and state agencies, universities, Native American groups, and private consultants. The result has been seminal scientific work in the fields of sedimentology, geomorphology, hydrology, limnology, and aquatic and riparian ecology. Information derived from these studies eventually influenced the passage of the Grand Canyon Protection Act (1992) and the EIS for the operation of Glen Canyon Dam (GCDEIS) (1995). During the second phase of their studies, from 1988 to 1995, GCES coordinated all the scientific studies needed for the GCDEIS to evaluate the environmental changes resulting from alterations in river flow.

While a large proportion of scientific studies in the Colorado River system have related to the effects of Glen Canyon Dam water releases on riverine components and processes and cultural elements in Grand Canyon National Park, scientific studies are underway in many locations throughout the Upper and Lower Colorado River Basins. With few exceptions, this work has been spawned by legislative imperative. Most studies have related to efforts to comply on a project-by-project basis with provisions of NEPA and the ESA. As a result, both the management objectives and the accompanying scientific work have tended to be fragmented. Fragmentation, in turn, results in gaps in knowledge; an incomplete understanding of how ecological components relate; and a failure to identify overall patterns, interactive processes, and system linkages. It also leads to redundancy, inefficiency, and (at times) conflict in management and scientific efforts.

There remains to be an overall acceptance of resource management approaches that address the whole rather than isolated parts (e.g., an emphasis on ecosystems rather than on individual endangered species).

However, many interests throughout the Colorado River Basin, from federal and state resource managers to private stakeholders in the water and power industries and in environmental organizations, are realizing the benefits of a more holistic, cooperative, basinwide approach to river management. Unfortunately, the realities of contending objectives and the legal constraints imposed by the "Law of the River[4]" and by environmental legislation present formidable obstacles to basinwide cooperation.

COLLISION OF FORCES IN THE COLORADO RIVER BASIN

THE CRSP ACT VS. THE ESA

Inevitably, strategies developed to manage segments of the Colorado River system for NEPA and ESA compliance collided with traditional water and hydropower projects. Today, the overriding management issue in the Colorado River Basin is the conflict between the consumptive uses of riverine elements and the protection of these elements, with emphasis on the preservation and recovery of listed species, particularly endangered native fish.[5]

The basis for the conflict between these forces is apparent if we look at the provisions of the Colorado River Storage Project (CRSP) Act of 1956 in light of current knowledge about the habitat requirements of native fish in the Colorado River system. The CRSP Act can be read as a formula for dramatically changing aquatic habitat. Consider that the project was authorized:

> *...for the purposes, among others, of regulating the flow of the Colorado River, storing water for beneficial consumptive use, making it possible for the States of the Upper Basin to utilize, consistently with the provisions of the Colorado River Compact, the apportionments made to and among them in the Colorado River Compact and the Upper Colorado River Basin Compact, respectively, providing for reclamation of arid and semiarid land, for the control of floods, and for the generation of hydroelectric power, as an incident of the forgoing purposes...*[emphasis added]

In the last few decades, biological and physical scientists have empirically documented the ways that riverine ecosystems, both large and small, have been altered to the extent that they are no longer suitable as habitat for native species. In large part, much of the scientific data on this issue has become available by simply monitoring the changes in rivers and streams resulting from Colorado River Basin development. Today, we know that if one were to make a deliberate attempt to remove fish habitat from an existing aquatic ecosystem, the most effective techniques would be to:

Regulate Flow and Control Floods, especially by removing annual cycles of river rise and fall. Throughout the Colorado River system, flow regulation has restricted formation of backwater habitats, used by fishes as important nursery areas; altered patterns of nutrient inflow; and interrupted or skewed reproductive cycles in fish.

