On the Edge: Challenges Facing Grand Canyon National Park

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Members of the Subcommittees, I thank you very much for inviting me here today to testify about the effects of Glen Canyon Dam operations on natural resources in Grand Canyon National Park.

My name is Steven Warren Carothers. I am an ecologist with over 40 years of experience studying the riparian and aquatic ecosystems of the Colorado River in Grand Canyon. My professional affiliations past and present include the National Park Service (contract employee); Northern Arizona University (adjunct professor); the Museum of Northern Arizona's Harold S. Colton Research Center (Curator of Zoology); and SWCA Environmental Consultants, a private environmental consulting company I founded in 1981. SWCA is now an employee-owned, science-based environmental firm with offices in 12 western states and Guam.

I believe I was invited to participate in this hearing because of the long-term perspective I can offer, having conducted my first research trip into the Canyon in 1969. That was only 6 years after the floodgates closed at Glen Canyon Dam. I have watched the riverine system evolve under the Dam's influence every year since. I have rowed the river, seined the river, electrofished the river; I have studied its beaches and birds and conducted university classes along its banks; I have written books about it. But most significantly for the purposes of this hearing, I served on the writing team for the Glen Canyon Dam Environmental Impact Statement (GCDEIS) from 1990 to 1995 and helped craft the adaptive management concept as it was incorporated into the Final GCDEIS (1995) and the Record of Decision (1996).

Issuance of the GCDEIS Record of Decision was one of three major actions taken by federal authorities in the 1990s to protect natural resources in Grand Canyon National Park from adverse impacts of operations at Glen Canyon Dam. The other two actions were passage of the Grand Canyon Protection Act of 1992 and issuance of the U.S. Fish and Wildlife Service's (USFWS's) Biological Opinion on the GCDEIS in 1994. All these efforts were prompted by research findings indicating that traditional operations at Glen Canyon Dam (high-volume releases, high daily fluctuations, and rapid upramping and downramping of flows), designed primarily to meet hydropower production priorities, were harming downstream natural and cultural resources in Grand Canyon.

The intent of the federal actions of the 1990s can be boiled down to this:

> Recover and achieve long-term sustainability of the Park's natural and cultural resources downstream of Glen Canyon Dam, and by doing so protect the values for which Grand Canyon National Park was established.

My principal objective here is to evaluate how effective dam management has been in meeting these goals. My focus will be on natural resources, with an emphasis on endangered and other native fish species and river-transported sediment. Native fish serve as an indicator of the state of aquatic biological resources as a whole. One fish species in particular, the endangered humpback chub, has been the subject of great concern and much research and monitoring. A second endangered fish, the razorback sucker, is *very* rare and possibly extirpated from Grand Canyon. Because of the much lower potential for success, considerably less attention has been paid to this species, and I won't deal with it here. The second resource I want to address is the river-borne sediment that constitutes sandbars along the river's edge. Below water level, sandbars form vital habitat for native fish. Above water level, they provide substrate for riparian vegetation and the insects, amphibians, reptiles, birds, and mammals that depend upon that vegetation. Sandbars also provide camping beaches for over 20,000 recreationists each year, and in some cases, support and protect archaeological sites. As with humpback chub, river-borne sediment has been the subject of a great deal of costly research and monitoring.

GLEN CANYON DAM ADAPTIVE MANAGEMENT PROGRAM (GCDAMP)

As a result of the Grand Canyon Protection Act and the GCDEIS, Glen Canyon Dam has been operated for the last 14 years within the context of adaptive management. In an adaptive management approach, management actions are explicitly designed as experiments to generate knowledge about the response of targeted resources to those actions. Knowledge gained through that experimental process is incorporated into subsequent management actions in an ongoing feedback loop that will ultimately yield a set of best management practices. The concept is sensible in theory but difficult in practice.

When the Glen Canyon Dam Adaptive Management Program (GCDAMP) was established in 1996, the humpback chub population appeared to be in steep decline, and the system was exporting more sediment than it was importing. Grand Canyon's sandbars were being washed downstream to Lake Mead. After 14 years of adaptive management, what is the status of these resources now? Here's the short answer:

- After a period of continued decline, the population of humpback chub has recently stabilized or even increased. Populations of other native species, particularly bluehead suckers, have definitely increased. The endangered razorback sucker continues to be extremely rare *at best* but is effectively gone from the system.
- Grand Canyon's sandbars are still being washed downstream to Lake Mead.

