TWG mtg 12/8/9
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THE STATE OF NATURAL AND CULTURAL RESOURCES IN THE COLORADO RIVER ECOSYSTEM: 1998 REPORT

PRELIMINARY * DRAFT

Prepared by the Grand Canyon Monitoring and Research Center

8 December 1998

EXECUTIVE SUMMARY

The status of physical, natural and cultural resources of the Colorado River affected by Glen Canyon Dam are summarized here to provide relevant information to stakeholders, the Adaptive Management Work Group and the public. In addition, this 1998 State of the Colorado River Ecosystem report summarizes long-trends in resource conditions, and focuses on scientific insights gained through analyses of previous and on-going scientific studies.

Physical resources reported here include climate, flow, changes in sediment transport, sandbar morphology, and campsite availability. Discharge remained high, often exceeding 20,000 cfs in the summer of 1998, as Lake Powell reservoir reached near full-pool stage. Flood-triggering flow criteria were not met in 1998. Several large Paria River flows in late summer increased sediment supplies in the Marble Canyon reach to the highest levels since 1980. Sediment inflow from the Little Colorado River was also substantial in 1998. If other flow and resource triggering criteria are met in 1999, the availability of abundant sediment means that planned flooding may be very successful for rejuvenation of sand bars in 1999.

Aquatic biological resources include the aquatic foodbase and fisheries. High flows from 1996-1998 resulted in extensive colonization of the 8,000 cfs to 20,000+ cfs zone by benthic macrophytes and invertebrates, which comprise the aquatic foodbase. The Labor Day 1997 8,000 cfs constant flow may have desiccated macrophyte beds, and the November 1997 31,000 cfs habitat maintenance flow (HMF) may have scoured some benthos, but those flows resulted in no detectable impact on the trout or native fisheries. Continued high discharges in 1998 have increased bethic colonization up to the 20,000 cfs stage. The general conclusion from 8 years of benthic analyses in this ecosystem is that high, steady flows enhance the aquatic foodbase, while lower, fluctuating flows reduce the benthos to the lowest stage achieved on about a monthly basis. Analysis of the relationship of the aquatic foodbase to higher aquatic trophic levels is underway.

Endangered humpback chub (HBC) exist in 9 mainstream populations in Grand Canyon but are restricted in breeding to the lower Little Colorado River (LCR). The status and health of the population have been difficult to determine with the given data; however, concern exists regarding condition factor and population size. Cool spring weather in 1998 retarded the HBC spawn, but this year appears to have been fair for reproduction in the mainstream. Another new finding from 1998 is the presence of more subadult HBC in the mainstream than has previously been reported. Reasons for this finding are related to gear type: the subadult size class (200-400 mm) is better sampled using mini-hoop nets, and is undersampled using electroshocking equipment. Other native fish populations appear to be in near-normal condition; however, time series monitoring data on condition or population trends have yet to be developed.

Asian tapeworm infestation in HBC is widespread, and remains a concern. Health of HBC is being monitored.

The Glen Canyon reach supports a blue-ribbon rainbow trout fishery, of which 70% may be naturally produced. The condition of this fisheries in 1998 appeared to be near-normal.

Some other non-native fish populations (e.g., red shiner) appear to be increasing, while time series analyses of the other non-native fish populations have yet to be developed.

Terrestrial biological resources include wetland and riparian soils, vegetation and fauna, including several species of concern. Slight gradients established under constant flows may direct groundwater flow and nutrient distribution. The extent of scour of marsh vegetation during the 1996 experimental flood varied, with some, including two at southwestern willow flycatcher foraging sites, sustaining considerable scour. In addition, recovery of marsh patches has remained slow, possibly because of increased soil texture. The timing of the 1996 BHBF (March) and the 1997 HMF (November) limited saltcedar seedling establishment during those two planned floods, but constant high flows from 1995-1998 have allowed increased some additional establishment downslope from the 30,000 cfs stage.

Terrestrial species of concern are being monitored to determine long-term population trends and responses to dam operations. The Kanab ambersnail (KAS) exists at Vaseys Paradise in native and non-native herbaceous vegetation. Habitat and population recovery from the 1996 planned flood continued in 1998, approaching levels near the pre-1996 BHBF levels in the stage zone below the 45,000 cfs stage. The impacts of the 1997 HMF were nominal, resulting in a "take" of no more than 50 KAS. In 1998, one or more tributary floods scoured some higher elevation habitat. The September (pre-dormancy) population survey indicated that 68.8 m2 (10.5%) of the KAS habitat existed below the 45,000 cfs stage, supporting an estimated 3170 KAS (7.3% of the total estimated population). Analysis of an extrapolated stage-to-discharge relationship at Vaseys Paradise suggests that 162.3 m2 (24.8%) of the KAS habitat and 9405 (21.6%) of the KAS population exist downslope from the 60,000 cfs stage.

Endangered southwestern willow flycatcher wetland feeding habitat had been reduced by the 1996 BHBF, and 2 of 4 marshes associated with nest site stands have recovered little from the 1996 test flood. The single pair at Mile 50.5L has not bred successfully in 1997 and 1998, having been subject to brown-headed cowbird brood parasitism and inclement weather conditions (high winds).

The -9L Spring populations of northern leopard frog and Niobara ambersnail survived the 1996 BHBF and appeared to be little affected by the November 1997 31,000 cfs HMF. Although frogs continue to be abundant at that site, flows in excess of 20,000 cfs through the summer of 1998 eliminated most of the habitat of the Niobrara ambersnail, and it was not evident in late summer. No flow-related impacts on peregrine falcons, bald eagles, osprey or belted kingfishers were reported in 1997 or 1998, and 1998 populations appear reasonably robust.

Overall, the short-term and long-term impacts of the Preferred Alternative flow regime, coupled with planned flooding, affect some (particularly terrestrial) species of concern and their habitats, so that the most conspicuous tradeoffs occur between aquatic and terrestrial resource components.

Cultural resources include: archaeological sites and traditional cultural resources such as springs, landforms, sediment and mineral deposits, and traditional plant locations and animals. All of these resources have the potential to be affected by the operations of Glen

Canyon Dam. The ultimate goal of the cultural resource efforts related to Glen Canyon Dam operations is *in-situ* preservation, with minimal impact to the integrity of the resources and when preservation is not possible data recovery efforts, as appropriate.

Hydroelectric power production data were compiled from the Bureau of Reclamation SCADA data. These data are tightly correlated with flow releases, and show a comparable variability over the past two years, with a peak during the November 1997 habitat maintenance flow test.

INTRODUCTION AND ADMINISTRATION

Administration Overview
  AMWG/TWG
  GCMRC
    GCMRC Annual and Strategic Plans

Administrative History

Study Area Description and Map
  Map of study area
  Flow diagram of ecosystem processes

Stakeholder Management Objectives
  Table of ranked Information Needs and Management Objectives (June 1998)

GCMRC Monitoring and Research Activities in 1998

Conceptual model development

Flow and Resource Triggering Criteria for High Flow Events
  Flow triggering criteria for floods
  Resource triggering criteria for floods

Protocol and Remote Sensing Review

Information Management

INTRODUCTION

Administrative Overview

The Colorado River ecosystem affected by Glen Canyon Dam is the subject of federally authorized monitoring and research to improve ecosystem management in Lake Powell, lower Glen Canyon and throughout Grand Canyon. These scientific studies are coordinated by the Department of the Interior's Grand Canyon Monitoring and Research Center (GCMRC) office in Flagstaff, Arizona, under direction from the Adaptive Management Work Group (AMWG). The AMWG is a Federal Advisory Committee consisting of a diverse group of stakeholders, including: Department of Interior agencies (Bureau of Indian Affairs, Bureau of Reclamation, Fish and Wildlife Service, National Park Service), Western Area Power Administration, Colorado River basin states, Native American tribes, economic development groups, and environmental organizations. The AMWG meets semiannually to discuss dam management, review the progress of the GCMRC's scientific activities, develop plans for future activities, and provide recommendations to the Secretary of the Interior on Glen Canyon Dam operations. The AMWG is advised by its representatives on the Technical Work Group (TWG).

The wide array of physical, biological and cultural resources and processes of the Colorado River ecosystem are highly dynamic, and some resources respond dramatically to different flow regimes. Effectively managed flow regimes may enhance some resources and ecological processes in this river ecosystem, and a science-based adaptive management process may ensure effective management that optimizes stakeholder concerns while affording appropriate protection of the river ecosystem. Colorado River ecosystem stakeholders have requested from GCMRC an annual scientific evaluation of the state of the ecosystem, and such a report fulfills part of the requirements of Section 1804, subsections (c) and (d) of the 1992 Grand Canyon Protection Act, as well as some requirements of the 1995 Glen Canyon Dam Environmental Impact Statement (GCD-EIS) and 1996 Record of Decision (ROD). This evaluation, combined with information on predictions of future reservoir storage and weather, can be used to discuss potential flow regimes to protect and/or enhance development of the Colorado River ecosystem.

This 1998 State of the Colorado River Ecosystem report provides information on current physical, aquatic biological, terrestrial biological, cultural and socioenconomic resource conditions over time, and especially related to 1996-1998 flows, including the March/April 1996 beach habitat building flow (BHBF), the November 1997 31,000 cfs habitat maintenance flow (HMF), and 1998 flows.

Administrative History of the Colorado River
(Updated from Stevens and Wegner 1995)

YEAR	EVENT
1902	Reclamation Act creates the Bureau of Reclamation.
1904	Grand Canyon declared a National Game Reserve (T. Roosevelt).
1916	National Park Service Organic Act.
1919	Grand Canyon declared a national park, stipulating "reclamation projects" within park boundaries.
1922	The Colorado River Compact allocates the river's water between the upper (Wyoming, Colorado, Utah and New Mexico) and lower (Arizona, Nevada and California) basins.
1920-25	U.S. Geological Survey of potential dam sites.
1945	The Mexican Treaty guarantees 1.5 million acre feet of water to Mexico.
1948	The Upper Basin Compact allocates Colorado River water between the upper basin states.
1956	The Colorado River Storage Project (CRSP) Act is passed, opening the way for construction of numerous upper basin dams.
1957-63	Glen Canyon Dam construction, power production starts in 1964.
1967	Humpback chub and Colorado squawfish listed as endangered.
1973	The National Environmental Policy Act was passed.
1974-76	The NPS coordinates the first ecological inventory of the Grand Canyon (Carothers and Aitchison 1976), and the first sociological studies.
1976	Last Colorado Squawfish caught in Grand Canyon at Havasu Creek.
1978	FWS Jeopardy Opinion on the operation of Glen Canyon Dam.
1980	Lake Powell fills for the first time; bonytail chub listed as endangered.
1981-82	Rewind of Glen Canyon Dam turbines, Bureau of Reclamation claims there will be no significant effect on downstream river ecosystem.
1983	James Watt orders Bureau of Reclamation Glen Canyon Environmental Studies (GCES) Program to study dam impacts; post-dam record 2,724 m^3/s spillover flood is released.
1983-86	Forty studies of dam effects conducted during exceptionally high inflow and unanticipated spillway release flooding.
1987	National Academy of Sciences (NAS) review of GCES Phase I (NAS 1987).
1988	Cooperating agencies conclude that GCES Phase I (Bureau of Reclamation 1988) showed: (1) dam affects river ecosystem, but (2) more data needed on low and fluctuating flows to determine how to best manage the system.
1989	Secretary Manuel Lujan orders an *ex post facto* EIS on dam operations; initiation of GCES Phase II to support EIS preparation.

1990-91	Test flows were used to determine effects of individual flow regimes (Patten 1991).
1991	Interim flows (low hourly change in flow) implemented to protect river resources while EIS is prepared on 1 August; Santa Fe "State of Knowledge" symposium (NAS 1991); razorback sucker listed as endangered.
1992	NAS "Delphi Process" symposium in Irvine, CA to plan long-term monitoring for the Colorado River corridor. Passage of the Grand Canyon Protection Act provides for a speedy resolution of the EIS and balancing environmental protection with economic benefits. Interim flows monitoring first implemented by the Bureau of Reclamation on 1 August 1991, formalized in November 1991.
1994	FWS Biological Opinion concludes that Glen Canyon Dam still jeopardizes native fish.
1995	Final EIS submitted to Secretary of Interior Bruce Babbitt, calling for (1) low flow fluctuations to preserve tributary derived bed sand, (2) planned flooding to restore higher elevation sand bars, (3) adaptive management based on (4) long-term monitoring and cooperative, interagency discussion.
1996	A Beach Habitat Building Flow (BHBF, experimental flood) was conducted from Glen Canyon Dam from 26 March-2 April. The FWS Biological Opinion on the planned flood restricted take of Kanab ambersnail habitat to <10%, and stipulated that no additional planned high flows be conducted until at least one additional KAS population is discovered or established in Arizona. The Secretary's Record of Decision (ROD) is signed, formalizing the flow regime and adaptive management framework.
1997	GCES is replaced by the Grand Canyon Monitoring and Research Center. Flows (27,000 cfs) above the ROD occurred in February/March, and again in mid-summer. The Adaptative Management Work Group (with the Technical Work Group) formally convened as a Federal Advisory Committee. An experimental Habitat Maintenance Flow was conducted in early November.
1998	BHBF flow triggering criteria formalized by AMWG; El Nino's predicted high snowpack failed to materialize; Lake Powell reaches near full pool (3700') in July.

AMWG/TWG

Hyperlink to GCMRC and BOR web pages

GCMRC

Hyperlink to GCMRC web page.

STUDY AREA

The Colorado River Ecosystem Affected by Glen Canyon Dam

Fig. IA1.1: Map of the Colorado River ecosystem under development, 7 December 1998.

Fig. IA1.2: Flow diagram of Colorado River ecosystem processes.

Geography and Boundaries

The Colorado River ecosystem considered by the Secretary of the Interior's 1996 Record of Decision encompasses the mainstream river and its floodplain affected by Glen Canyon Dam, from Lake Powell to the westernmost boundary of Grand Canyon National Park. In addition, the study area includes some analyses of Lake Powell, as well as some aspects of flow, sediment transport, biology and other aspects of some tributaries.

This is a large, dynamic desert river ecosystem, and is an essential water source for much of the Southwest. The Colorado River flows 475 km from the base of Glen Canyon Dam (975 m elevation) to Lake Mead (350 m elevation) through Sonoran and Mohave desert terrain, through lower Glen Canyon and all of Grand Canyon (Turner and Karpiscak 1980). By convention, locations along the Colorado River are designated in river miles from Lees Ferry. The river passes through 13 bedrock-defined geomorphic reaches, and the Paria (km 1) and Little Colorado (km 98) rivers create three turbidity segments (Schmidt and Graf 1990, Stevens et al. 1997b).

Stakeholder Management Objectives

Table IA 1.1: AMWG stakeholder management objectives (revised June 1998). These management objectives (MO's) and information needs (IN's) were prioritized: "O" category represented a general vote on the importance of the category, with a maximum score of 14; "X" category represented a ranking vote within a resource topic of individual IN or MO importance. The status of IN's and MO's were categorized by GCMRC as being monitoring, research, protocol assessment, or administrative in nature.