Store Water behind dams. Dams create lakes from streams, and fishes that have evolved in stream environments, like the native species of the Colorado River system, do not reproduce or survive as well[6] in lakes. Therefore, stretches of river that have been converted to reservoirs no longer support some species of native fish. Aquatic habitats downstream of reservoirs, below dams, are altered as well. Because water released through dams like Glen Canyon is drawn from cold layers deep below the reservoir surface, its temperatures are far colder throughout most of the year and less seasonally variable than was true of predam flows. The implications for native fish are profound, primarily because their reproductive cycles, an evolutionary adaptation, are triggered by temperature changes from one season to the next. As a case in point, native fish can no longer successfully reproduce in the mainstem of the Colorado River below Glen Canyon Dam because water temperature is too low. Colorado River Basin water storage projects also have altered the distribution of sediment and nutrients in the river system, trapping large percentages of both in reservoirs. The native fishes of the Colorado River system evolved in an aquatic environment of high volumes of suspended sediments and dynamic patterns of deposition and erosion in both the riverbeds and channel margins. Their feeding and defensive behaviors and habitat requirements at different life stages are very much tied to predam sediment conditions. And needless to say, the depletion of vital nutrients below dams can have catastrophic effects on fish growth, reproductive potential, health, and, ultimately, survival.

Utilize Water by diverting it from natural stream and river channels for agricultural and municipal water uses. The actual wetted perimeter of a stream usually exerts strong control on fish population size. The extreme impact of dewatering is evidenced in the Lower Colorado River Basin below Laguna Dam to the international boundary; where native fishes were once abundant, the river is now mostly dry.

Reclaim Aridland. "Reclaiming" aridland, or making it more useful for human needs, has primarily meant transporting water through irrigation systems to land previously unsuitable for agriculture or for raising particular high-value crops. In addition to the inherent impacts of aridland irrigation on the indigenous terrestrial flora and fauna adapted to the aridland, and the impacts of dewatering as mentioned above, irrigation projects have an impact on water quality. Once the water has irrigated crops and cycled back into the river or watertable, the water quality usually declines, generally because of high concentrations of salts leached from the soil. High concentrations of metals and irrigation-related pesticides are a problems as well. The degraded quality of Colorado River water is not only detrimental for aquatic wildlife, but for consuming humans as well.

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[4] *The Law of the River is an informal designation for the body of laws, court decrees, treaty obligations, and contracts that govern water rights and uses of the Colorado River.*

[5] *It may seem that the emphasis placed here on native fish populations is misplaced, and that we should be focusing on the ecosystem as a whole and its interrelatedness to quantifiable changes in the independent variables of river flow, temperature, sediment transport, channel geometry, turbidity, etc. However, legislation does not exist which specifically operates to protect, restore, or enhance ecosystems. On the other hand, legislation does exist, the ESA, to protect species, and thus, by inference, the ecosystems within which they live. So, scientists and managers alike tend to focus on the condition, distribution, and population trends of species. A more appropriate paradigm for the future will be to focus on the restoration and protection of endangered ecosystems*

[6] *Impacts of reservoirs on native species of fish are species-dependent, and not all fishes of lotic (moving water) origin find lentic (standing water) habitats inimical to their survival. For example, razorback suckers and bonytails reproduce in Lake Mohave, but are thwarted in recruitment by predation by sunfish, carp, and catfish. Archaeological evidence and direct observations of the Salton Sea filling after the turn of the century also indicate that some big river fishes can live in lentic environments.*

Generate Hydroelectric Power. At its extreme, hydropower production can compress into one day, and sometimes one-half day, the total discharge variation normally experienced by the redevelopment stream or river in a year. Daily fluctuations in discharge caused by changing power demands can destabilize nearshore environments where young-of-the-year fishes seek protection from predation and swift currents. Daily fluctuations in flow can also preclude establishment of nearshore vegetation, a source of cover and food for aquatic life in redevelopment systems.