So, Is Adaptive Management Working at Glen Canyon Dam?

The answer is—yes and no. Numerous experiments have been conducted, reams of monitoring data have been collected, and extensive modeling has been done. We know a lot more about this complex riverine system than we did 14 years ago. We also have a very positive outcome: native fish populations are stabilized or increasing. Unfortunately, we do not know exactly *why* this is happening. Shifting from high daily fluctuating dam releases to lower fluctuating dam releases probably improved conditions for native fish. It was expected to. Four months of steady dam releases in the summer of 2000 probably increased the success of a brood year or two (very important for a long-lived fish like humpback chub). This was expected as well. Reducing the abundance of nonnative trout through 3 years of experimental winter releases and mechanical removal likely helped native fish. At least researchers hope this is the case. And then there's Mother Nature. A prolonged drought has lowered water levels in Lake Powell, resulting in substantially warmer dam releases since 2005. Warmer water has almost certainly benefited native fish, which are all warmwater species.

Ask a fisheries biologist working in the system which of these factors most aided native fish and which should guide future dam management decisions, and the biologist will likely say—"Well, I don't know. It was probably a combination of some or all of them. Let's keep testing variations on these scenarios and watch the monitoring data to see how native fish species are doing. In time we should be able to identify specific cause-and-effect relationships and determine which management actions give us the biggest bang for the buck and which aren't beneficial enough to justify the cost." The upshot? Adaptive management *probably* has served native fish well, but to what degree and exactly how we are not sure. One of the objectives of adaptive management is to reduce uncertainty in a complex ecosystem. For native fish (and warmwater nonnative fish), the GCDAMP has achieved only modest progress in this regard.

The situation with sediment is more clear. With construction of Glen Canyon Dam, the Colorado River stopped transporting huge amounts of sediment into Grand Canyon. Now, the only sources of new fine-sediments (mostly sand) are tributaries within Grand Canyon, and tributaries provide only about 16% of predam sand levels. New inputs have shrunk, but the river continues to transport sand out of the Canyon and into Lake Mead. As a result, sandbars are shrinking; camping beaches are disappearing. The GCDAMP has not halted this depletion, but adaptive management has worked the way it is supposed to work *in at least one respect*. Experimentation has provided scientifically valid information that can inform management decisions that have a high probability of benefiting a valued resource. Thanks to well designed high-flow experiments in 2004 and 2008 and other projects, scientists believe they have identified a strategy for achieving a sediment balance in Grand Canyon that will maintain sandbars at an acceptable level over the long term.

This strategy hinges on taking maximum advantage of sporadic flood flows in two tributaries, the Paria River and the Little Colorado River. Together, these two streams deliver the bulk of sediment to the Colorado River in Grand Canyon. Sand from a tributary flood accumulates in the mainstem riverbed and starts to work its way downstream to Lake Mead. The strategy is two-pronged. First, manipulate river flow to pick up the accumulated sand from the riverbed, suspend it in the water column, and deposit it high on riverbanks throughout the Canyon. This is achieved by releasing very high flows (above power plant capacity) from the Dam over a short period. Second, minimize erosion of the newly rebuilt sandbars by maintaining low, steady dam releases (less than about 11,000 cfs) between the high-flow events. In other words, steady flows replace daily fluctuating flows in normal operations. Both scientists and managers within the GCDAMP have known for several years that both phases of the strategy are required to conserve sandbars in Grand Canyon. However, only the first part of the strategy has been implemented, and that only reluctantly. High-flow experiments were conducted in 2004 and 2008, but in both cases dam operations returned to fluctuating flows. As a result, substantial sediment gains from the high flows have been lost.

Adaptive management is based on the principle of adjusting management in response to knowledge gained through experimentation. We have gained useful knowledge about sediment retention through experimentation; however, that knowledge has not been folded back into dam management to the degree it could have been. Failing to test high-flows in conjunction with intervening steady flows is, in my view, a clear case of adaptive management failing to work as it is supposed to work. As a result, a valued resource in Grand Canyon National Park is not being recovered or sustained.