Resource Category	**Short Name**	**Info Need**	**Mgt Obj**	**O**	**X**	**Monitor or Resch Status**
Ecosytem assessment	Conceptual model	IN 1.1	MO 1:	7	14	R
Aquatic foodbase	Aquatic foodbase - monitor	IN 1.1	MO 1:	10	9	M
Aquatic foodbase	Aquatic foodbase - dam FX	IN 1.2	MO 1:	10	9	R
Aquatic foodbase	Aquatic foodbase for fish	IN 1.3	MO 1:	10	10	R
Trout	Trout population dynamics	IN 2.1	MO 2:	8	9	R
Trout	Trout population trends	IN 2.2	MO 2:	5	5	M
Trout	Trout condition #1	IN 2.3	MO 2:	2	1	M
Trout	Trout spawning habitat availability	IN 2.4	MO 2:	4	4	R
Trout	Trout condition #2	IN 2.5	MO 2:	4	0	M&R
Trout	Trout maintenance RX#1	IN 2.6	MO 2:	4	3	R
Trout	Trout/foodbase trophic dynamics	IN 2.7	MO 2:	3	4	R
Native Fish	HBC population dynamics	IN 3/4.1	MO 3/4:	10	10	M&R
Native Fish	HBC recruitment	IN 3/4.2	MO 3/4:	11	8	M&R
Native Fish	HBC winter survival	IN 3/4.3	MO 3/4:	10	8	R
Native Fish	HBC intrxn with NN fish	IN 3/4.4	MO 3/4:	2	0	R&M
Native Fish	HBC habitat availability	IN 3/4.5	MO 3/4:	10	6	R
Native Fish	HBC protocol and recreation FX	IN 3/4.6	MO 3/4:	2	1	Protocol R
Native Fish	HBC trophic dynamics	IN 3/4.7	MO 3/4:	7	6	R
Native Fish	HBC YOY habitat and NNS interxs	IN 3/4.8	MO 3/4:	7	6	R
Native Fish	HBC population loss to flows	IN 3/4.9	MO 3/4:	6	5	R
Native Fish	HBC good year strategy	IN 3/4.10	MO 3/4:	4	2	Admin.
Native Fish	HBC downstream transport	IN 3/4.11	MO 3/4:	6	3	R
Native Fish	HBC flow-related take	IN 3/4.12	MO 3/4:	9	8	R
Native Fish	HBC flow criteria to limit take	IN 3/4.13	MO 3/4:	8	7	Admin.
Native Fish	Threatened fish - RPM test flows	IN 3/4.14	MO 3/4:	5	4	R
Native Fish	Native fish - mainstream thermal model	IN 5.1	MO 5:	6	2	R
Native Fish	Native fish - thermal mod FX#1	IN 5.2	MO 5:	10	10	R
Native Fish	Native fish - thermal mod FX#2	IN 5.3	MO 5:	14	14	R
Native Fish	Thermal mod impacts on LP fish	IN 5.4	MO 5:	7	2	R
Native Fish	NN fish control - temperature and floods	IN 5.5	MO 5:	9	9	R
Native Fish	HBC population mgt. criteria	IN 6.1	MO 6:	9	8	R
Native Fish	HBC 2nd pop. feasibility study	IN 6.2	MO 6:	9	7	R
Native Fish	RBS 2nd pop. feasibility study	IN 7.1	MO 7:	7	5	R
Native Fish	Native fish pop. status	IN 8.1	MO 8:	9	8	M
Native Fish	Native fish pop. dynamics#1	IN 8.2	MO 8:	7	4	M
Native Fish	Native fish historic pop. dynamics #1	IN 8.3	MO 8:	3	1	M&R

Native Fish	Native fish historic pop. dynamics#2	IN 8.4	MO 8:	5	2	M&R
Native Fish	Native fish flow regime FX	IN 8.5	MO 8:	7	4	R
Native Fish	Native fish maintenance criteria	IN 8.6	MO 8:	7	4	R
Native Fish	Native fish experimental flows design #1	IN 9.1	MO 9:	3	2	R
Native Fish	Native fish experimental flows design #2	IN 9.2	MO 9:	5	1	R
Native Fish	Native fish trib flows and recruitment	IN 9.3	MO 9:	7	3	M&R
Native Fish	Native - NN fish nearshore intrxns	IN 9.4	MO 9:	6	1	R
Native Fish	Native/NN fish intrxns #1	IN 10.1	MO 10:	6	5	R
Native Fish	Native/NN fish intrxns #2	IN 10.2	MO 10:	4	3	R
Native Fish	Native/NN fish mitigation intrxns	IN 10.3	MO 10:	3	3	R
Native Fish	NN fish distrib. and natural history	IN 10.4	MO 10:	5	2	M
Native Fish	Native/NN fish intrxns #3	IN 10.5	MO 10:	6	2	R
Native Fish	Native and NN fish autecology	IN 10.6	MO 10:	6	2	M&R
Riparian	Autecology of riparian species	IN 11.1	MO 11:	9	9	M&R
Riparian	Riparian population variability	IN 11.2	MO 11:	4	6	M&R
Riparian	Riparian SOC population changes	IN 11.3	MO 11:	2	4	M&R
Riparian	Riparian species habitat distribution	IN 11.4	MO 11:	5	7	M&R
Riparian	Riparian habitat map	IN 11.5	MO 11:	5	4	R
Riparian	Monitor leopard frogs	IN 11.6	MO 11:	6	8	R
Riparian	Feasibility of 2nd leopard frog populations	IN 11.7	MO 11:	1	1	Admin.
Riparian	Evaluate amphibian sensitivity	IN 11.8	MO 11:	2	3	R
Riparian	Riparian spp - dam FX on demography #1	IN 12.1	MO 12:	6	8	R
Riparian	Riparian spp - ranges	IN 12.2	MO 12:	1	1	R
Riparian	Riparian spp - age classes	IN 12.3	MO 12:	0	0	R
Riparian	Riparian spp - dam FX on demography #2	IN 12.4	MO 12:	2	2	R
Riparian	Riparian spp - general dam FX	IN 12.5	MO 12:	1	1	R&M
Riparian	Riparian food webs: SOC	IN 13.1	MO 13:	7	7	R&M
Riparian	Riparian food webs: birds	IN 13.2	MO 13:	6	8	R
Riparian	Pefa - aerie distribution	IN 13.3	MO 13:	1	1	R&M
Riparian	Pefa - population dynamics	IN 13.4	MO 13:	2	2	R
Riparian	Bald eagle - dam FX	IN 13.5	MO 13:	3	3	R&M
Riparian	KAS - habitat RX #1	IN 14.1	MO 14:	9	8	M
Riparian	KAS - special flow impacts	IN 14.2	MO 14:	7	7	R&M
Riparian	KAS - habitat RX #2	IN 14.3	MO 14:	8	8	R&M
Riparian	KAS - monitor exceptional flow impacts	IN 14.4	MO 14:	7	7	M
Riparian	KAS - life history schedule	IN 14.5	MO 14:	7	7	R&M
Riparian	KAS - monitor #1	IN 14.6	MO 14:	11	10	R&M
Riparian	KAS - monitor #2	IN 14.7	MO 14:	5	6	M
Riparian	KAS - genetic relationships	IN 15.1	MO 15:	7	5	R
Riparian	KAS - habitat propagation	IN 15.2	MO 15:	6	4	R
Riparian	Riparian veg - distribution: all #1	IN 16.1	MO 16:	5	6	M
Riparian	Riparian veg - distribution: OHW	IN 16.2	MO 16:	4	5	R&M
Riparian	Riparian veg - maintain and restore	IN 16.3	MO 16:	0	0	M
Riparian	Riparian veg - dam FX	IN 16.4	MO 16:	4	4	R&M
Riparian	Riparian veg - life histories	IN 16.5	MO 16:	2	2	R

Riparian	Riparian veg - NNS and dam FX	IN 16.6	MO 16:	4	5	R&M
Cultural	Cultural sites - monitor	IN 1.1	MO 1:	12	13	M
Cultural	Cultural sites - risk assessment	IN 1.2	MO 1:	6	4	R
Cultural	Cultural sites - info needs	IN 1.3	MO 1:	7	7	Admin.
Cultural	Cultural sites - monitor risk	IN 1.4	MO 1:	6	5	R&M
Cultural	Cultural sites - preserve terraces #1	IN 1.5	MO 1:	5	2	M
Cultural	Cultural sites - preserve terraces #2	IN 1.6	MO 1:	6	2	R&M
Cultural	Cultural sites & recreation FX	IN 1.7	MO 1:	1	0	R
Cultural	Cultural sites - mitigation strategies	IN 2.1	MO 2:	9	9	Admin.
Cultural	Cultural sites - data recovery strategies	IN 2.2	MO 2:	5	2	Admin.
Cultural	Cultural sites - characterize dam FX	IN 3.1	MO 3:	9	6	R
Cultural	Cultural site data management	IN 4.1	MO 4:	7	5	Admin.
Socioeconomic	Socioeconomics - monitor hydropower $	IN 1.1	MO 1:			M
Socioeconomic	Socioeconomics - costs of ROD	IN 1.2	MO 1:			M
Socioeconomic	Socioeconomics - research costs	IN 1.3	MO 1:			M
Socioeconomic	Socioeconomics - integrated systems mgt.	IN 1.4	MO 1:			Admin.
Water	Flow - monitor releases	IN 1.1	MO 1:			M
Water	Flow - monitor WQ and dam FX on major ions	IN 2.1	MO 2:	9	9	M
Water	Flow - thermal modification	IN 2.2	MO 2:	6	6	R&M
Sediment	Sediment - historic distribution & flow FX: all #1	IN 1.1	MO 1:	5	7	R&M
Sediment	Sediment - minimum storage for sustainability	IN 1.2	MO 1:	9	11	R
Sediment	Sediment - monitor flow FX by reach	IN 1.3	MO 1:	7	10	R
Sediment	Sediment - monitor inputs: all	IN 1.4	MO 1:	8	10	R&M
Sediment	Sediment - GCNRA bar distribution, sand input	IN 1.5	MO 1:	5	6	R&M
Sediment	Sediment - bar & backwater distribution: '90-91	IN 2.1	MO 2:	1	1	M
Sediment	Sediment - establish baselines	IN 2.2	MO 2:	3	2	Admin.
Sediment	Sediment - monitor sand bar distribution #1	IN 2.3	MO 2:	3	5	R&M
Sediment	Cultural - monitor terraces	IN 2.4	MO 2:	2	3	M
Sediment	Sediment - bar & backwater distribution: model	IN 2.5	MO 2:	3	3	R&M
Sediment	Sediment - bar, backwater and camp distribution	IN 2.6	MO 2:	6	8	R&M
Sediment	Sediment - bar & backwater distribution	IN 2.7	MO 2:	2	5	R
Sediment	Flow - spillway impacts on bed and benthos	IN 2.8	MO 2:	1	1	R&M
Sediment	Backwater distribution: '90-91, 96-97 #1	IN 3.1	MO 3:	4	3	R
Sediment	Backwater distribution: '90-91, 96-97 #2	IN 3.2	MO 3:	3	2	R
Sediment	Sediment - bar & backwater distribution #2	IN 3.3	MO 3:	3	4	R&M
Sediment	Sediment - linkage to biota	IN 3.4	MO 3:	7	8	R
Sediment	Backwater distribution: '90-91, 96-97	IN 3.5	MO 3:	2	3	R

	#3					
Sediment	Backwater distribution: '90-91, 96-97 #4	IN 4.1	MO 4:	6	6	R&M
Sediment	Sediment - model dam FX on bars, backwaters	IN 4.2	MO 4:	4	6	Admin.
Sediment	Sediment - assess dam FX on bars, backwaters	IN 4.3	MO 4:	5	5	Admin.
Sediment	Sediment - monitor inputs: Marble Canyon	IN NH1.	MO 4:	3	3	R&M
Sediment	Sediment - GCNRA high terrace erosion #1	IN NH2.	MO 4:	1	1	R
Sediment	Sediment - monitor inputs: GCNRA	IN NH3.	MO 4:	2	2	R
Sediment	Sediment - GCNRA high terrace erosion #2	IN NH4.	MO 4:	2	1	R&M
Sediment	Sediment - GCNRA bed morphology dynamics	IN NH5.	MO 4:	2	4	R
Sediment	Sediment - GCNRA grain size distribution	IN NH6.	MO 4:	1	1	R
Sediment	Sediment - historic distribution & flow FX: GCNRA	IN NH7.	MO 4:	0	2	R&M
Sediment	Sediment - historic distribution & flow FX: all #2	IN NH8.	MO 4:	2	3	R&M
GIS	GIS - map topography, geology, soils	IN 1.1	MO 1:	1	1	R
GIS	GIS - data archival and storage	IN 1.2	MO 1:	0	2	Admin.
Recreation	Recreation - experience	IN 1.1	MO 1:	4	9	R&M
Recreation	Recreation - monitoring and research impacts	IN 1.2	MO 1:	2	5	R
Recreation	Recreation - mitigate negative flow FX	IN 1.3	MO 1:	4	10	Admin.
Recreation	Recreation - angler satisfaction, use and harvest	IN 1.4	MO 1:	2	3	R&M
Recreation	Water - heavy metal impacts on fish	IN 1.5	MO 1:	0	0	R
Recreation	Recreation - camp distribution,carrying capacity	IN 2.1	MO 2:	1	10	R&M
Recreation	Recreation - dam FX on camp distribution	IN 2.2	MO 2:	6	8	Admin.
Recreation	Recreation - develop campsite monitoring strategy	IN 2.3	MO 2:	1	3	Admin.
Recreation	Recreation - model flow FX on campsites	IN 2.4	MO 2:	2	2	R
Recreation	Recreation safety - boating: GCNRA	IN 3.1	MO 3:	1	3	R&M
Recreation	Recreation safety - boating: all	IN 3.2	MO 3:	3	3	R&M
Recreation	Recreation safety - boating: Grand Canyon	IN 3.3	MO 3:	2	1	R&M
Recreation	Ecosystem Assessment - FX of flows for safety on ecosystem	IN 3.4	MO 3:	1	0	Admin.
Recreation	Recreation - Resource conflicts with day rafting	IN 3.5	MO 3:	2	1	Admin.
Recreation	Trout - flows RX for 100k trout	IN 4.1	MO 4:	2	7	R
Recreation	Waterfowl - hunter use, satisfaction, conflicts	IN 5.1	MO 5:	1	2	R
Lake Powell	Water - Lake Powell WQ	IN 1.1 (Phys)	MO 1:	10	14	R&M
Lake Powell	Water - dam FX on Lake Powell WQ	IN 1.1 (Biol)	MO 1:	5	12	R