Thus, development of basin water resources, by definition, has been inimical to maintenance of habitats required by native aquatic species. This is not to imply that such development has been the sole cause of native fish population declines in the Colorado River system over the last 100 years. On the contrary; many fisheries biologists believe that competition and predation on native fish by nonnative species constitutes the single most important threat to endangered species recovery throughout the Basin. Early introductions of nonnative species around the turn-of-the-century had a catastrophic effect on endemic species, and, more recently, managing the newly created reservoir and tailwater habitats for sportfishing by introducing non-native fish species has aggravated the problem. Some estimates of the comparative biomass of native vs. non-native fishes within the Colorado River Basin are in the range of 10% vs. 90%, respectively. The relative harm caused by habitat alteration as opposed to competition and predation pressures from introduced fish species is not fully understood, but it is abundantly clear that the two factors are interrelated. Together they have had a significant effect on the fish species that evolved in the Colorado River system—fish species that, for the most part, are found nowhere else.

THE STATUS OF NATIVE FISH POPULATIONS

Of fewer than a dozen fishes known to have originally inhabited the mainstem Colorado River from Wyoming to Mexico, four have been federally listed as endangered: Colorado squawfish (*Ptychocheilus lucius*), bonytail (*Gila elegans*), humpback chub (*G. cypha*), and razorback sucker (*Xyrauchen texanus*). At least three additional species are either being considered for listing or have been extirpated over much of their former range: Flannelmouth sucker (*Catostomus latipinnis*), bluehead sucker (*C. discobolus*), and roundtail chub (*G. robusta*).

- Colorado squawfish are extirpated from the Lower Colorado River Basin, but small populations do remain in the Colorado, Gunnison, Dolores, Green, Yampa, White, and San Juan Rivers of the Upper Basin.

- Razorback suckers are found in moderate numbers in the Lower Basin in Lakes Mead and Havasu, and a few individuals may remain in the Colorado River in Grand Canyon. The largest and apparently only reproducing population in the entire Colorado River Basin lives in Lake Mohave. Razorback suckers continue to be found in small numbers in the Upper Basin in the Colorado, Gunnison, Green, Yampa, and San Juan Rivers.

- Bonytails appear to be hovering on the verge of extinction, with fewer than 50 individuals recovered from throughout the Colorado River Basin between the mid-1970s and 1988. Very few individuals have been captured since then, and this species does not appear to be reproducing outside of hatcheries. The largest concentration of bonytails, composed of a few individuals, occurs in Lake Mohave.

- Humpback chub exist in six populations throughout the Colorado River Basin, with the largest population centered in the Little Colorado River (LCR) and in the Colorado River near its confluence with the LCR. This is a healthy, self-sustaining population. The five remaining populations are much smaller and are found in the Upper Basin in the Colorado, Green, and Yampa Rivers.

Native fisheries in tributaries and in isolated springs have also declined dramatically throughout the Basin. One species in particular, the speckled dace (*Rhinichthys osculus*), has fared relatively well in smaller tributaries, but mainstream populations of the speckled dace are thought to be less abundant and more fragmented than they once were.

NEPA AND ESA COMPLIANCE IN THE COLORADO RIVER BASIN

Glen Canyon Dam Environmental Impact Statement. The collision between conservation and development interests in the Colorado River Basin has recently been exemplified in the Glen Canyon Dam Environmental Impact Statement (GCDEIS)[7]. The GCDEIS, released in March 1995, represents a compromise between dramatically opposing beliefs on how the river should be managed. To effect this compromise, Reclamation (the EIS lead agency) assembled a committee of cooperating agencies composed of representatives of several federal and state management agencies, power users, Native American groups, and environmental organizations. This committee administratively advised the EIS Team and reviewed their work. After two years of often contentious debate, the EIS Team developed a compromise preferred alternative for operation of the dam that called for a release regime of low fluctuating flows. The compromise was between seasonally adjusted steady flows (advocated by environmental groups and the U.S. Fish and Wildlife Service [USFWS]) and high fluctuating flows (advocated by power user groups and the U.S. Western Area Power Administration). All but one cooperating agency agreed to the compromise. The dissenting agency was the USFWS, which subsequently issued a jeopardy ruling on the preferred alternative in their draft biological opinion. Eventually, Reclamation and the USFWS reached a final compromise position that incorporated experimental steady flows into a low fluctuating flow regime under the umbrella of "adaptive management." (We will say more about this later.)