Unfortunately, sediment loss is not the only example of this failing. Here's another example: the Dam is currently being managed according to an experimental design that includes two months of low steady flows every year from 2008 to 2012. The two months are September and October. The stated purpose of these flows is to stabilize and warm nearshore environments to benefit young-of-year humpback chub and other native fish emerging from the Little Colorado River. But there is something puzzling about this. Young fish disperse into the mainstem beginning with the first heavy summer precipitation events, which invariably start in July. In fact, a group of leading fisheries biologists from both within and outside of the GCDAMP recommended in 2007 that this steady flow experiment be conducted June through August. Why the shift from summer to fall and from four months to two? As stated in the 2008 Environmental Assessment for the experiment, "increased hydropower costs was a factor in proposing a steady flow test during the fall rather than the summer when much higher economic impacts would occur." The ultimate decision to conduct the 5-year experiment in September–October was driven by factors other than knowledge gained through research. As a result, the design of a scientific experiment was comprised. This again can be seen as a failure of adaptive management, although it is unclear whether the decision was made within the structure of GCDAMP or outside of it.

Problems Inherent in the Glen Canyon Dam Adaptive Management Program

I want to restate here what I touched on before: an impressive amount of work has been done within the GCDAMP, including first-rate science conducted by first-rate scientists.[1] We do know much more than we once did about the physical and biological systems downstream of the Dam. And, of course, the status of the native fish species appears to be improving. Nonetheless, progress toward protecting downstream resources has been frustratingly slow. Much of this must be attributed to the extreme variability of the environmental system being studied: nearly 300 miles of complex relationships among a shifting array of variables: water flow and temperature,

[1] Research and monitoring for the GCDAMP is performed by scientist either working for or contracted by the Grand Canyon Monitoring and Research Center (GCMRC). The GCMRC is a unit of the U.S. Geological Survey.

topography, geomorphology, turbidity, tributary influences, terrestrial and aquatic biotic communities, habitat needs of and interrelationships between native and nonnative species—the list goes on and on. This complexity makes it difficult to identify cause-and-effect relationships, and every management action carries the threat of undesirable, unintended consequences. Problems associated with this situation are often beyond human control, but the GCDAMP is afflicted with several other problems that *are* within our ability to address and that should be addressed.

I believe several structural characteristics of the GCDAMP seriously limit its effectiveness in guiding operation of the Dam in such a manner as to recover and sustain downstream resources in Grand Canyon National Park.

- Diffuse and numerous program objectives with no prioritization and no single overarching goal. Objectives at times conflict; for example, maintaining a wild reproducing population of rainbow trout is not consistent with maintaining a viable population of native fish, and maintaining (even increasing) power production capacity is not consistent with attaining levels of sediment storage or establishing flow dynamics to achieve ecosystem goals.
- Management by democracy without a shared vision. The group that oversees the program, the Adaptive Management Work Group (AMWG) includes representatives of five federal agencies, seven states and one state wildlife agency, six Native American tribes, two hydropower user groups, two environmental organizations, and two recreational interests. Membership on the Technical Work Group (TWG) is even larger. Each stakeholder organization represents and works to further its own interests rather than an agreed upon common goal, and those interests are often in direct conflict. *Trying to include every conceivable stakeholder in the process inhibits consensus and final decision making.*
- The majority of members on the two GCDAMP work groups have no management responsibility for either the Dam, resources in Grand Canyon National Park, or endangered species, yet those members can severely constrain the ability of the agencies that *are* legally responsible to execute those responsibilities. For example, the National Park Service has come to believe that to fulfill their obligation under the Organic Act to leave Grand Canyon values unimpaired, the Dam should be operated under a scenario of seasonally adjusted steady flows to mimic the natural hydrograph. Yet as recently as 2007, a motion in the AMWG to do just that was defeated by a sizable majority, with most nay votes cast by entities with no jurisdiction over either the Dam or the Park.
- Cumbersome organization. The management and technical work groups are simply too large to be efficient. Meetings can easily have more than 70 attendees. Efficiency is also hampered by the lack of an objective decision-making pathway and a clear understanding among parties (the AMWG, the TWG, and the scientists) about where responsibilities lie when it comes to designing research and monitoring programs. Draft ideas can bounce back and forth among the parties in seemingly endless cycles.
- No structural means to prioritize information needs to guide research and monitoring designs. Significantly, in 14 years the GCDAMP has not been able to define desired future conditions for downstream resources. It is not even clear who is responsible for

coming up with those definitions. In the absence of clearly defined and prioritized desired future conditions, program scientists are swamped by a plethora of information needs and no objective criteria for choosing among them (let alone the authority).