	&productivity					
Lake Powell	Water - Lake Powell, selenium impacts #1	IN 1.2	MO 1:	1	0	R
Lake Powell	Water - water temperature impacts in Lake Powell	IN 2.1	MO 2:	1	9	R
Lake Powell	Lake Powell - dam FX on surface flux impacts	IN 2.2	MO 2:	0	1	R&M
Lake Powell	Water - Lake Powell, selenium impacts #2	IN 2.3	MO 2:	0	0	R
Lake Powell	Lake Powell - dam FX on advective flow	IN 2.4	MO 2:	0	1	R&M
Lake Powell	Lake Powell - fish: dam FX on pred-prey rels.	IN 2.5	MO 2:	1	1	R
Lake Powell	Lake Powell - fish: dam FX on movement	IN 2.6	MO 2:	1	5	R
Aquatic foodbase	Fisheries - habitat distribution: mainstream+ tribs	IN 1.7 (App.)	MO 1:	1	3	R
Aquatic foodbase	GIS - aquatic habitat map by stage	IN 1.8 (App.)	MO 1:	1	1	R
Aquatic foodbase	Fisheries - dam FX on habitat distribution	IN 1.9 (App.)	MO 1:	2	4	R
Aquatic foodbase	Aquatic foodbase - exposure FX	IN 1.10 (App.)	MO 1:	2	3	R
Aquatic foodbase	Aquatic foodbase - dam FX on hyporheic comms.	IN 1.11 (App.)	MO 1:	0	0	R
Aquatic foodbase	Water - selenium impacts on benthos/hyporheic	IN 1.12 (App.)	MO 1:	1	0	R
Native fish	FMS spawning hab. distrib. #1: recruitment	IN 1. (App.)	MO 8:	3	1	R&M
Native fish	FMS adult origins	IN 2. (App.)	MO 8:	2	2	R&M
Native fish	FMS spawning hab. distrib. #2: Glen Canyon	IN 3. (App.)	MO 8:	3	1	R&M
Native fish	FMS mechanisms of spawning failure	IN 4. (App.)	MO 8:	2	1	R
Native fish	Native fish - FMS dam FX on recruitment	IN 5. (App.)	MO 8:	3	2	R
Native fish	Native fish - spawning and trib. Mouths	IN 6. (App.)	MO 8:	2	1	R&M
Native fish	Aquatic foodbase - dam FX on distribution	IN 7. (App.)	MO 8:	0	0	R&M
Native fish	Native fish - FMS habitat RX	IN 8. (App.)	MO 8:	1	0	R
Native fish	Native fish - FMS spawning hab. distrib. #3: site fidelity	IN 9. (App.)	MO 8:	1	0	R&M
Native fish	Native fish - MS spawning hab. Distrib. #4: historic use	IN 10. (App.)	MO 8:	0	0	R&M
Native fish	Native fish - FMS population model	IN 11. (App.)	MO 8:	2	1	R
Native fish	Native fish - FMS habitat modification RX	IN 12. (App.)	MO 8:	1	0	Admin.
Native fish	Native/NN fish intrxns #4	IN 13. (App.)	MO 8:	2	0	R
Native fish	Water - selenium FX on native fish	IN 14. (App.)	MO 8:	0	0	R

GCMRC Monitoring and Research Activities in 1998

Hyperlink to GCMRC model pages

Conceptual model development

Hyperlink to GCMRC model pages

Flow and Resource Triggering Criteria for High Flow Events

Physical Criteria for Triggering High Releases

Hyperlink to Flow Triggering Criteria for floods (R. Peterson)

Resource Criteria Triggering High Flows.

Hyperlink to Resource Triggering Criteria for floods (B. Ralston, R. Winfree)

Protocol and Remote Sensing Review

Hyperlink to PEP (T. Melis and M. Liszewski, Coordinators)

Hyperlink to June 1998 Remote Sensing Workshop Report

Information Management

Hyperlink to GCMRC homepage

PHYSICAL RESOURCES AND PROCESSES

Colorado River Corridor Climate
  Phantom Ranch Air Temperature
  Phantom Ranch Precipitation

Mainstream Hydrology
  Historical flows at Lees Ferry, Water Years 1921-1998
  Flows at Lees Ferry, Water Years 1996-1998
  Ramping Rates at Glen Canyon Dam, Water Years 1996-1998

Tributary Flows
  Paria River, Water Years 1924-1998
  Little Colorado River, Water Years 1948-1998

Mainstream Sediment Transport, Sand Bar Erosion and Campsite Availability
  Channel Sand Storage, 1990-1998
  Paria River Sediment Input, Water Year 1991-1998
  Sand Bar Volume and Area Changes, 1991-1998

Debris Fans and Rapids

GCMRC 1998 Monitoring and Research Projects

Colorado River Corridor Climate

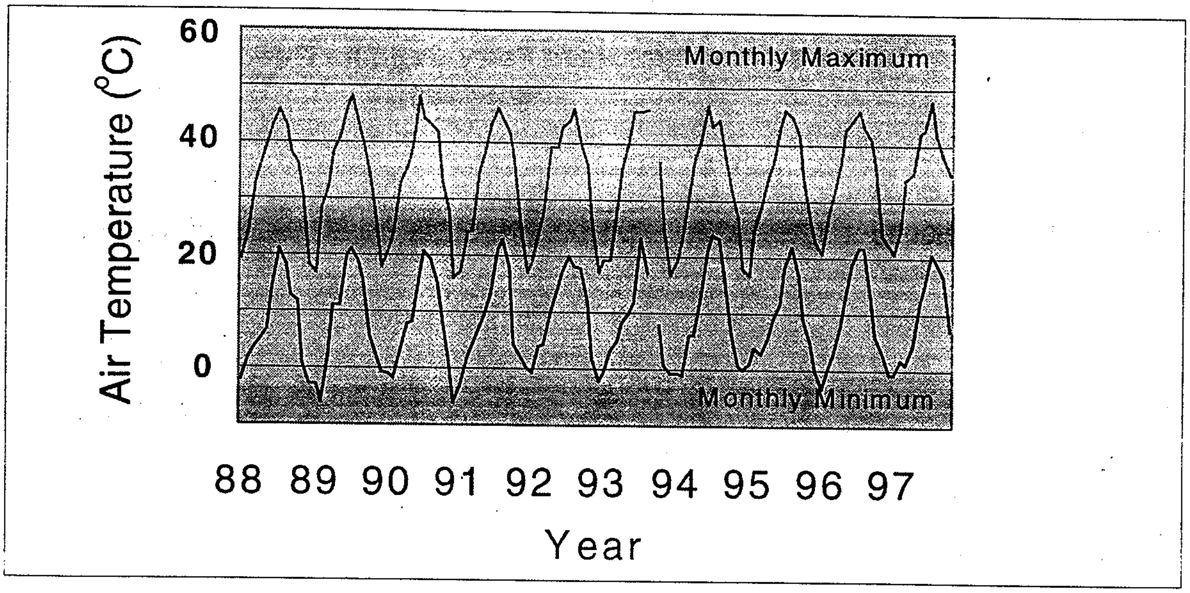


Figure P1.1: Monthly minimum and maximum air temperatures (°C) at Phantom Ranch, Grand Canyon National Park, 1988-1997. Data from NOAA, updated 4 December 1998.

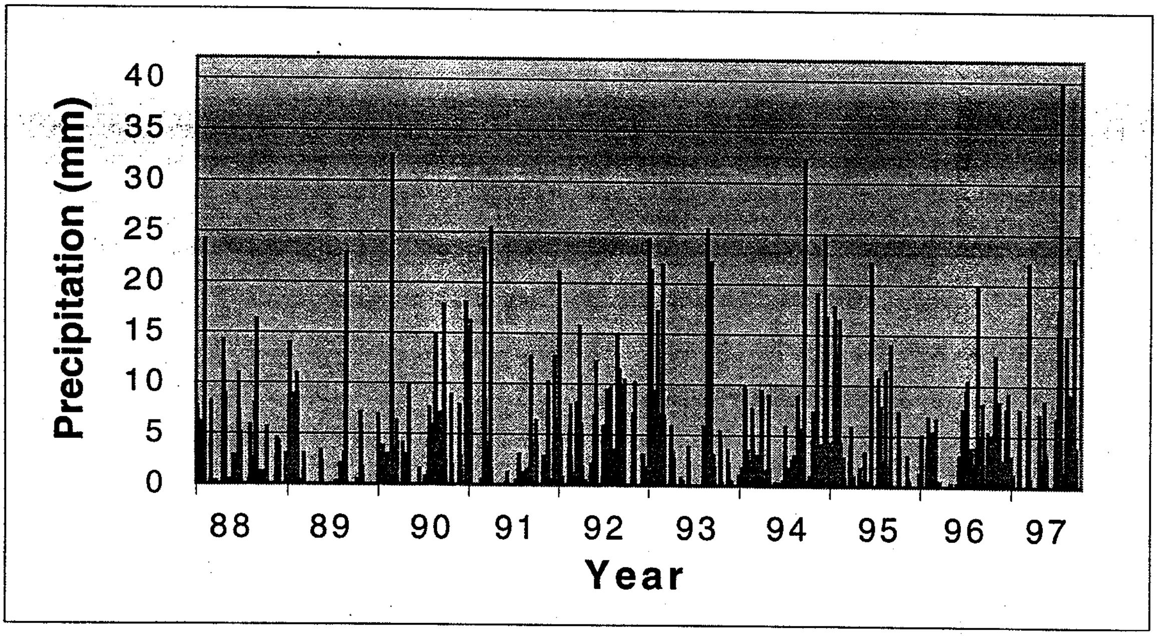
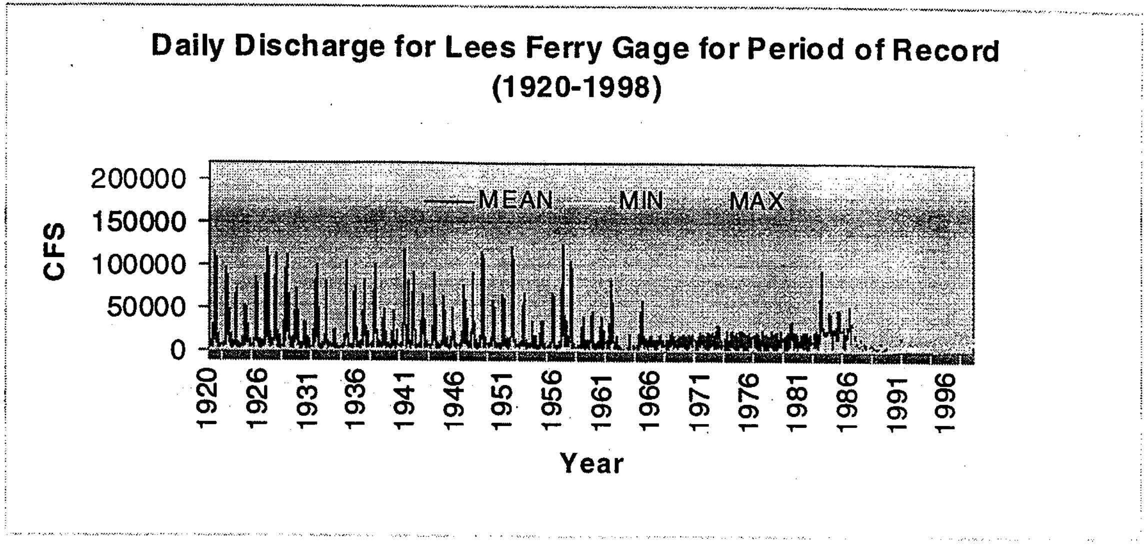


Figure P1.2: Daily precipitation (mm) at Phantom Ranch, Grand Canyon National Park, 1988-1997. Data from NOAA, updated 4 December 1998.



P2.1: Mean daily flow at Lees Ferry, Arizona, 1921-1998. Daily minimum and maximum flow data are presented from 1987-1998. Data from USGS, updated 6 December 1998.

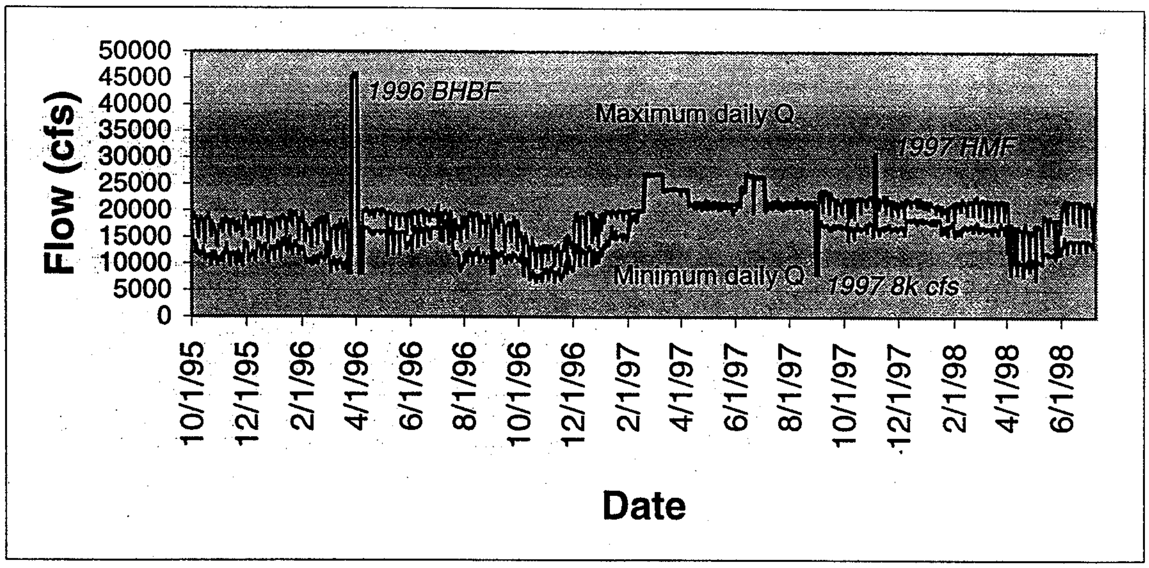


Figure P2.2: Minimum and maximum daily flow (cfs) at the U.S.G.S. streamflow gauge at Lees Ferry, AZ, Water Years 1996-1998. Data from USGS; updated 6 December 1998.