Two lessons stand out in this example. The first is the potency of the ESA, even in the context of a NEPA deliberation. The crux of the entire NEPA process and the basis of the final conflict over selection of a preferred alternative was how water releases were thought to affect endangered fishes in Glen and Grand Canyons. Effects on all other elements of the riverine ecosystem analyzed in the GCDEIS, including power generation and costs, assumed a subordinate role. The second lesson is that—despite a gargantuan effort to reach consensus, an effort that involved a cast of hundreds, cost several millions of dollars, and extended over five years—no constituency has been entirely pleased with the outcome. Members of the environmental community believe the compromise (the preferred alternative) to be too little, too late, and water and power users believe that the compromise unnecessarily restricts hydropower production flexibility. And, last but not least, the USFWS still believes it will ultimately get seasonally adjusted steady flows.

Implementation of Recovery Plans for Endangered Fish Species in the Upper Basin. The GCDEIS is just one instance of the clash between water and power

[7] *An environmental impact statement (EIS) is a form of NEPA compliance*

development and the ESA. Concern for endangered fishes is also the most troublesome and costly issue for river managers in the Upper Colorado River Basin. In that region, attempts to comply with the ESA as efficiently as possible have taken the form of recovery implementation programs (RIPS), which are cooperative efforts led by the USFWS to allow development to move forward where endangered species conflicts either exist, or are perceived to exist, while providing elements of conservation for listed species. The ideal result of a RIP is to achieve healthy, self-sustaining populations of endangered fish species, thereby causing them to be removed them from federal and state lists of threatened and endangered species. Water users support the concept of RIPS because removing species from the endangered list would remove today's single greatest hindrance to water project development.

Two RIPS are currently underway in the Upper Basin. Both plans use a determination of sufficient progress toward species recovery to evaluate and permit development activities. The first of these RIPS, the *Recovery Implementation Program for Endangered Fish Species in the Upper Colorado River Basin*, was formally established in 1988 as a way to comply with the ESA while proceeding with appropriate water project development. In the years immediately prior to establishing the RIP, development in the Upper Basin was entwined in a mesh of individual and controversial ESA Section 7 consultations with the USFWS (33 between 1981 and 1985). This RIP, which serves as the reasonable and prudent alternative for water development activities, is based on a cooperative agreement between the States of Colorado, Utah, and Wyoming, the Department of the Interior, and the Western Area Power Administration. Several other stakeholders in the Upper Basin participate in the program as well. Voting by consensus; thus a single dissenting vote can derail any particular effort. Estimates of costs to implement the RIP in the 10-year period beginning in 1993 range from $84 to $134 million. A supporting, multidisciplinary science program focuses on propagation and genetics, life history, and habitat of the humpback chub, bonytail, Colorado squawfish, and razorback sucker in the Upper Basin, particularly as they relate to instream flow.

The second RIP, the *San Juan Recovery Implementation Program*, initiated in 1992, grew out of jeopardy opinion issued by the USFWS for the Animas-La Plata project in southwestern Colorado and northwestern New Mexico. This RIP is similar in intent and structure to the Upper Basin RIP. Significant differences do exist, however. The San Juan RIP's focus is restricted to the San Juan River system; it does not serve as the reasonable and prudent alternative for water development activities; a two-thirds majority is required to make a decision; and the program has a specified duration of 15 years. The budget for the San Juan RIP has not been finalized, but annual research and management costs are likely to range from $1.3 to $1.9 million for the life of the program. Habitat restoration projects have not been fully determined; however, approximately 20 million dollars's worth of capital projects have been identified (pers. comm., Jim Brooks USFWS). The scientific research supporting the San Juan RIP has been organized into six categories of investigation: 1) essential research for long-range planning and program goal development; 2) protection of genetic integrity and management, and augmentation of populations; 3) protection, management and augmentation of habitat; 4) water quality protection and enhancement; 5) interactions between native and nonnative fish species; and 6) monitoring and data management. A main emphasis of the research program is to examine and quantify flow and habitat relationships in the San Juan River.