As a result of these characteristics, the GCDAMP often suffers from a deficiency of focus, timely decision making, and effective integration of science and management.

Remedies?

In a 2007 workshop sponsored by the Grand Canyon Monitoring and Research Center (GCMRC)—the scientific arm of the GCDAMP—participating scientists developed an experimental research design based on what they called the environmental triggers approach to dam management. This approach uses specific environmental cues (rather than committee decisions) to trigger new experimental treatments or management actions. For the approach to work, desired future conditions, or measurable targets, must be established for downstream resources. I strongly concur with this approach and hope the Department of the Interior ensures that desired future conditions are established *post haste*.

The environmental triggers approach to dam management has a great deal to recommend it, but I find it difficult to believe that such an approach can be effected within the GCDAMP as it is currently structured. While involving all stakeholders in decision making is an attractive idea and may keep litigation to a minimum, the results of the GCDAMP to date demonstrate that in practice adaptive management by "consensus" of 25 stakeholders is a recipe for ineffective adaptive management. Narrowing the advisory group to the three responsible managing agencies—Bureau of Reclamation, National Park Service, and USFWS—is worth considering. These three agencies are required to prepare National Environmental Policy Act (NEPA) documents for all major actions that affect dam operations and protection of Grand Canyon National Park. All stakeholders have the opportunity for input and the ability to influence those actions through the NEPA process.

A BRIEF HISTORY OF ADAPTIVE MANAGEMENT AT GLEN CANYON DAM

The GCDAMP grew out of the Grand Canyon Protection Act, the Glen Canyon Dam EIS and Record of Decision, and issuance of the USFWS's Biological Opinion on the GCDEIS. I summarize the most important provisions each of those documents below, and describe (in tabular form) how and to what degree those provisions have been implemented to date. The last section provides additional information about the relative confusion over the relationship between operations of Glen Canyon Dam and fluctuations in the humpback chub populations.

The Grand Canyon Protection Act (1992)

The Grand Canyon Protection Act directed the Secretary of the Interior to manage Glen Canyon Dam "in such a manner as to protect, mitigate adverse impacts to, and improve the values for which Grand Canyon National Park and Glen Canyon National Recreation Area were established." The Act also mandated completion of the GCDEIS (already underway) and required future dam operating criteria and plans to be based on the findings, conclusions, and recommendations of that document.

Glen Canyon Dam EIS Record of Decision (1996)

The basis of the Bureau of Reclamation's (Reclamation's) Record of Decision was "to find an alternative dam operating plan that would permit recovery and long-term sustainability of downstream resources while limiting hydropower capability and flexibility only to the extent necessary to achieve recovery and long-term sustainability." Implicit in this quotation is the admission on the part of Reclamation that Glen Canyon Dam operations had created a situation by which downstream resources had been harmed, and that the Dam could and should be operated in the future in such a way as to allow those resources to "recover" to some unspecified condition and be sustained in that condition over the long term.

The recommendations of the GCDEIS, as modified and given legal force by the Record of Decision, include the following provisions that had and continue to have significant implications for the status of natural resources in Grand Canyon:

- Selected Dam Release Alternative: Reclamation decided to implement the Modified Low Fluctuating Flow (MLFF) alternative as described in the final GCDEIS, with a change in the timing of beach/habitat building flows (described below). The MLFF alternative reduced daily flow fluctuations well below the historical pattern of dam releases. This alternative was the preferred alternative of the EIS Cooperating Agencies (with the exception of USFWS, which preferred seasonally adjusted steady flows - SASF). Most of us working in the system at that time thought the MLFF would create conditions that would promote the protection and improvement of downstream resources while maintaining some flexibility in hydropower production (although we recognized there would be a significant loss of hydropower benefits). Reclamation selected the MLFF despite USFWS's jeopardy ruling in its Biological Opinion.
- Beach/Habitat-building Flows: The MLFF alternative incorporated beach/habitat-building flows (now referred to as "high-flow experiments," or HFEs). These are sporadic, steady, short-duration dam releases of between 42,000 and 45,000 cubic feet per second (cfs). Technical power plant capacity is 33,200 cfs, so HFEs allow releases that bypass hydropower generators. HFEs are designed to rebuild high elevation sandbars, deposit nutrients, restore backwater channels, and provide some of the dynamics of a natural riverine system. In the final GCDEIS, it was assumed that these flows would occur with a frequency of 1 in 5 years. This was changed in the Record of Decision, which defined these flows as "reservoir releases in excess of power plant capacity required for dam safety purposes," that would be implemented under "certain [undefined] conditions" in the spring. Timing of the HFEs has been a source of contention among stakeholders ever since.
- Adaptive Management: An adaptive management program would be established for operation of Glen Canyon Dam that would include long-term monitoring, research, and experiments that "could result in some additional operational changes."
- New Population of Humpback Chub: In consultation with USFWS, National Park Service, and Arizona Game and Fish Department, Reclamation committed to making every effort