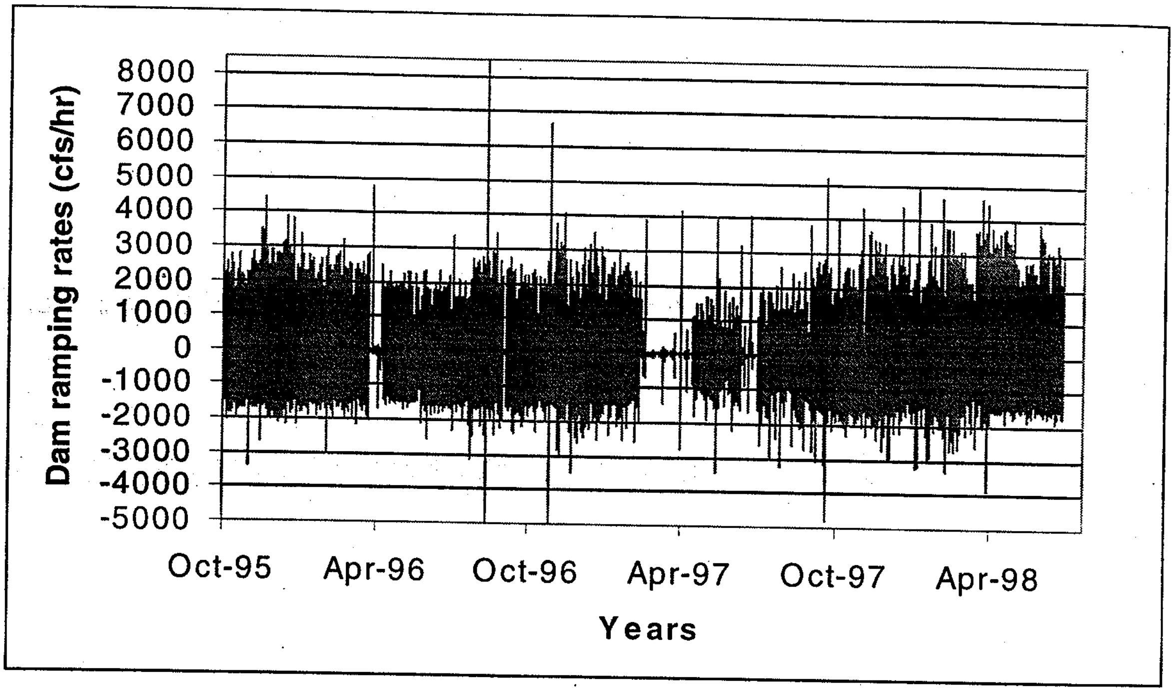


Fig. P2.3: Daily minimum and maximum ramping rates (cfs/hr), Water Years 1996-1998. Data courtesy of W. Vernieu from Bureau of Reclamation SCADA; updated 6 December 1998.

Mainstream FY 1996-98 Hydrograph: Discharge from Glen Canyon Dam from 1995 through 1998 reflects continuing transition from Interim Flows to ROD management strategies, and a transition from a relatively normal year to a high inflow year (Fig. P2.1-2.2). Dam releases in 1996 generally varied between 8,000 cfs and 19,000 cfs, with higher fluctuating flows predominating prior to, and after the 1996 BHBF. During the late March/early April Test Flow, discharge was maintained at 45,000 cfs for 7 days. Lower mean and fluctuations in the autumn of 1996. High snowpack accumulation in the Rocky Mountains in the winters of 1996-98 increased the likelihood of surplus runoff into Lake Powell, and discharge levels from Glen Canyon Dam were increased to constant 27,000 cfs in late February and March 1997. High constant flows of 24,000 predominated in March and April, and was maintained at nearly constant flows of 20,000 to 21,000 cfs from May through August 1997. A 3-day constant 8,000 cfs flow experiment was conducted from August 30 through 1 September (Labor Day) 1997 to compare sandbar size and distribution with that of previous years. The 31,000 cfs HMF was conducted in November 1997, and winter flows were kept at high levels to create additional storage in Lake Powell in anticipation of high spring inflows.

Flows in 1998 were generally high and steady to prevent spills from Lake Powell. A constant 15,000 cfs constant flow was conducted over the Labor Day weekend for aerial photography of the river corridor. Ramping rates exceeded ROD levels several times in 1998, but with no detectable effect downstream (Fig. P2.3).

Tributary Flows

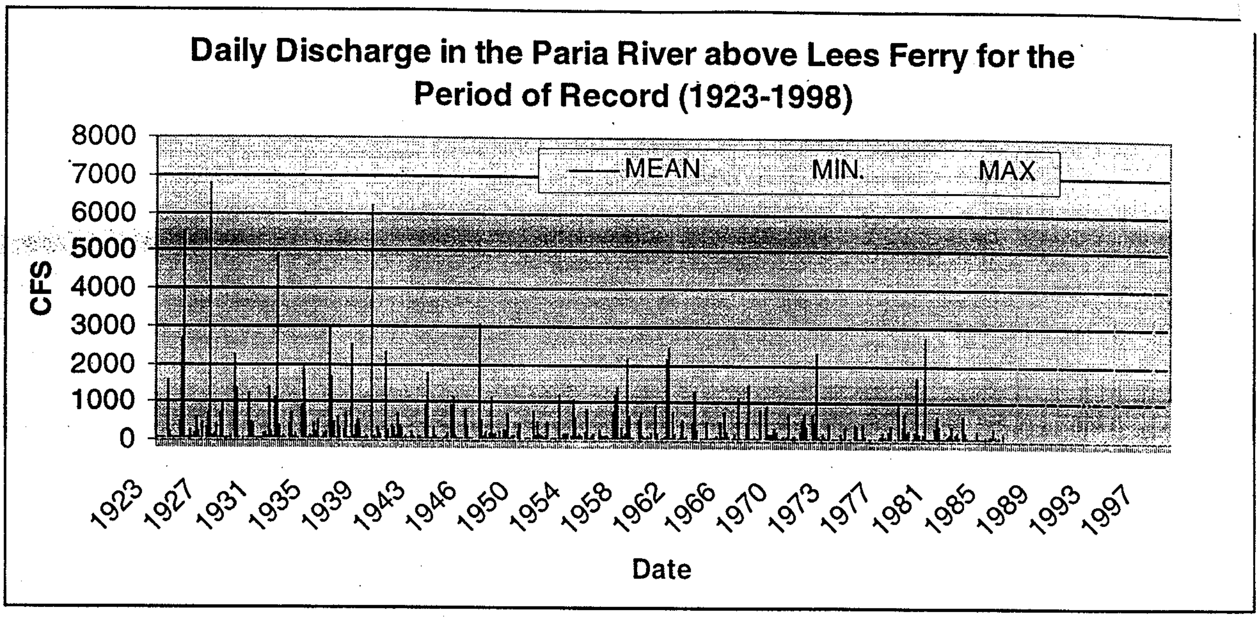


Fig. P3.1: Paria River flow, 1924-1998. Data from the USGS, updated 6 December1998.

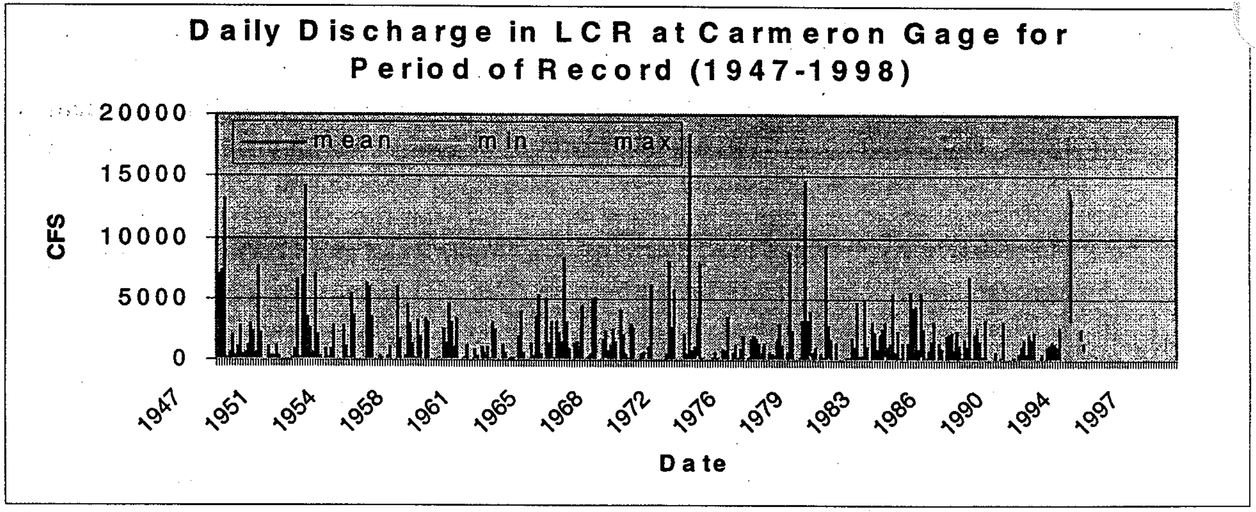


Fig. P3.2: Daily mean flow of the Little Colorado River at Cameron, AZ, 1947-1998. Minimum and maximum flow data are presented from 1995-1998. A record historical flow of approximately 100,000 cfs occurred on the LCR in August 1923. Data from USGS, updated 6 December 1998.

Mainstream Sediment Transport, Sand Bar Erosion and Campsites

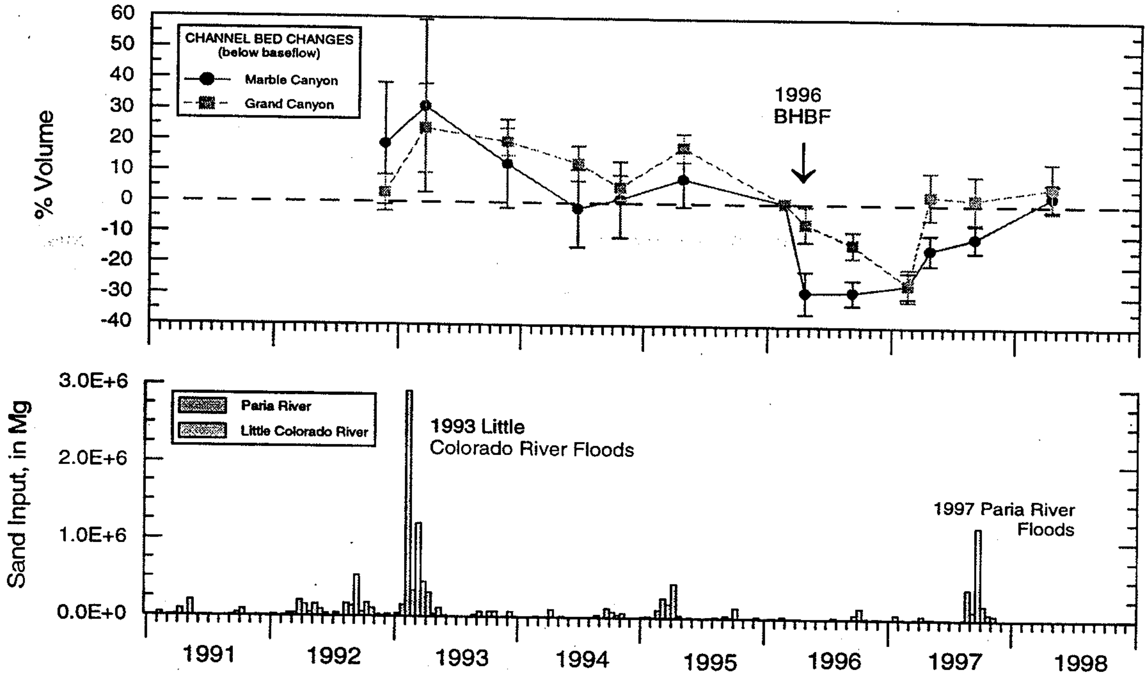


Figure P4.1: Upper graph - channel sand storage above river mile 61(Marble Canyon) and below the Little Colorado River confluence, 1991-1998. Lower Graph – estimated sand inputs from the Paria and Little Colorado rivers, Water Years 1991-1997, using the Randle and Pemberton rating curves. Data from Kaplinski et al. (1998), courtesy of J. Hazel, NAU Geology Department, updated 1 July 1998.

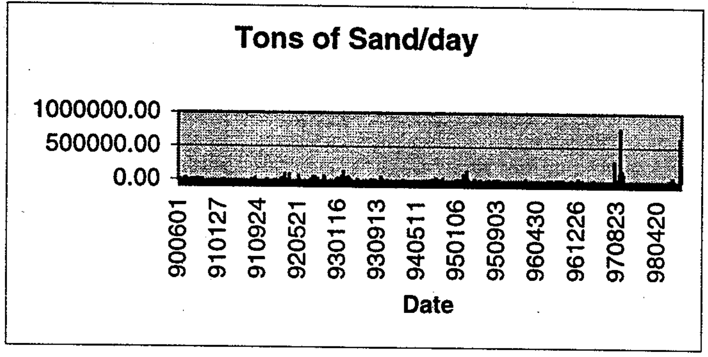
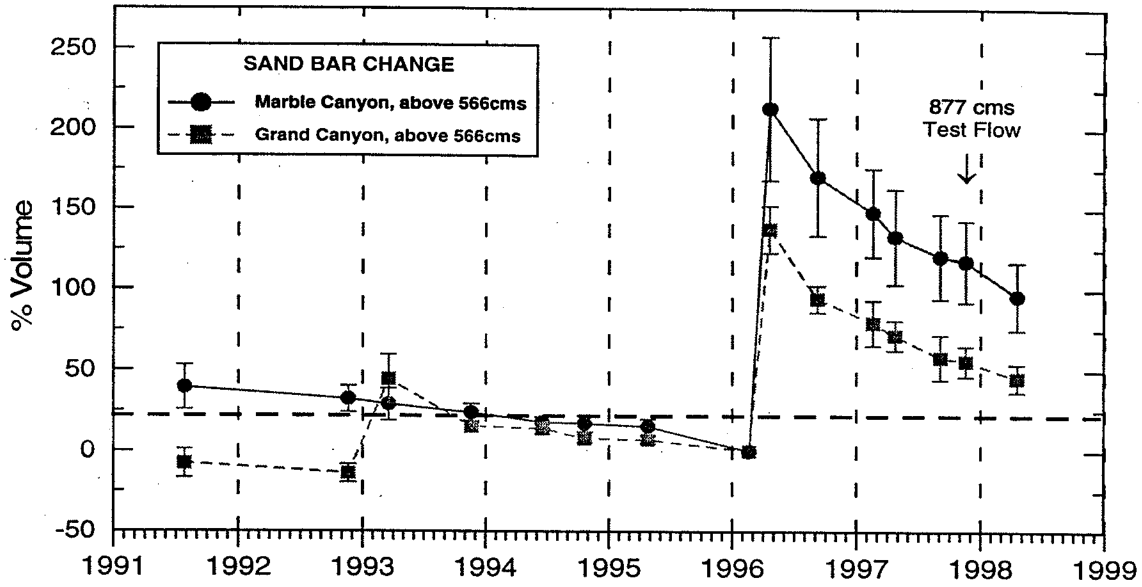
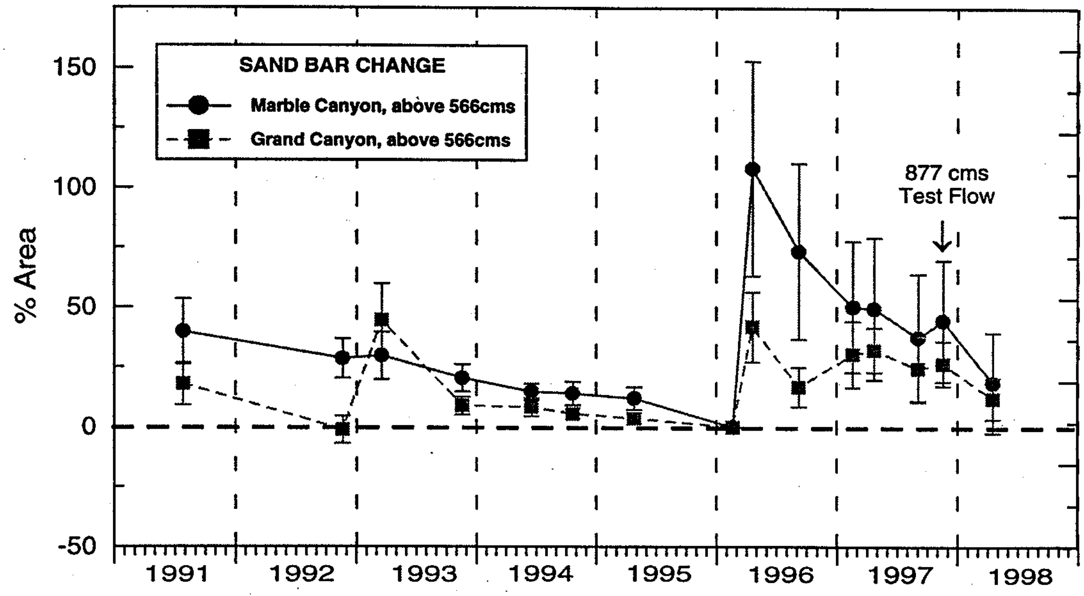


Fig. P4.2: Sediment discharge from the Paria River, Water Years 1990-1998, showing exceptional sand inputs from summer monsoon storms in late summer of 1997 and 1998.