Proposed Lower Basin Habitat Conservation Plan. The Lower Basin states (Arizona, California, and Nevada), casting a wary eye upstream through the Grand Canyon and into the Upper Basin, are conscious of the fact that endangered fishes issues drive river management in those areas. Taking a proactive stance, they have joined forces in a spirit of confederation to address their Colorado River endangered species problems in a way that best accommodates their other river management priorities. Consequently, water, power, and wildlife management interests in those states, both public and private, are exploring the possibility of developing a habitat conservation plan for the Lower Colorado River under Section 10(a) of the ESA. Theoretically, such a plan, if approved by the USFWS, would allow water and power projects to proceed if agreed-upon mitigation measures were in place and those measures continued to meet specified performance criteria. The mitigation measures could take the form of a RIP for the Lower Colorado Basin.

It should be pointed out that very different endangered species management issues exist throughout most of the Lower Basin compared with the Upper Basin. In the former, nearly full development of the basin has taken place (the next major issue will mostly focus on dewatering the mainstem), and the big river fishes are mostly extirpated. Recent efforts have centered around 1) protecting the razorback sucker population in Lake Mohave (by developing grow-out embayments free from predators) and, to a lesser extent, in Lake Mead, and 2) reintroducing the mostly extirpated bonytail.

While discussion of any cooperative ESA compliance action in the Lower Basin is only speculative at this point, impetus for some kind of action was provided by Reclamation's decision in 1994 to conduct a biological assessment of its dam operations on the Lower Colorado River. The biological assessment is part of an ESA Section 7 consultation with the USFWS. Its purpose is to determine if the dam operations are likely to adversely affect listed or proposed species or designated or proposed critical habitat. A finding of adverse affect could result in mandatory changes in the operation of water and power projects.

GROWING PUBLIC RESISTANCE TO THE ESA (KILLING THE GOOSE?)

When the ESA was originally passed in 1973, public support was strong, if not universal. The average citizen probably had endangered animals like bald eagles, song birds, and grizzly bears in mind, not bottom-feeding suckers and snails and the like. The implications of the ESA for ordinary people, their livelihoods, and their personal convenience and comfort (in some cases their very ways of life and aspirations) were not widely apparent. Certainly the enormous monetary costs and broad reaching effects of enforcement were unanticipated.

Once the reality of protecting species and their habitats reached the local level, however, as it has for the past several years within the Colorado River Basin, public support for the ESA dwindled. The NIMBY phenomena ("Not in My Back Yard"), common to new development projects, seems equally pervasive when it comes to environmental preservation. Throughout the Colorado River Basin, resistance to efforts to recover habitats and species is increasing, especially if such efforts conflict with perceived states rights, personal property rights, and financial entitlements granted through the "Law of the River" and historical use.