to ensure that a new population of humpback chub would be established in the mainstem Colorado River or one or more of the tributaries within Grand Canyon. At the time of the Record of Decision, the only confirmed reproducing population of humpback chub was in the Little Colorado River, the largest tributary in Grand Canyon.

- Selective Withdrawal: Reclamation committed to supporting research on the effects of installing selective withdrawal structures at Glen Canyon Dam and using the results of the research to decide whether or not to pursue construction. The intent of the structures was to allow for the release of warmer water from nearer the top of the reservoir to improve the survival of endangered and other native fish (all of which are warmwater species).

U.S. Fish and Wildlife Service Biological Opinion (1994)

As noted above, USFWS registered a dissenting opinion on the adoption of MLFF as the GCDEIS preferred alternative. In their Biological Opinion on that alternative, USFWS held firm to their position and determined that low fluctuating flows would likely jeopardize the continued existence of the endangered humpback chub and razorback sucker and would destroy or adversely modify their designated critical habitat. Their Reasonable and Prudent Alternative (RPA) included the following elements:

- Implement an adaptive management program.
- Release experimental steady flows from April through October (high in spring, low in summer and fall) during low water years (8.23 maf annual release, the lowest amount that can legally be released from the Dam in a year). Design of the experimental steady flows and associated studies were to begin as soon as possible and be targeted for completion by October 1996. Unless USFWS determined information provided by those studies seriously questioned the validity of the experimental designs developed, steady flows were to be initiated in April 1997. If Reclamation had not completed its studies and research design by April 1997, but demonstrated sufficient progress and good faith effort toward meeting that goal, steady flows could commence later in 1997. However, if USFWS concluded by April 1997 that sufficient progress had *not* been made toward developing an experimental design, dam mangers would be required to implement the seasonally adjusted steady flow (SASF) alternative beginning in April of the following year (1998). This stipulation was familiarly called "the hammer clause."
- Determine the feasibility of installing a selective withdrawal structure at Glen Canyon Dam to increase water temperatures downstream for the benefit of endangered and other native fish.
- Conduct research and monitoring to determine effects of management actions on endangered and other native fish.
- Develop a management plan for the Little Colorado River, the spawning tributary for humpback chub in Grand Canyon. This element stemmed from a concern that contamination or other major disturbance of the Little Colorado River could have catastrophic consequences for the only known reproducing population of humpback chub in the Lower Colorado River Basin. A draft Little Colorado River management plan was to be completed by the end of 1996.

- Develop actions to help ensure the continued existence of the endangered razorback sucker. Such actions would include, but not be limited to, convening a workshop attended by experts on the species as a first step toward preparation of a razorback sucker management plan for Grand Canyon.
- Establish a second spawning aggregation of humpback chub in Grand Canyon.

Reversal of USFWS's Position - 2008 Biological Opinion on Operation of Glen Canyon Dam and 2009 Supplement

USFWS issued a Biological Opinion in 2008 on a proposed experiment design for dam operations covering the period 2008–2012. In that opinion, together with a court-ordered supplemental Biological Opinion issued in 2009, USFWS reversed its findings of 1994 and determined that modified fluctuating flows, when combined with various other adaptive management actions, "has not resulted in jeopardy to humpback chub or destruction or adverse modification of its critical habitat since 1995." USFWS went on to say that "although MLFF results in adverse affects to humpback chub, Reclamation's implementation of MLFF through an adaptive management program appears to have benefited humpback chub, and we believe is likely to continue to do so."