Paria River Sediment Transport: Topping (1997 and draft USGS report) reassessed Paria River sediment transport, and developed an improved model of sand, silt and clay transport. He tested this model on exceptional discharge events during 4 large floods in August and September 1997, which ranged up to 115 m^3/s and delivered 2.2 million tons of sand and 2.7 million tons of silt and clay to the Colorado River. Paria River flows during August and September 1998 exceeded those in 1997, adding much additional sediment to the mainstream in the Marble Canyon reach.

Fig. P4.3 (below): Sand bar volume (upper graph) and area (lower graph) upstream and downstream from the Little Colorado River, 1990-1998. Error bars are ± 1 se. Data courtesy of J. Haze, M. Kaplinski and R. Parnell, NAU Geology Dept., updated 6 December 1998.





Mainstream Sand Bars and Campsites: In 1996 the Bureau of Reclamation conducted an experimental flood from Glen Canyon Dam. A flow of 45,000 cfs was maintained for 7 days in late March and early April, and the results of the flood are still being monitored. This large scale experiment was conducted successful in creating and rejuvenating many new sand bars. Sand bars were typically built to a higher stage elevation, but bar area generally decreased. Although successful as a sand management event, the 1996 event was not of sufficient magnitude to rejuvenate the large return current backwaters, which are believed to be important to early life stages of native fish. The results of the 1996 experimental BHBF are being compiled and presented in two large syntheses: an American Geophysicists Union monograph (edited by R.H. Webb and J.C. Schmidt), and an Invited Feature in Ecological Applications (edited by D.T. Patten and L. E. Stevens).

In addition, various papers are being presented in other peer-reviewed journals. In one such paper, Rubin et al. (1998) reported that flood deposits produced by the 1996 experimental BHBF, as well as those from pre-dam terraces, coarsen upwards. This pattern indicates that fine sediment supplies are depleted during Grand Canyon floods. One implication of these findings is that future planned floods may need to be of shorter duration to prevent excess export of fine sediments.

Long-term data on the status of Grand Canyon sand bars are being synthesized. Grams and Schmidt (1998) present a synthesis of existing information on the status of six sites for which historical information is available. Their study sites are in wide reaches of the river from Mile 44 (above the Little Colorado River (LCR) confluence) to Mile 68.4 (below the LCR confluence). Their sources of data include analyses of aerial photography, bar cross-section data compiled by Howard and Dolan (1981), and the results of sand bar topographic monitoring projects by Northern Arizona University (e.g., Kaplinski *et al.* 1998). Schmidt (1992) demonstrated progressive loss of sand bar area and volume at Badger Rapid over the period of record, but Grams and Schmidt (1998) conclude that sites farther downstream do not shown progressive losses in either bar volume or area over post-dam time. They conclude that the bars being monitored by NAU do characterize system dynamics, but the unique morphology and sediment storage characteristics of individual eddies suggests that monitoring of sand bar erosion should be conducted at multiple sites.

Recent side-scan SONAR and other analyses indicate that little sand is stored on the channel bed outside of eddies (T. Melis, GCMRC Physical Program Manager, personal communication). Even large contributions of sand, such those from recent Paria River floods, appear to move rather rapidly through the channel.

Fig. 4.4: Campsite data under analysis, 6 December 1998.

Debris Fans and Rapids

Fig. P5.1: Analyses underway, 6 December 1998.

Recent Debris Flows in Grand Canyon: Debris flows are extraordinary floods in which large quantities of rock and other debris slurry down tributary canyons, sometimes reaching the Colorado River. The more than 500 tributaries in the lower Glen Canyon and Grand Canyon segments of the Colorado River sustain debris flows, on average, about every 20-200 years. Recently, Webb et al. (in press) reviewed Grand Canyon debris flow activity and mapped debris flow frequency in all the tributaries of Grand Canyon.

Debris fans at tributary confluences with the mainstream are primarily responsible for all but two of the Colorado River's world-renown whitewater rapids. Glen Canyon Dam has reduced the likelihood of exceptionally large flows (≥100,000 cfs), flows which in pre-dam time cleared rapids of tributary debris. Therefore, a continuing concern exists regarding the increasing navigational severity of Grand Canyon rapids. On average, several debris flows reach the Colorado River each year, and 1998 was no exception. Large debris flows occurred in the lower Grand Canyon in August and September 1998. A large debris flow at 194 Mile Canyon in mid-August narrowed the river considerably, but failed to create new navigational difficulties.

GCMRC Monitoring and Research Projects, 1998

Hyperlink to GCMRC Homepage

BIOLOGICAL RESOURCES

- **Aquatic Biological Resources**

  - **Water Quality**
    - **Lake Powell**
    - **Downstream Colorado River**

  - **Aquatic Foodbase**

  - **Fish Habitats**

  - **Native Fish**
    - **Endangered Native Fish**
      - **Humpback Chub**
      - **Razorback Sucker**
    - **Non-endangered Native Fish**
      - **Flannelmouth Sucker**
      - **Bluehead Sucker**
      - **Speckled Dace**

  - **Non-native Fish**
    - **Rainbow Trout**
    - **Other Non-native Fish**

- **Terrestrial Ecosystems**
  - **Riparian Nutrient Dynamics**
  - **RiparianVegetation**
    - **Hydro-Riparian Vegetation (Fluvial Marshes)**
    - **Lower Riparian Zone Vegetation**
    - **Upper Riparian Zone Vegetation**

- **Species of Special Concern**
  - **Endangered Species**
    - **Kanab Ambersnail**
    - **Humpback Chub**
    - **Razorback Sucker**
    - **Bald Eagle**
    - **Peregrine Falcon**
    - **Southwestern Willow Flycatcher**
  - **Non-Endangered Arizona State Species of Concern**
    - **Niobrara Ambersnail**
    - **Northern Leopard Frog**
    - **Osprey**
    - **Belted Kingfisher**

Water Quality

Lake Powell

Hyperlink to Lake Powell Home Page

Downstream Colorado River

Hyperlink to Lake Powell Home Page

AQUATIC BIOLOGICAL RESOURCES

Aquatic Foodbase: Glen Canyon Reach

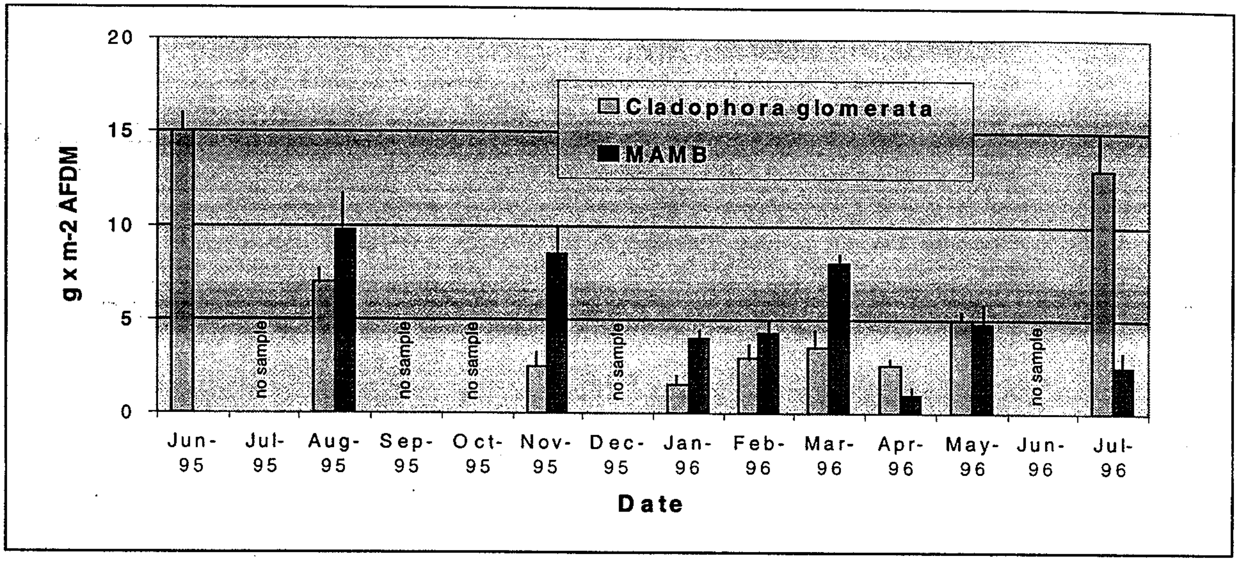


Figure AB1.1 : Average ash-free dry mass (AFDM, g C/m2 ± 1 se) of *Cladophora glomerata* and other macrophytes from benthos collections at Lees Ferry cobble bar, June 1995 - August 1996 (Shannon, 1996). Updated 1 July 1998.

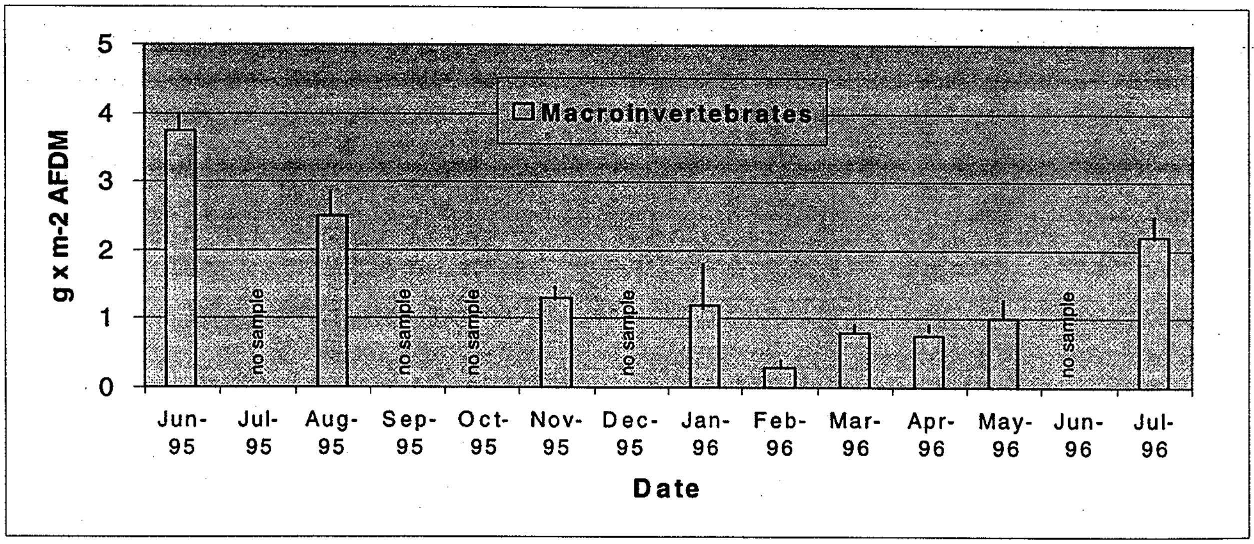


Figure AB1.2: Average ash-free dry mass (AFDM, g C/m2 ± 1 se) of macroinvertebrates from benthos collections at Lees Ferry cobble bar, June 1995 - August 1996 (Shannon, 1996). Updated 1 July 1998.

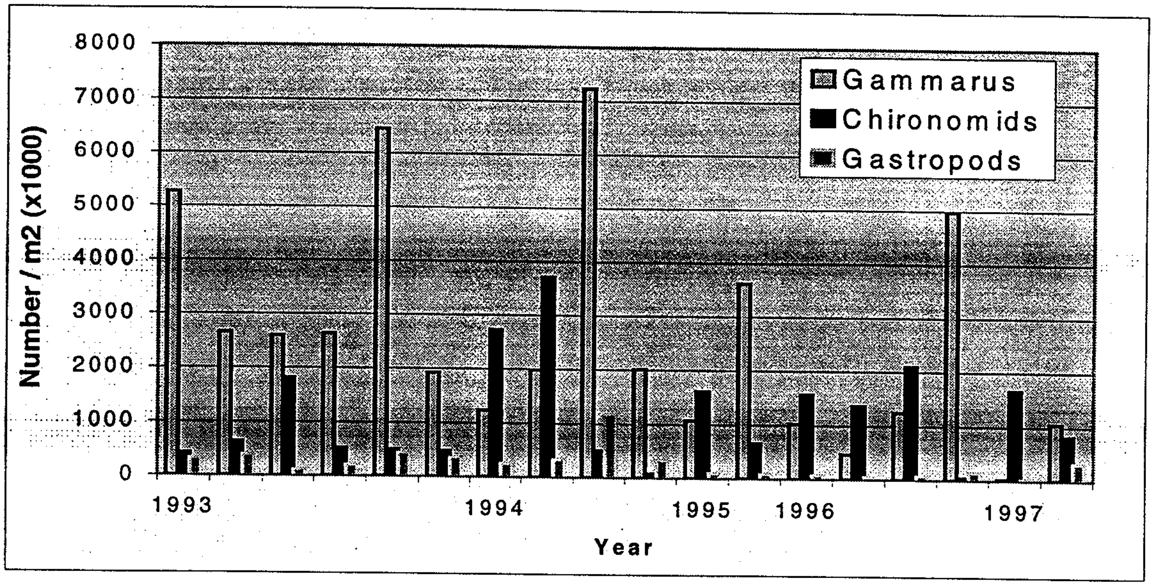


Figure AB1.3: Density of macroinvertebrates ((no./m2) x 1000)) in the Glen Canyon Reach, 1993-1997 (Arizona Game and Fish Department). Updated 1 July 1998.

Grand Canyon benthos through space and time

Fig. AB1.4: Analyses underway, 3 December 1998.

Grand Canyon drift

Fig. AB1.5: Analyses underway, 3 December 1998.