Part of the problem of declining support for the ESA rests with the fact that the connection between the loss of specific habitats and species and the well-being of individual people and their families is abstract at best and rests primarily in the realm of subjective value judgments. The possible long-term consequences of habitat and species loss to human quality of life are difficult to comprehend, and scientists have not been as effective as they could be in communicating what those consequences might be. It is much easier for the average citizen to grasp and care about the immediate repercussions of a hike in the monthly electric bill or the loss of a job or a business opportunity. The situation is exacerbated by the fact that some environmentalists and agency operatives have been over-zealous in their application and enforcement of the ESA in specific situations. Some agency and consulting biologists have been known to be lax about basing their conclusions on data. As W. Dean Carrier, a wildlife biologist and consultant, points out in his paper "The Killing of the Goose," it is not unheard of for people in authoritative positions to abuse the power bequeathed by the ESA to further agendas quite distinct from species preservation; for example, preventing any or all development in a treasured natural environment—or in their own backyards, for that matter. In the case of some ESA consultations with the USFWS, the mitigation required of a project for species recovery seems punitive in nature, perhaps punishing project proponents for previous development sins with the attitude "you must do something, even if there's no reason to believe it would benefit species recovery." On the other side of the issue, opponents of the ESA have been known to exaggerate, even fabricate, cases of enforcement abuse to further their own agendas. Such stories (the more outrageous the better) play well in the media and have been effective reinforcing negative public opinion.

Also problematic, particularly in the West and especially within the religious right, is the fact that many people believe that development and the consumption of natural resources is a God-given right, even a directive—endangered species be damned. Those holding this view are firmly convinced that the Lord and technology will eventually deliver the righteous, regardless of how spoiled our nest becomes. This is a tough attitude to overcome. It may not even be possible.

The consequence of this mounting public opposition to the ESA and its enforcement is vocal and broad support in Congress for revising the Act when it undergoes deliberation for reauthorization. Many would like to eliminate it or at least destroy its effectiveness. While revisions are needed, loss or emasculation of the ESA could have profound negative repercussions for the endangered fishes of the Colorado River system, their habitat, and any hope we might have of developing a sustainable ecosystem in the Basin.

SUMMARY OF THE STATUS QUO

Assumption C: *Neither society in general, nor the scientific community, nor agency personnel currently have a coherent vision to guide river management into the future. Special interest groups may have such visions, but their objectives are by definition narrowly focused, and the vision of one group is often at odds with that of another.*

We can summarize the current status of science in resource management in the Colorado River Basin in the following terms: 1) Scientific research and monitoring have been on a steep upward trajectory in the last two decades. 2) This work focuses on the components and workings of riverine ecosystems and is driven by the need to comply with environmental legislation (primarily federal). 3) Scientific work related to the protection and recovery of listed species and species proposed for listing has the highest priority because the ESA is the strongest piece of federal environmental legislation. 4) Management programs and the scientific studies that support them, like the Upper Basin RIP and the GCDEIS/GCES, are increasingly cooperative, multidisciplinary, and regional in scope. 5) Despite this trend, the various programs scattered throughout the Basin are largely isolated from one another, resulting in a fragmented and inefficient approach to management from a basinwide perspective. 6) Conflict between environmental legislation compliance requirements (particularly the ESA) and water and power development dominates management activities throughout the Colorado River. 7) This conflict has been enormously costly to both public and private interests. 8) A public backlash against the ESA now threatens its continued existence and/or effectiveness.

OPTIONS

THE GOAL: LONG-TERM ECONOMIC AND ECOLOGICAL STABILITY

Assumption D: *An integrated, basinwide, long-term vision of what society wants the Colorado River system to be is needed to develop an overarching management philosophy that will minimize conflict among divergent interests and best serve the public good. A holistic view of Colorado River Basin management would acknowledge that the river system has been forever altered and that power and water projects are an integral part of that system. It would also acknowledge that, in the long term, economic stability within human societies is dependent upon sustainable ecosystems.*

Economic and ecological stability within a region implies that the human population can extract a portion of the renewable and nonrenewable natural resources without destroying ecosystem processes and/or species. If achieving long-term economic and ecological stability in the Colorado River system is what the American people (specifically, the American electorate) want, we must work together to modify our approach to Colorado River management.

The several constituencies who have interests in the Colorado River System must be willing to cooperate in the never-ending business of balancing management priorities and planning short- and long-term management objectives. This requires a good faith effort to use science objectively without intentional distortion or misrepresentation. Above all, it requires a willingness to explore all possibilities and to accept compromise. We need to acknowledge that nothing is sacrosanct. Not any single endangered species. Not the "Law of the River." Not a narrow, partisan vision of "how it should be."