To What Extent Have the Provisions of the GCDEIS and 1994 Biological Opinion Been Implemented?

The requirements of the GCDEIS Record of Decision and the related 1994 Biological Opinion largely overlap with the exception of normal dam operations (fluctuating flows vs. steady flows). The GCDEIS Record of Decision called for low daily fluctuating releases from the Dam. That release scenario was implemented and is still in effect 14 years later, with occasional deviations for experimental flows designed and implemented within the context of adaptive management. Table 1 (attached) describes progress toward complying with the Reasonable and Prudent Alternative (RPA) in USFWS' 1994 Biological Opinion on the GCDEIS preferred alternative. Table 2 (attached) summarizes the major actions that have been taken within the context of adaptive management, a major tenet of both the GCDEIS and the Biological Opinion.

Endangered Humpback Chub in Grand Canyon

As far back as 1978, USFWS had issued a Biological Opinion that future operations of the Glen Canyon Dam jeopardized the continued existence of the humpback chub and the razorback sucker. High fluctuating flows and cold water (approximately 50°F) released from deep within Lake Powell appeared to be the major problems. Historically, flow fluctuations could range between 1,000 and 31,500 cfs in a day, and ramp rates could exceed 8,000 cfs in an hour. As a result, cold river water flushed in and out of shallow, nearshore habitats, destabilizing essential habitat for native, warmwater fish. High fluctuating flows, particularly rapid down-ramp rates, also eroded the return-current channel backwaters used by native fish and disrupted the supply of important aquatic food sources.

When the MLFF alternative was selected as the preferred alternative in the 1995 GCDEIS, it was believed by its adherents to have the potential to reverse the decline of native fish populations.

Substituting a regime of low fluctuating dam releases would reduce the severity of flow-related impacts. Steady flows would reduce the impacts even more, but steady flows would severely restrict hydropower flexibility, precluding the Dam's ability to generate peaking power. Most participants in the GCDEIS process, including me, believed it was not necessary to go to that extreme. We believed the benefits of the MLFF alternative would be sufficient to stabilize or even increase populations of native fish, while retaining substantial flexibility at the power plant. If this proved *not* to be true, the adaptive management provision in the GCDEIS would allow for future changes in dam operations. As I mentioned earlier, USFWS demurred in this view. They were not willing to support any scenario that did not maximize benefits to endangered species. In hindsight, one can argue that neither position, neither MLFF nor steady flows, was wrong.

Beginning in the early 2000s, the downward trend in the estimated population size of adult humpback chub has reversed (Figure 1). Monitoring data and modeling results now show an upward trend. As a result of this trend, USFWS found in its 2008 Biological Opinion that the MLFF alternative does not appear to be jeopardizing the continued existence of humpback chub after all. And scientists[2] now suggest that the steady flow experiment in 2000 may have contributed to the increasing chub abundance. So, both MLFF and steady flows are receiving some credit. But the situation is complicated. Several different kinds of experiments have been run in the last 14 years (see Table 2). Attempts have been made to determine the impact of *each* of these experiments on native fish, but it is difficult to sort out causal relationships, especially in such a complex system. It does not help that a considerable amount of time can pass before effects of an experimental release show up in monitoring data, if it ever does.

To further complicate matters, dam operations are not the only factors influencing native fish populations. Parasites and other diseases can be a factor. Conditions in the LCR, crucial spawning habitat for the humpback chub, can determine a good brood year—or a bad one. Predation and competition from nonnative fish, which dominate the mainstem river, are significant issues as well. Efforts designed to reduce predation/competition pressure on humpback chub have included mechanical removal of large numbers of trout in the mainstem near the inflow of the LCR and from spawning habitat in Bright Angel Creek. Yet another variable was added to the mix in 2005: the warming of river water due to drought. Lake Powell is now only 57% full, hence water passing through the Dam's generators is drawn from nearer the surface and is warmer than when the reservoir was full or near full. Has warmer river water benefitted native warmwater fish? Probably. But it probably has given a boost to *nonnative* warmwater fish as well, and these also pose a risk to native species.