Aquatic Habitat

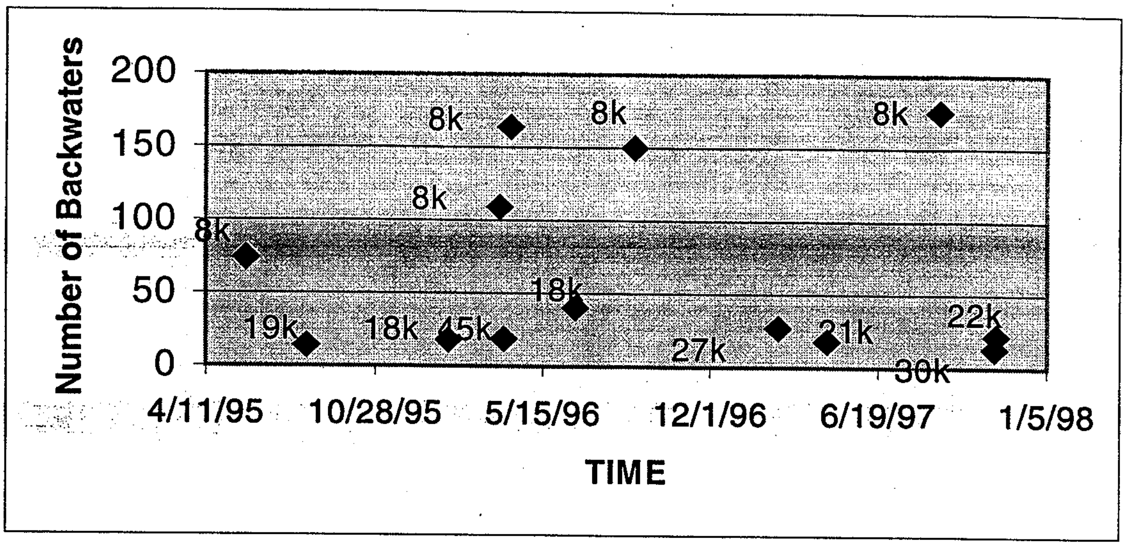


Fig.AB2.1: The number of backwaters between Lees Ferry and Diamond Creek, 1995-1997. Numbers represent discharge levels associated with backwater measurements. For example, 8k = 8,000 cfs. Draft data from Stevens and Hoffnagle (pers. comm.). 3 December 1998.

Native Fish

Endangered Humpback Chub (CYPRINIDAE: *Gila cypha*)
Hyperlink to Species of Concern, 3 December 1998.

Endangered Razorback Sucker (CATOSTOMIDAE: *Xyrauchen texanus*)
Hyperlink to Species of Concern, 3 December 1998.

Flannelmouth Sucker
CATASTOMIDAE: *Catostomus latipinnis*

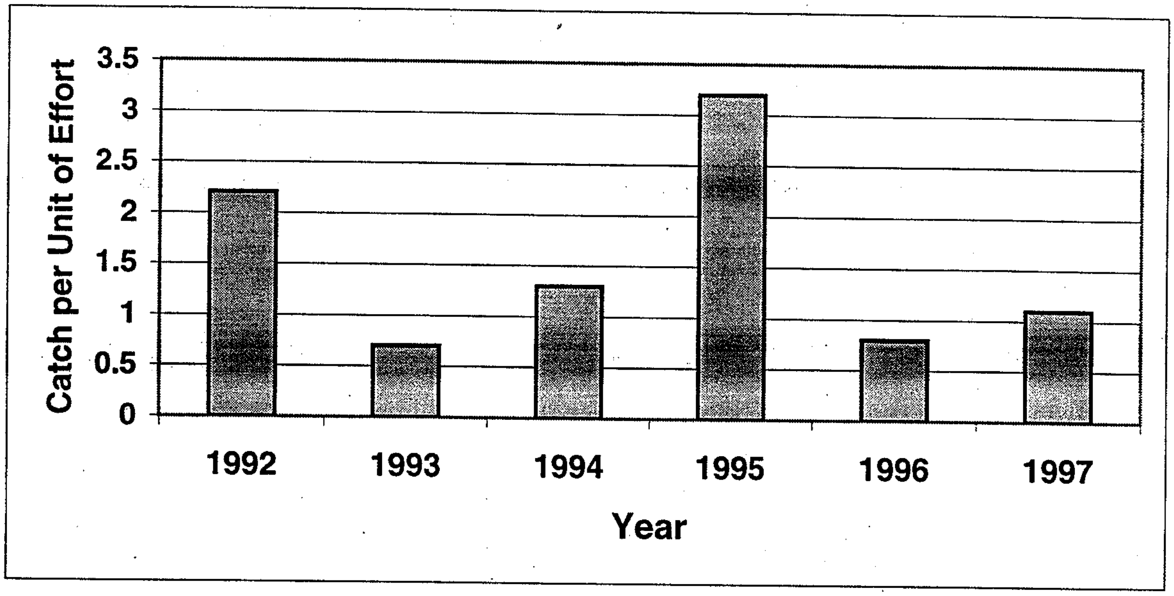


Figure AB3.1: Catch per unit of effort of flannelmouth sucker in the Glen Canyon reach, 1992-1997 (Ted McKinney AGFD, unpublished data). Updated 1 July 1998.

OTHER NATIVE FISH SPECIES:

BLUEHEAD SUCKER
CATOSTOMIDAE: *Catostomus discobolus*

Fig. AB3.2: Data compilation underway, 3 December 1998.

SPECKLED DACE
CYPRINIDAE: *Rhinichthys osculus*

Fig. AB3.3: Data compilation underway, 3 December 1998.

Speckled Dace Species Account

Little synthesis of previously collected data has been attemped for speckled dace in Grand Canyon. This is the most common native fish species in the mainstream and in most tributaries. Little is known about population size, distribution, reproductive success, movement, genetics of several potential subspecies, or survival of this species. Because of its widespread distribution and abundance, it may serve as a regional indicator species of ecological health of the various Grand Canyon fish habitats.

RAINBOW TROUT
SALMONIDAE: *Oncorhynchus mykiss*

Trout in the Glen Canyon Reach

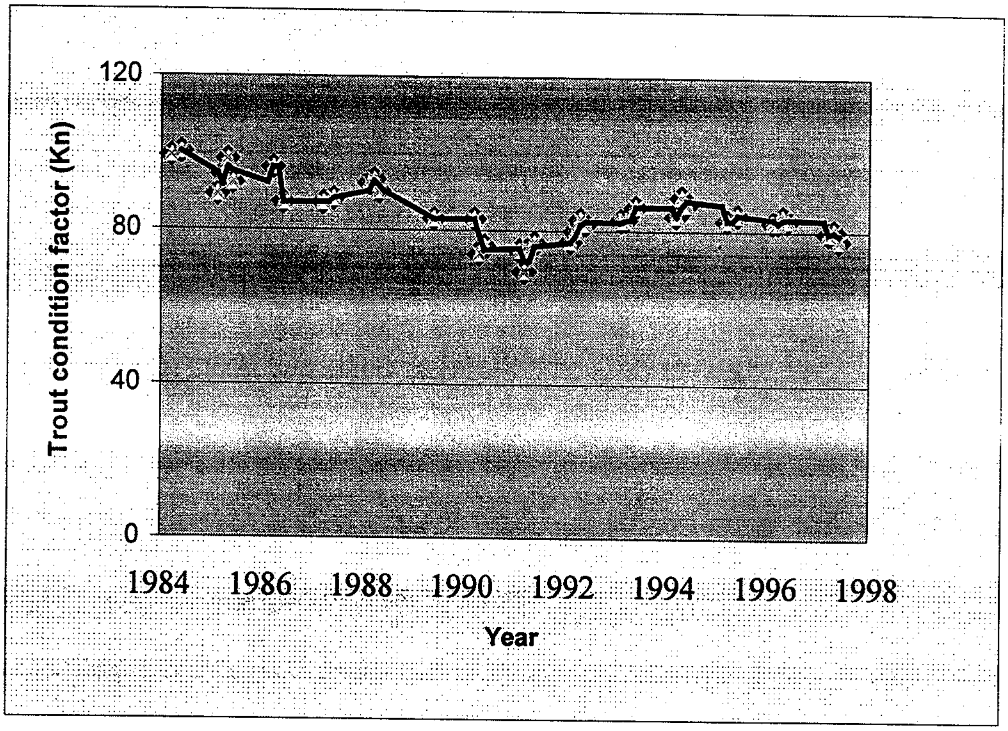


Figure AB4.1: Trout condition factor ((length^3/weight)x10000) in the Glen Canyon reach, 1984-1997 (Arizona Game and Fish Department).

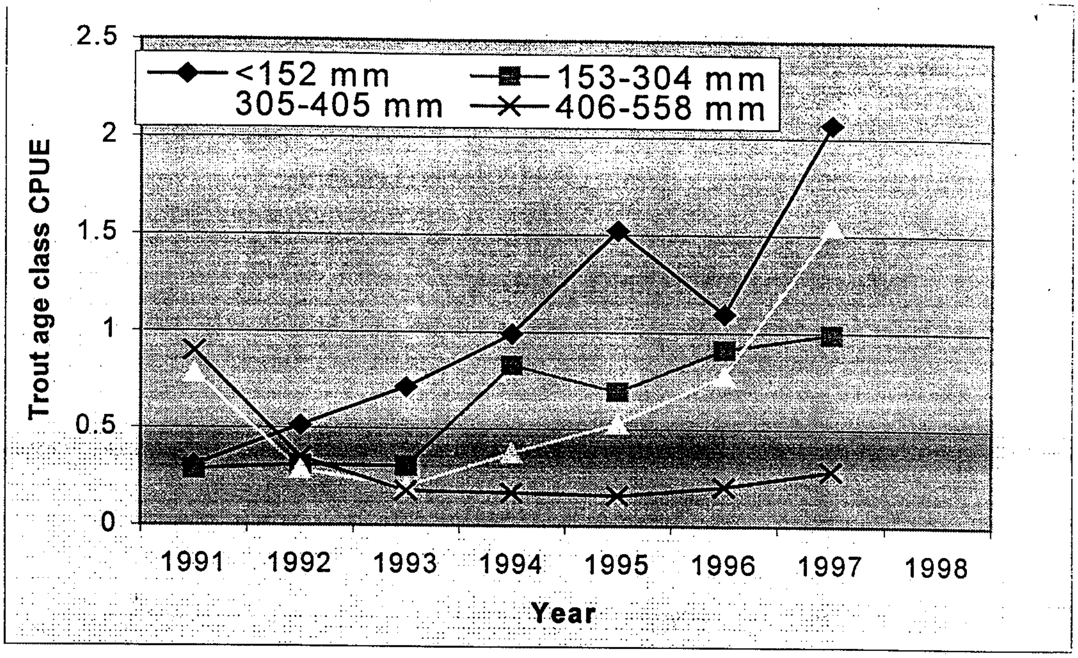


Fig. AB4.2: Rainbow trout catch per unit of effort by size class in the Glen Canyon Reach, 1991–1998 (data courtesy of theArizona Game and Fish Department; updated 1 July 1998).

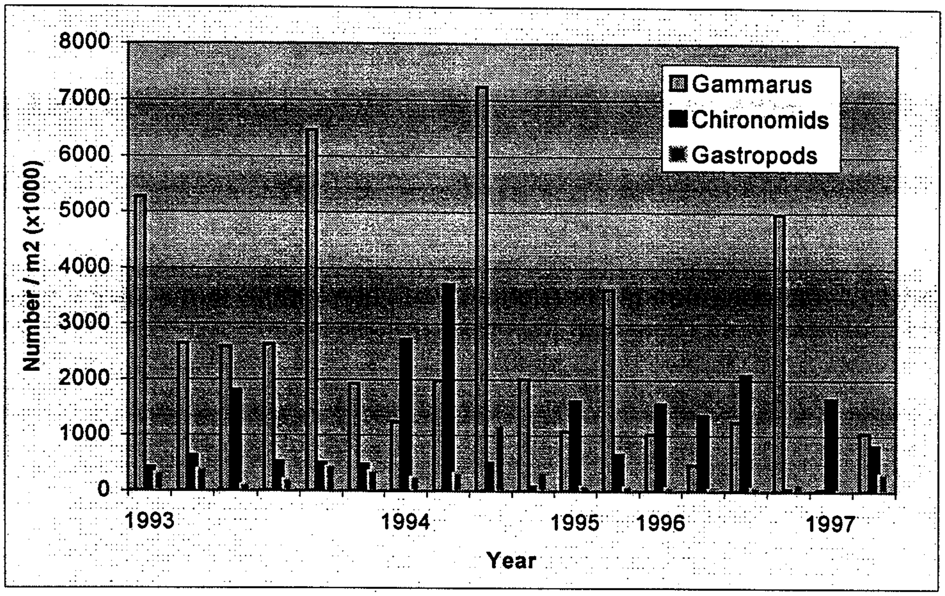


Fig. AB4.3: Density of macroinvertebrates [number / m2(x1000)] in the Glen Canyon Reach, 1993-1997 (data courtesy of the Arizona Game and Fish Department; updated 1 July 1998).

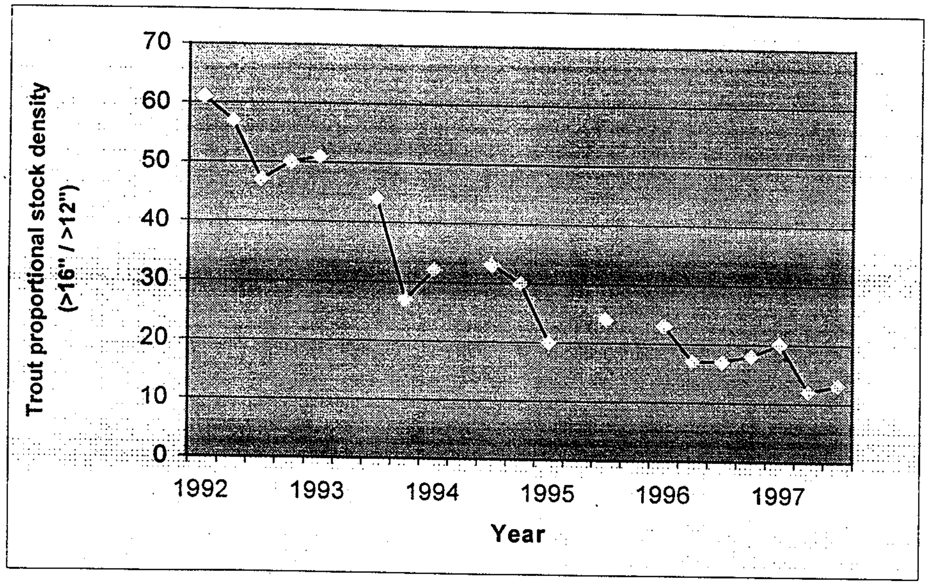


Fig. AB4.4: Proportional stock density (the proportion of fish over 12 inches of quality size (16 inches) to anglers) in the Glen Canyon Reach, 1992-1997 (data courtesy of the Arizona Game and Fish Department; updated 1 July 1998).