Management of every component within the Colorado River Basin must be viewed from a basinwide and ecosystem perspective. This is particularly true of endangered fish management. We should consider looking at the Basin as a whole and investing resources in specific reaches that have the highest potential for recovery of a given species. We should consider discontinuing or curtailing sportfishery management practices at some locations. This could mean, for example, concentrating all recovery efforts for the razorback sucker in Lake Mohave and limiting recreational use there. It could also mean giving up all efforts to preserve bonytails in the wild. In short, we should consider all possibilities and make choices based on relative probabilities of success.

Assumption E: *A long-term vision and concomitant management philosophy should be based on sound scientific knowledge of how the physical and biological components of the Colorado River system function and interrelate.*

Scientific information must guide management decisions, and scientifically based processes must be integrated into management systems. Balancing the requirements of sustainable ecosystem structure and function with economic stability means that careful choices and wise compromises must be made. Clearly, this cannot be accomplished in an environment of ignorance and guesswork. Using scientific information to guide decisions applies not only to conservation of natural resources, but to how and why resources are developed and used.

Members of the public, their elected representatives, teachers, media commentators—the whole spectrum of society needs to be able to make informed decisions about how we should collectively address dwindling species and natural habitats. Resource managers do not operate in a political vacuum. Quite the opposite. All efforts to integrate science into management and to balance ecological and development goals are moot if the weight of public sentiment does not support those efforts. This brings us full circle to our original proposition. We maintain that social values drive science, but science can and should inform choices. This is simply another way of saying that successful democracy requires an informed electorate.

ADAPTIVE MANAGEMENT OUR BEST OPTION?

Assumption F. *To most effectively realize long-term goals, evolving management strategies should incorporate scientific processes in a continuous, dynamic, feedback relationship. The widely accepted term for such a relationship is "adaptive management."*

Students of resource management are increasingly promoting the concept of adaptive management. Cindy L. Halbert, in her 1993 article "How Adaptive is Adaptive Management? Implementing Adaptive Management in Washington State and British Columbia," defines adaptive management as an:

> *...innovative technique that uses scientific information to help formulate management strategies in order to 'learn' from programs so that subsequent improvements can be made in formulating both successful policy and improved management programs.*

This approach is characterized by a feedback loop between science and management based on a process of experimentation. Managers must be willing to design and implement management policies and practices as experiments, then measure the results against predictors as predetermined performance criteria. Each "experiment" must test a clearly defined and articulated hypothesis, and managers must be willing to follow through with the experiment, learning from negative as well as positive results. This approach is fluid, directed, and pragmatic and requires a relatively high tolerance for risk and uncertainty. The payoff, theoretically, is that managers and scientists work together to find out what kinds of strategies best accomplish long-term management goals. Halbert reported that adaptive management has worked well in circumscribed management situations where the underlying principles of adaptive management have been understood and conscientiously applied. It has not worked well when program participants have failed to agree on a definition of adaptive management (which appears to be an illusive concept in practice), have failed to identify management goals, or have been unwilling or unable to follow through when they begin to get negative results.

Adaptive management is on trial in the Colorado River Basin. An adaptive management program (AMP) for the operation of Glen Canyon Dam was incorporated into the preferred alternative of the GCDEIS. Although the program cannot formally begin until the Secretary of the Interior signs a Record of Decision for the EIS, a Transition Technical Work Group, largely composed of the GCDEIS Cooperating Agencies, is currently laying the structural foundation. The organization will eventually consist of an advisory/policy group that would ensure coordination between the scientific studies and dam operations, a technical group that would develop research objectives and criteria and standards for long-term monitoring and research, and a monitoring and research center that would actually manage the work

and conduct the synthesis. During the current transition period, the GCES is developing the AMP's first scientifically based experimental programs.