The conundrum all of this presents to decision makers is how to identify which of all these variables should be incorporated into future dam management and which should fall by the wayside. The adaptive management for Glen Canyon Dam has been exceedingly expensive, both in terms of defrayed hydropower revenues and actual expenses. After more than 14 years of data gathering and experimentation we would like to think we are closing in on some definitive answers. All we really know is that for some reason or combination of reasons, populations of humpback chub and two other native species, bluehead sucker and flannelmouth

[2] Coggins, Jr., L.G., and Walters, C.J. 2009. Abundance trends and status of the Little Colorado River population of humpback chub; an update considering data from 1989–2008. U.S. Geological Survey Open-File Report 2009-1075. 18 p.

sucker, have stabilized or are increasing. According to Coggins and Walters (2009), the GCDAMP scientists who modeled the trend shown in Figure 1, data show a tendency toward population stabilization beginning in the 1990s, *before* the water began to warm or efforts were made to suppress nonnative species. They do not discuss possible causes for the apparent improvement in the status of humpback chub, other than to point out strong 1999 and 2000 brood-years and suggest that the 2000 steady flow experiment may have benefited the chub hatched in those years. They also note a punctuated increase in recruitment beginning in brood-year 2003, which *would* coincide with increased water temperatures and the trout removal program.

The prognosis for humpback chub has begun to look promising, although the estimated population of approximately 7,650 adults is still well below the 1989 estimate of 11,000 (see Figure 1). Scientists are not sure why the chub (and bluehead sucker and flannelmouth sucker) are doing better, and do not know if this trend will continue; however, it would be hard to argue that the GCDAMP was not at least been partially responsible for this positive development.

CLOSING

In closing, I want to once again thank the members of the U.S. House of Representatives Subcommittee on National Parks, Forests and Public Lands and the Subcommittee on Water and Power for giving me this opportunity to share my views on the current management of Glen Canyon Dam and its continuing effects on Grand Canyon National Park.

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ATTACHMENTS

Table 1. Progress in complying with the Reasonable and Prudent Alternative (RPA) in USFWS' 1994 Biological Opinion on the GCDEIS preferred alternative.

RPA Element	Compliance to Date
Implement an adaptive management program	The Glen Canyon Dam Adaptive Management Program (GCDAMP) was chartered in 1997 in accordance with the Federal Advisory Committee Act; the charter was renewed in 2006.
Design and implement experimental steady flows	Experimental steady flows were released in March–September 2000, but the SASF alternative was not implemented as required by the 1994 RPA. Several times since 1997 USFWS notified Reclamation of insufficient progress toward implementing SASF. USFWS backed off SASF in 2008 and accepted low steady flow experimental flows for fall 2008–2012.
Determine the feasibility of installing a selective withdrawal structure at Glen Canyon Dam	Preliminary plans are in place, but evaluation of potential effects on native fish and potentially harmful warmwater, nonnative fish is still underway. Lowered water levels in Lake Powell due to extended drought and the resulting warmer dam releases, combined with uncertainty about future reservoir levels, have reduced the immediacy of acting on this element.
Conduct research and monitoring to determine effects of management actions on endangered and other native fish	Monitoring and experimental programs conducted as part of the GCDAMP are listed in Table 2, below.
Develop a management plan for the Little Colorado River (LCR)	Progress on this element has been frustrated by the legal and practicable complexities of designing a management plan that includes a multitude of jurisdictions and interests throughout the LCR basin. Nonetheless, a draft management plan for the LCR was completed in 2009.
Develop actions to help ensure the continued existence of the endangered razorback sucker	A workshop of experts was held in 1996, but it did not result in a management plan for this species in Grand Canyon. A few radiotagged razorback suckers were released in lower Grand Canyon in 1997, but were not subsequently detected. A feasibility study to reintroduce this species into lower Grand Canyon is underway and will be completed this year.
Establish a second spawning aggregation of endangered humpback chub in Grand Canyon.	A study of the potential to establish a second population in a tributary other than the LCR was conducted in 2000. A translocation of humpback chub to Shinumo Creek was accomplished by the National Park Service in 2009. It is too soon to evaluate the outcome. Beginning in 2003, several translocations have been completed in the LCR to sites above a natural impediment to upstream passage (Chute Falls).

Table 2. Summary of Glen Canyon Dam Adaptive Management Program monitoring and experimental management actions.