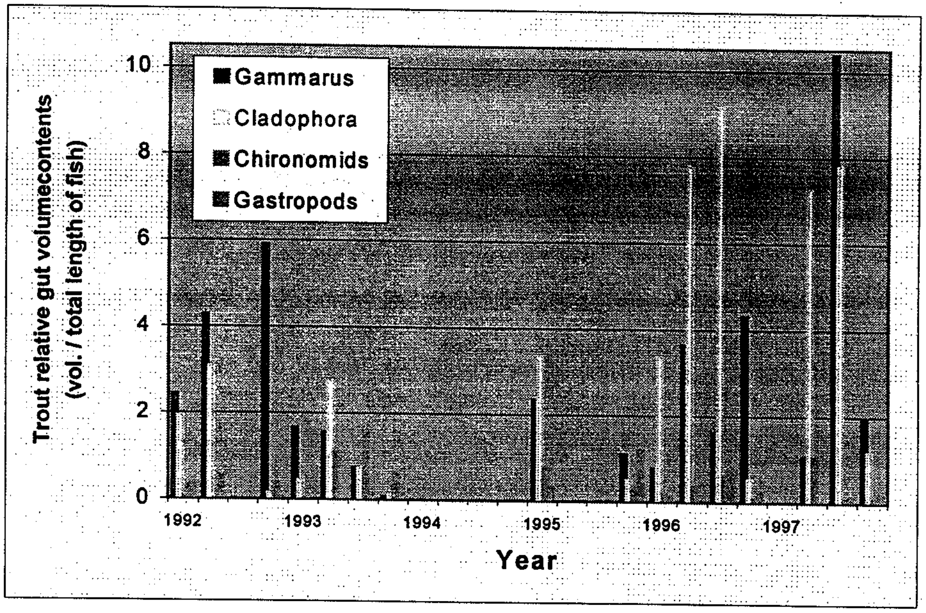


Fig. AB4.5: Relative volume (volume/ total length of fish) of macroinvertebrates in trout gut contents in the Glen Canyon Reach, 1992-1997 (data courtesy of the Arizona Game and Fish Department; updated 1 July 1998).

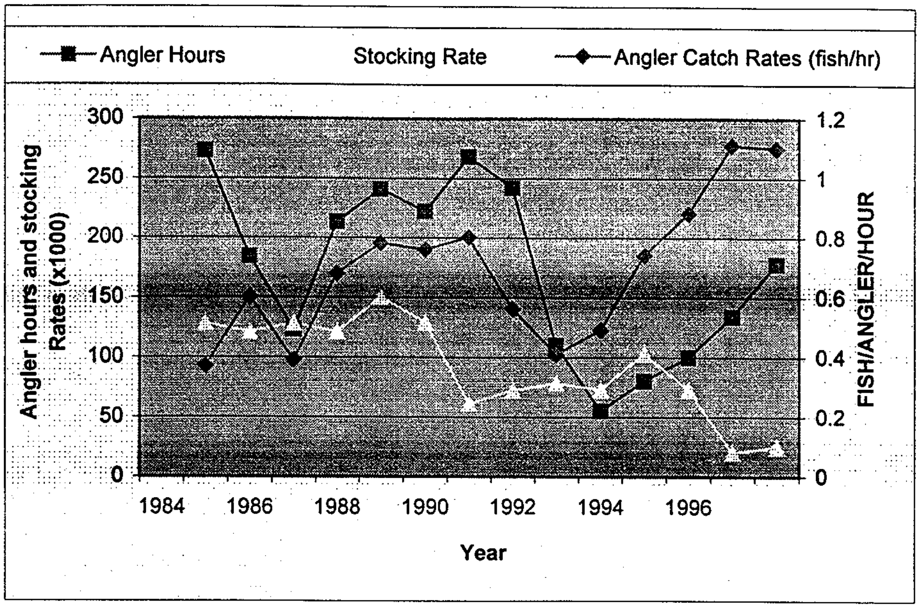


Fig. AB4.6: Angler catch rates compared with angler hours and rates of stocking in the Glen Canyon reach, 1984-1998 (data courtesy of the Arizona Game and Fish Department; updated 1 July 1998).

OTHER NON-NATIVE FISH SPECIES

Fig. AB5.1: Analyses underway, 03 December 1998.

Aquatic Biological Resources Monitoring Projects

Hyperlink to GCMRC Projects page

TERRESTRIAL BIOLOGICAL RESOURCES

Riparian Nutrient Dynamics

Research by Parnell et al. (1997) revealed that the 1996 test flood buried large quantities of sand bar vegetation, and decomposition of that material substantially increased soil and bank-stored groundwater nitrogen and carbon, but not ortho-phosphate, concentrations. Their analyses of carbon and nitrogen dynamics indicate that bank storage may strongly influence mainstream nutrient concentrations. Springer et al. (1997) demonstrated that slight gradients of directional groundwater movement are established under prolonged constant flows. Constant flows ≥20,000 have dominated the post-test flood hydrograph.

Hydro-Riparian Vegetation: Fluvial Marshes

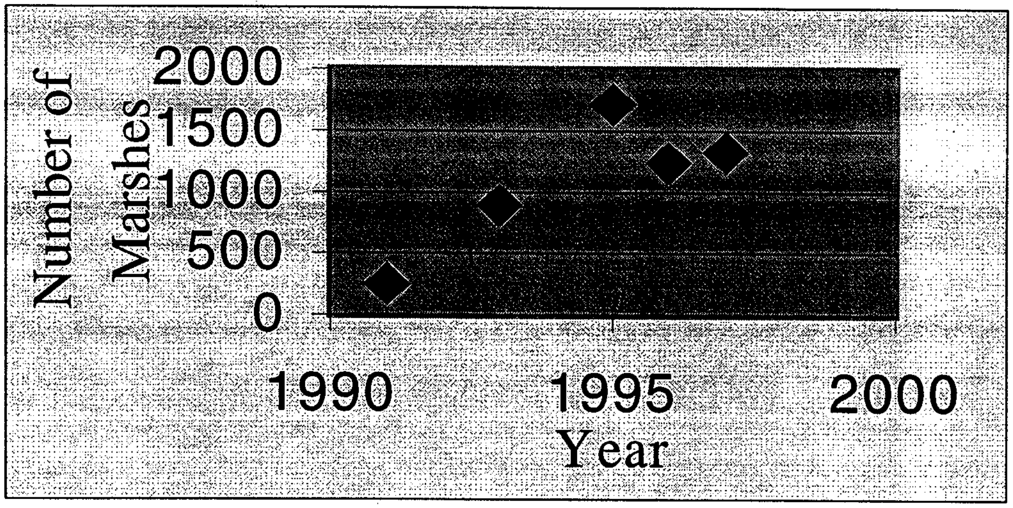


Fig. TB1.1: Estimated number of marsh patches along the Colorado River from Lees Ferry to Diamond Creek, 1991-1997 (draft data from L. Stevens, GCMRC). Updated 3 December 1998.

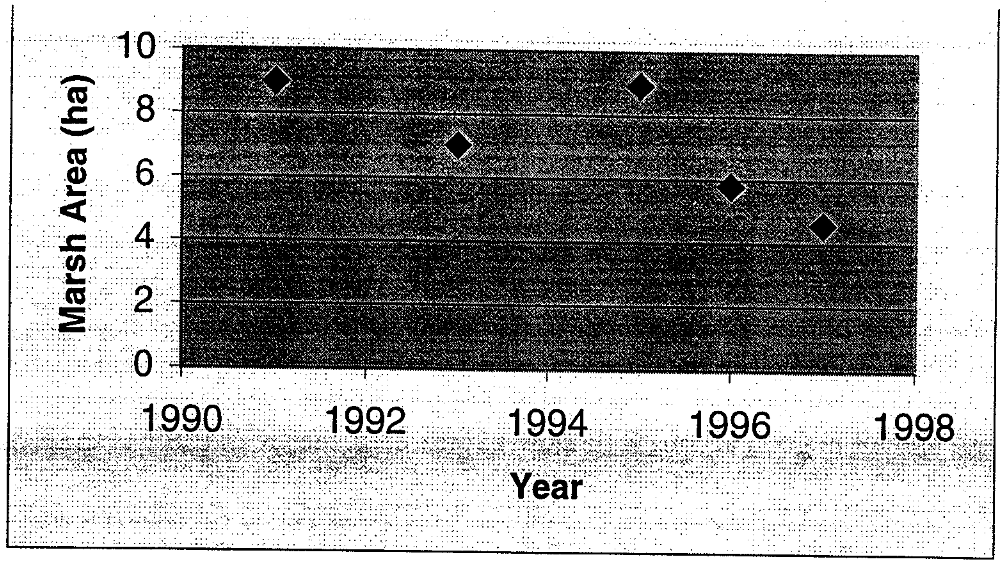


Fig. TB1.2: Estimated area of marsh patches along the Colorado River from Lees Ferry to Diamond Creek, 1991-1997 (draft data from L. Stevens, GCMRC). Updated 3 December 1998.

Fluvial Marsh Development

Fluvial marshes are biologically diverse and highly productive habitats that have developed in the post-dam Colorado River corridor (Stevens *et al.* 1995). Fluvial marshes colonize low-lying, fine-grained habitats which are periodically inundated, such as return current channels, and integrate the interaction between flow and sediment conditions. Therefore, we used marshes as an indicator variable to assess the impacts of flow regimes on habitat availability. Stevens (unpublished data) recorded the number and estimated area of all fluvial marsh patches along the Colorado River from Lees Ferry to Diamond Creek during an annual late summer or early fall river trip in 1980, 1984, 1991, 1993, 1995, 1996 and 1997.

An overall increase in the number and area of marsh patches was detected through the Interim Flows period, with a maximum number of 1,519 patches and total estimated area of 8.47 ha in 1995. The use of planned flooding as a sediment management strategy was predicted by Stevens et al. (1995) to reduce the number and area of fluvial marshes by scouring or burial of patches that had developed during Interim Flows, and marsh recovery was predicted to be limited by increased grain-size which limits germination of marsh plant species.

Stevens et al.'s (1995) predictions were supported by the September 1996 survey. A total of 1,241 marsh patches were detected (18.3% fewer than in 1995) with an estimated total area of 5.59 ha (34.0% less area than in 1995). Most of the patches that were scoured by the 1996 test flow were channel margin or bar face settings, and few large, established return current channel marshes were scoured (Ayers and Kearsley 1997). Importantly, several large, established marshes associated with endangered southwestern willow flycatcher (*Empidonax trailii extimus*) breeding and foraging sites were reduced in area by more than 70% (Stevens et al. in press). Narrow reaches lost greater proportions of marshes than did wide reaches. Post-1996 reestablishment of marsh patches has been slow and area continued to decrease because of larger grain-size on bars: a total of 1,322 patches covering an estimated 4.6 ha were detected in 1997.

Lower Riparian Zone Vegetation

Fig. TB2.1: Data in preparation, 8 December 1998.

The management objectives expressed for the 1996 test flood emphasize management for open sand bars, as well as maintaining emergent wetland and woody sandbar/channel margin vegetation. Subsequent assessment has demonstrated that those management objectives are not in good accord with those expressed in the GCD-EIS and the ROD, which place substantial emphasis on maintenance of wildlife habitat (T. Melis and L. Stevens, GCMRC Memorandum 23 November 1998). However, the primary objective of the 1996 test flood was to test sediment transport mechanisms, and riparian vegetation was expected to, and did, sustain some reduction in cover.

In contrast to wetlands, established woody vegetation on sand bars and along channel margins largely survived the test flood, growing up through newly deposited sand and becoming reestablished (Ayers and Kearsley 1997). The newly deposited 1996 sediments were well sorted fine sand, with a reduced seed bank and bar surfaces are higher, and therefore drier, than those prior to the experiment. This reduces the potential for germination of many riparian species. Therefore, the newly formed sand bars are less likely to be overgrown by germinating tamarisk, and more likely to become colonized by clonal or rhizomatous species (e.g., coyote willow, *Salix exigua*; arrowweed, *Tessaria sericea*; and non-native camelthorn, *Alhagi camelorum*).

An additional concern with the test flood was that non-native plant species would become more widely distributed by planned floods. The test flood was scheduled to allow sufficient time after the flood to dry out the sand bars and limit tamarisk germination. In this respect, the test flood was quite successful. While not wholly preventing tamarisk germination, relatively little establishment was observed at -6.5R, 43L, 44L, 55.5R, 65L and 194L by Stevens (personal observation). However, high flows since the 1996 test flood have allowed tamarisk seedlings that became established to grow rapidly. Among the other non-native species: camelthorn vigorously resprouted and recolonized many sand bars; tumbleweed and lovegrass appear to have become more widely distributed; and Ravenna grass distribution also increased to the river corridor downstream from Diamond Creek for the first time (Stevens, personal observation).

Flood impacts on cultural landscapes along lower Grand Canyon and Lake Mead appear to have been affected in a fashion similar to that which occurred in the upstream reaches (Phillips 1997, Christianson 1997). The high flows extended below Mile 250, indicating that potential impacts of planned flooding may occur a fair distance out onto Lake Mead.

Upper Riparian Zone Vegetation

Fig.TB3.1: Data in preparation, 3 December 1998.

SPECIES OF SPECIAL CONCERN

ENDANGERED KANAB AMBERSNAIL
SUCCINEIDAE: *Oxyloma haydeni kanabensis* Pilsbry

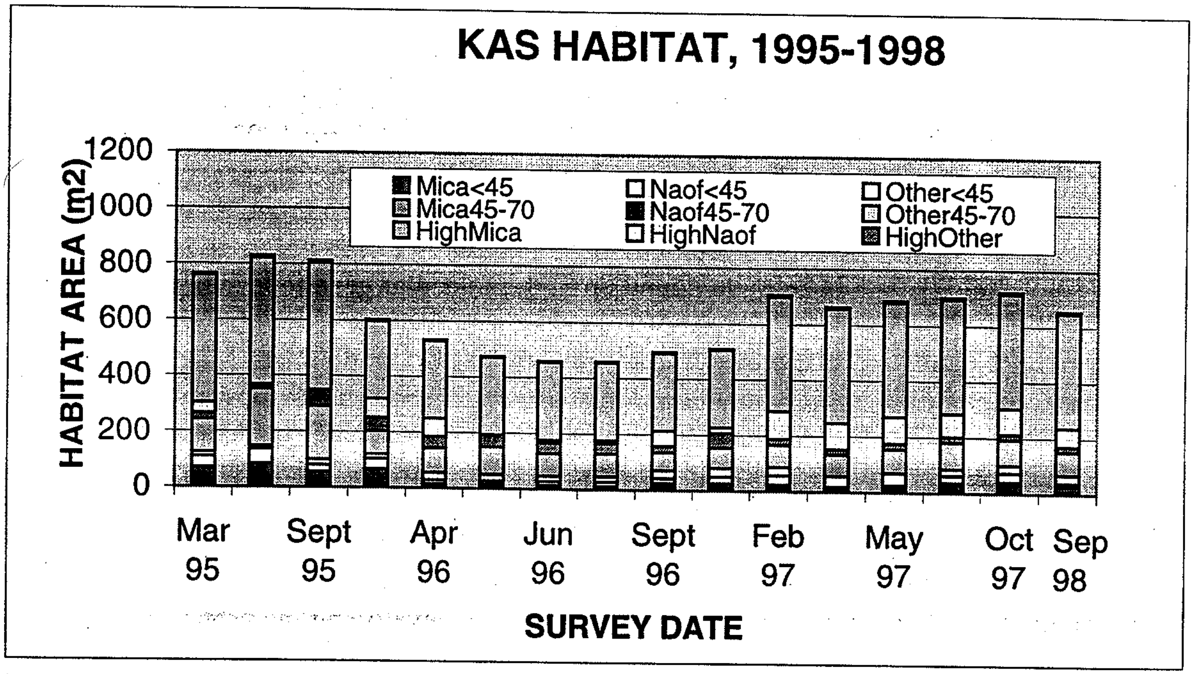


Figure ES1.1: Kanab ambersnail habitat changes, March 1995-September 1998 at three stage elevations (draft data courtesy of V.J. Meretsky). Updated 3 December 1998.