These programs include a short-term, high-flow release from Glen Canyon Dam scheduled for spring 1996. The purpose of this experiment is to gather data on the flows needed to move sand from the river bottom onto the channel margins and its eddies. Managers would like to be able to do this periodically in order to rebuild beaches and reconstruct backwater habitats for endangered fish. The AMP also calls for a multi-year experimental regime of seasonal steady flows so that scientists can study the effects of these flows on backwater habitats and endangered fish. Depending on the results of these experiments, "spike" flood flows and steady flows may or may not be incorporated into the routine operation of Glen Canyon Dam.

The AMP for Glen Canyon Dam will be a good test of the effectiveness of this management approach in the Colorado River Basin. The road will not be a smooth one. When first proposed, the experimental flow experiment ran into heavy opposition from the basin states and power users, who objected to water releases in excess of power plant capacity (33,200 cubic feet per second). They did not remove their threat of litigation until Reclamation, with the support of GCES scientists and the Transition Technical Work Group, agreed to schedule the experimental flow and any subsequent spike flows in high-water years rather than in low-water years as originally planned. This was a compromise between two priorities. One set of constituents (the basin states and power users) were concerned about depleting water from Lake Powell in low-water years. The other set of constituents (natural resource managers in Grand Canyon and scientists) were concerned about potential for negatively influencing downstream riverine elements by releasing too much water in high-water years.

Controversy also surrounds the seasonal steady flow experiments scheduled to begin in 1998. Power users, the Western Area Power Administration, and Reclamation are opposed to steady flows because they are costly in terms of lost power revenues. A hydroelectric power operation is most profitable if it produces electricity on demand by fluctuating the amount of water that runs through the turbines. In fact, everyone agrees that steady flows are an inefficient way to use a hydroelectric power plant. However, some constituencies, notably the USFWS and many environmental groups, believe that seasonal steady flows are beneficial to endangered fish, that fluctuating flows are harmful, and that this concern must take precedence over all others. Whether or not their concern is justified by scientific evidence is vigorously debated. Studies associated with the experimental steady flows are being designed (it is hoped) to provide data that will help clarify the situation. Once managers have more substantive information about the effects of steady flows on endangered fish, they should have a better idea of how to operate the dam for the maximum benefit of endangered fish without incurring unnecessary revenue losses.

Theoretically, adaptive management is an attractive option for management programs throughout the Colorado River Basin, but the concept has proven difficult to put into practice elsewhere, particularly on a large scale. An AMP does provide a forum for the resolution of contending priorities, but it can only work if participants are willing to cooperate, and when necessary, compromise. How effectively it will work in the case of Glen Canyon Dam remains to be seen.

CONCLUSION

Existing scientific data are probably sufficient to describe the advantages of and options for a basin-wide and holistic river management framework. The political and economic forces unleashed in 1922 with the formalization of the Colorado River Compact have, until now, precluded serious discussion of such a plan. The time has come to begin these discussions.

A holistic view of Colorado River Basin management would acknowledge that the river system has been forever altered and that power and water projects are an integral part of that system. It would also acknowledge that, in the long term, economic stability within human societies is dependent on sustainable ecosystems, and we cannot hope to achieve sustainable ecosystems without scientifically based management processes.

SUGGESTED DISCUSSION QUESTIONS

- Should the public continue to support scientific work in the Colorado River Basin? If so, to meet what objectives?
- To what degree is Basinwide coordination of management and scientific efforts necessary, desirable, or possible? Is it possible for society to reach a consensus on what the Colorado River system should look like in the foreseeable and long-term future?
- How should science relate to ongoing management? How should priorities be set and by whom? Who should direct, fund, and perform the work?
- How do we determine if and when the work (e.g., species recovery) is a) completed or b) abandoned as impossible? Should there be a "sunset clause" on expenditures in endangered species recovery programs?

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