Monitoring		
Extensive monitoring of natural resources, including native and nonnative fish, aquatic foodbase, water quality, sediment transport, riparian vegetation, etc., by GCMRC staff and various contractors, resulting in large amounts of data. Monitoring is needed to both assess the changing status of resources and determine the effects of specific experimental programs.		Some monitoring activity every year
Experimental Management Actions	***Purpose of Action***	**Year(s)**
Week-long, steady 42,000–45,000 cfs Beach/Habitat-building Flows, or "high-flow experiments" (HFEs), March–April	Test effects on sandbars. Desired outcome: build sandbars needed as habitat by native plants and animals and as camping beaches by recreationists.	1996, 2004, 2008
Steady flows of 31,000 cfs for 48 hours	Test effects on sandbars. Desired outcome: maintain sandbars for reasons cited above.	1997
Stable spring flows of 14,000–19,000 cfs, followed by steady 8,000 cfs, May–August	Test effects on fish populations. Desired outcome: enhance native fish survival and recruitment.	2000
High fluctuating flows, 5,000–20,000 cfs, January–March	Test effects on reproduction of rainbow trout, an introduced species. Desired outcome: suppress abundance of rainbow trout, the most common fish species in Grand canyon and competitor/predator of native fish.	2003, 2004, 2005
Translocation of young humpback chub from the lower LCR (near the confluence) to upstream sites above Chute Falls	Test effects on LCR aggregation of humpback chub. Desired outcome: expand species' range to retain young-of-year in the LCR, which is more hospitable to young fish than the mainstem, and increase carrying capacity of the LCR.	2003–present
Mechanical removal of nonnative fish (especially rainbow and brown trout) from the Colorado River in the vicinity of the LCR confluence	Test effects on abundance of nonnative fish in the test area. Desired outcome: benefit native fish by reducing predation on young chub and suckers emerging from the LCR.	2003–2006, 2009
Series of two-week-long alternating steady and fluctuating dam releases, September–October	Test effects of daily fluctuations on water quality parameters and biotic constituents of shoreline habitats. Desired outcome: identify flows that improve nearshore conditions for native fish.	2005
Steady flows of approximately 10,800 cfs in 2008 and 9,200 cfs in 2009, September–October	Test effects of moderate, fall steady flows on native and nonnative fish. Desired outcome: increase in survival rates of endangered and other native fish.	2008–2009

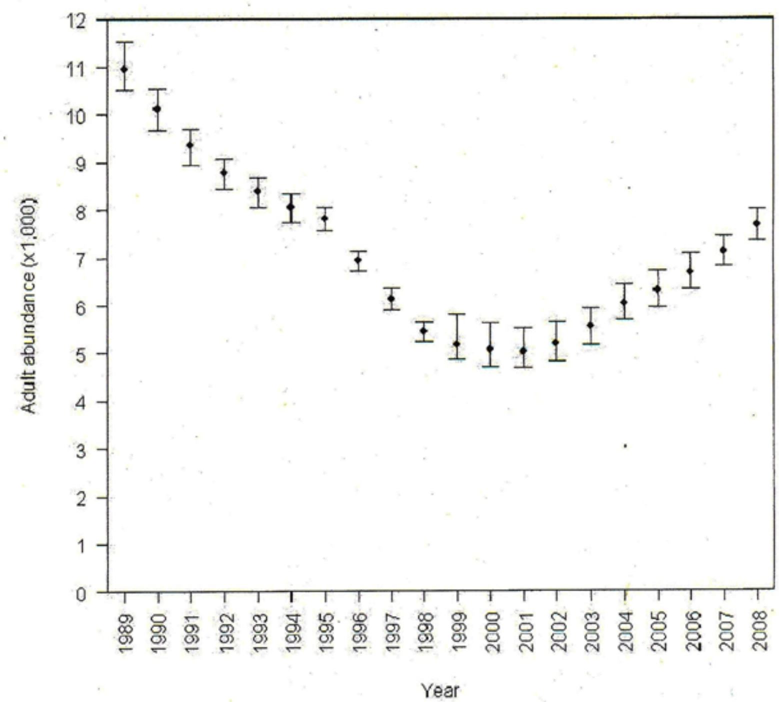

Figure 1. Estimated adult humpback chub abundance, age 4+ (from Coggins and Walters 2009).