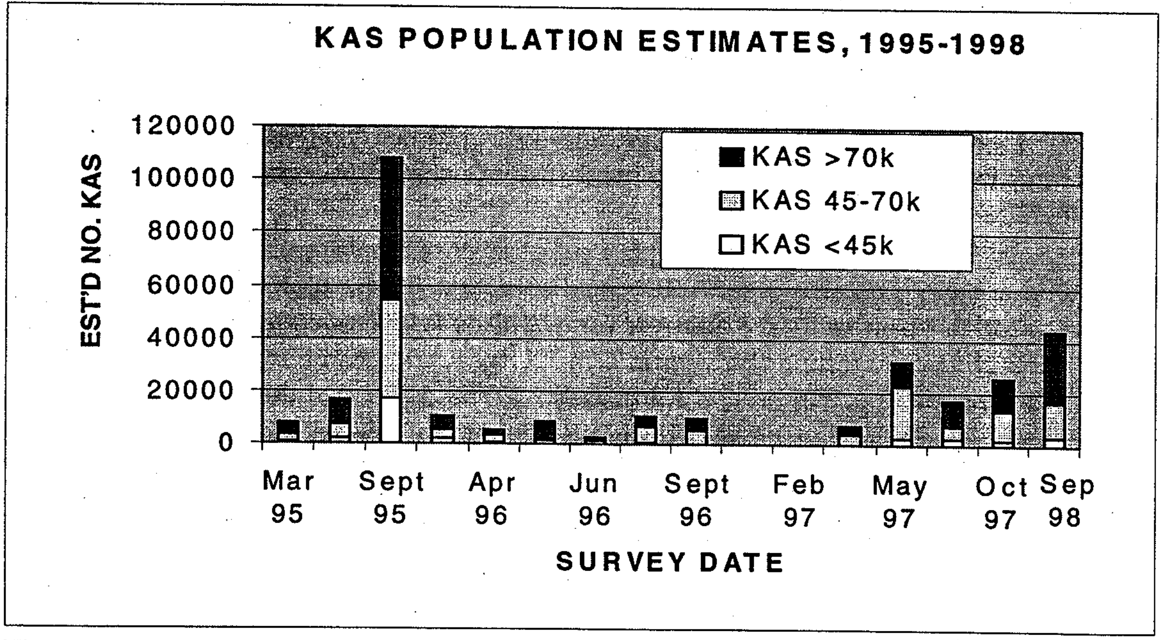


Figure ES1.2: Kanab ambersnail estimated population size, March 1995-September 1998 (draft data courtesy of V.J. Meretsky). Updated 3 December 1998.

Kanab Ambersnail Species Account

Distribution and Abundance

Kanab ambersnail (KAS; Succineidae: *Oxyloma haydeni kanabensis* Pilsbry 1948), is a federally endangered landsnail that was proposed for emergency listing (U.S. Fish and Wildlife Service 1991a, 1991b) and officially listed in 1992 (U.S. Fish and Wildlife Service 1992). Fossil *Oxyloma* shells have been recovered from sediments in Grand Gulch (lower San Juan River) that date to 9,200 years ago (Kerns 1993). Living KAS were first collected by J.H. Ferriss in 1909 near Kanab, Utah in seep vegetation (Ferriss 1910, Pilsbry and Ferriss 1911, Pilsbry 1948). This genus has a broad distribution (North America, Europe and South Africa), but the taxonomy has been based on internal and shell morphology, and is being revisited through molecular genetic techniques. Extant populations of KAS presently occur at: (1) Three Lakes, near Kanab Utah; Kanab Creek, near Kanab, Utah; and at Vaseys Paradise, a spring at Colorado River Mile 31.5R, in Grand Canyon, Arizona (Spamer and Bogan 1993a, 1993b). Two populations were originally identified in the Kanab, Utah area, but the type locality population was believed to have been extirpated by desiccation of its habitat. The recently discovered metapopulation in Kanab Creek is believed to overlap the vicinity of the type locality (V. Meretsky, personal communication). The Three Lakes population occurs at several, small spring-fed ponds on cattail (*Typha* sp.; Clarke 1991). The Three Lakes site is privately-owned and the land owner is commercially developing the property.

KAS were first collected at Vaseys Paradise in 1991 (Blinn et al. 1992, Spamer and Bogan 1993), and an interagency team lead by Reclamation examined KAS ecology there from 1995 through 1997 (Kanab Ambersnail Interagency Work Group 1997a). Within Grand Canyon, KAS is apparently restricted to Vaseys Paradise: no KAS have been detected at more than 100 other Grand Canyon springs surveyed from 1991 through 1997. This suggests that the Vaseys Paradise KAS population, like many southwestern spring species, is a Pleistocene relict which has become restricted in distribution as Holocene climate dried out. Genetic dissimilarity with other *Oxyloma haydeni* populations in the Colorado River drainage further supports this contention (Miller et al. in press).

Vaseys Paradise is a popular water source and attraction site for Colorado River rafters; however access is limited by the dense cover of poison ivy (Toxicodendron rydbergii) and the nearly vertical terrain (Stevens et al. 1997b). Rematched historical photographs of Vaseys Paradise (e.g. Turner and Karpiscak 1980:58-59) reveal that vegetative cover has increased greatly at lower stage elevations since completion of Glen Canyon Dam, and that flow regulation by the dam has increased primary KAS habitat area at Vaseys Paradise by more than 40%. All vegetation below the approximate 90,000 cfs stage was scoured by annual pre-dam floods in normal years.

Stevens et al. (1997b) defined primary KAS habitat at Vaseys Paradise as that dominated by crimson monkeyflower (*Mimulus cardinalis*), non-native watercress (*Nasturtium officinale*), sedge (*Carex aquatilis*) and smartweed (*Polygonum amphibium*). Secondary, or marginal, habitat has been defined as patches of other riparian vegetation that are not dominated by these species and are not used extensively by KAS. Land surveys from 1995 through 1997 revealed rapid changes in vegetation cover over the growing season, with 11.2% to 16.1% of the estimated total primary habitat occurring below the 45,000 cfs stage in 1995, and 7.0-12.0% of the estimated total primary habitat occurring downslope from the 45,000 cfs stage from 20 April 1996 through 3 October 1997. The total estimated area of primary habitat was estimated to be 905.7 m^2 (0.22 acres), equivalent to the area of secondary habitat, and the total vegetated area was 1811.4 m^2 (0.44 acres) in June, 1995. Photogrammetric analyses indicate that the upper primary habitat area in November 1997 had decreased to approximately 720 m^2 (L.E. Stevens, personal communication).

The total estimated Vaseys Paradise KAS population rose from 18,476 snails in March 1995 to more than 100,000 snails in September, 1995 as reproduction took place in middle to late summer (Stevens et al. 1997b; Table 1). This latter figure has been questioned on the basis of topographic survey accuracy: most recent population peaks have been 20,000-40,000 KAS. The proportion of the total estimated KAS population occurring below the 45,000 cfs stage was 3.3% in March, 11.3% in June, and 16.4% in September in 1995. Three years of population data indicate that the KAS population undergoes a substantial reduction through over-wintering mortality (Kanab Ambersnail Interagency Work Group 1997b).

The KAS population and habitat lying downslope from the 45,000 cfs stage was scoured in the BHBF in 1996 (Kanab Ambersnail Interagency Work Group 1997a; Table ES1.1). Habitat recovery was delayed in 1996 and 1997 because of high flows (20,000 to 28,000 cfs) that resulted from high reservoir forecasts and large summer monsoon floods on the Paria River, particularly in 1997. Recovery of habitat continued during the high flows of 1998 (Stevens, personal observation).

Analyses of oblique photographs taken in November of 1994-1997 indicate that no major changes have occurred in the vegetation cover lying upslope from the 70,000 cfs stage (Kanab Ambershail Interagency Work Group 1997). In October 1997, 101.22 m^2 (12% of the estimated total primary habitat at Vaseys Paradise existed downslope from the 45,000 cfs stage. October 1997 population data indicate that an estimated 2187 KAS exist downslope from the 45,000 cfs stage, 6.4% of the estimated total KAS existing at Vaseys Paradise (Kanab Ambersnail Interagency Work Group 1997b). Also, these data indicate that recovery of the Vaseys Paradise KAS habitat and population to pre-1996 BHBF conditions has required more than 2 full years. By late September 1998, preliminary estimates revealed 68.8 m^2 of KAS habitat and 3,170 KAS downslope from the 45,000 cfs stage, and approximately 162.3 m^2 of habitat with 9,405 KAS downslope from the approximate 60,000 cfs stage elevation. The percentage of the total KAS habitat area and population represented by the September 1998 data cannot be determined until photogrammetic analyses are completed in November 1998.

Life Requisites

KAS occurs on little-disturbed, saturated soil and associated wetland vegetation at Three Lakes, near Kanab, Utah (V. Meretsky, personal communication), where *Typha* and *Scirpus* are the predominant macrophytes. These snails are genetically distinct from the Vaseys Paradise population (Miller et al., in press). In contrast, Vaseys Paradise is a fast-flowing, cool, dolomitic-type spring, with abundant wetland and phreatophyte vegetation, especially native crimson monkeyflower, sedge, smartweed, and poison ivy, and non-native watercress. Monkeyflower, sedge, smartweed and watercress are persistent aquatic wetland or hydrophytes (Kearney and Peebles 1960), and KAS is generally restricted to those species at Vaseys Paradise (Stevens et al. 1997b, Kanab Ambersnail Interagency Work Group 1997a,b, L. Stevens personal communication). KAS were rare to absent on other plant species and bare substrata.

The accidental introduction of watercress at Vaseys Paradise provided KAS with an alternate host plant. KAS densities are generally higher on watercress than on the native host plants during the growing season (Kanab Ambersnail Interagency Work Group 1997b). Although watercress is an annual species, its life cycle at Vaseys Paradise is unpredictable. In part, this irregularity is due to the unithermal warm flows of the spring (ca. 16°C), which keep the microenvironment warm enough to prevent freezing during moderately cold winter months. Also, warm winters, such as 1995-1996, do not freeze watercress back, while cold winters (e.g. 1990) freeze and kill the plants. Warm spring flow and warm winters decouple the watercress life cycle from climate, and limit predictability of habitat conditions.

Demographic analyses based on size class distribution indicate that KAS is essentially an annual species, with much of the population maturing and reproducing in mid-summer (July and August), and most snails over-wintering as small size classes (Kanab Ambersnail Interagency Work Group 1997b). Loose, gelatinous egg masses were observed on the undersides of moist to wet live stems, on the roots of water-cress, and on dead or decadent stems of crimson monkey-flower in mid-summer of all years of study. No data on egg development or emergence success are presently available. In warm winters, such as that of 1995-96, KAS may emerge from dormancy early, and produce a double generation within one year (Kanab Ambersnail Interagency Work Group 1997a).

KAS at Vaseys Paradise are parasitized by the trematode flatworm, *Leucochloridium cyanocittae*, with 0.0% to 9.5% of the mature snails expressing sporocysts in mid-summer from 1995 through 1998 (Stevens et al. 1997b, Kanab Ambersnail Interagency Work Group 1997 a,b, V. Meretsky personal communication). Parasitized KAS are apparently able to continue to reproduce. Potential vertebrate predators of KAS at Vaseys Paradise include deer mice (*Peromyscus crinitus* and *P. maniculatus*), as well as rainbow trout (*Oncorhynchus mykiss*) in the stream mouth), resident common raven (*Corvus corax*) and canyon wren (*Catherpes mexicanus*), summer breeding Says and black phoebe (*Sayornis sayi* and *S. nigricans*), and winter resident American dipper (*Cinclus mexicanus*).

Impacts of High Flow(s)

In its 21 December 1994, Final Biological Opinion (BO) the Service evaluated impacts to KAS from the operation of Glen Canyon Dam according to operating and other criteria of the Preferred Alternative in the GCD-EIS. The Service determined implementation of the Preferred Alternative would not jeopardize the continued existence of the KAS. This opinion also supported the concept of BHBF flows as part of the Preferred Alternative. The 1994 B.O. indicated that incidental take of KAS resulting from scour of more than 10% of the occupied habitat at Vaseys Paradise requires re-consultation. The 1996 B.O. recognized the importance of BHBFs for ecosystem management, but included as Reasonable and Prudent Measures (RPMs) mitigation of impacts by moving snails in the flood zone to higher locations immediately prior to the BHBF. Stevens et al. (1997b, Kanab Ambersnail Interagency Work Group 1997a) predicted the 1996 BHBF would result in primary and secondary KAS habitat loss of 16.1%, and KAS population losses of 11.4% to 16.4%, without mitigation through translocation. A total of 1,275 KAS were transferred upslope of the 45,000 cfs stage in the week preceeding the 1996 BHBF, reducing the estimated number of KAS lost by 40% (Kanab Ambersnail Interagency Work Group 1997a). Before another habitat-building flow, Reclamation will enter into informal consultation with the Service to evaluate prior test flow studies, the establishment or discovery of a second population of Kanab ambersnail in Arizona, and reinitiate formal consultation with the Service if incidental take will exceed the 10 percent as established in the 1996 B.O. Also, the 1996 B.O. indicated that the impacts of all flows above ROD levels (25,000 cfs) should be evaluated prior to, within one month after, and 6 months after exceptional high flows.

In October 1997 the Service followed the 1996 B.O. recommendations regarding consultation and mitigation on a proposed November 1997 Fall Test Flow. The Service issued an opinion that the test flow was not likely to jeopardize the continued existence of the humpback chub or Kanab ambersnail and was not likely to destroy or adversely modify designated critical habitat for the humpback chub. No critical habitat had been designated for the Kanab ambersnail. The Service did determine that incidental take of humpback chub and Kanab ambersnail was likely to occur and established several reasonable and prudent measures to be taken by Reclamation designed to minimize incidental take, including monitoring to be conducted immediately before, within one month after, and 6 months after the test flow. The November 1997 test flow lasted 2 days, and inundated 29.79 m^2 of existing habitat (3.5% of the estimated existing total primary habitat at Vaseys Paradise), scouring 4.3 m^2 of habitat (0.5% of the estimated total primary habitat). That test flow eliminated no more than an estimated 181 KAS, which was 1.4% of the estimated KAS population existing downslope from the approximate 70,000 cfs stage, and 0.5% of the estimated total KAS population at Vaseys Paradise (Kanab Ambersnail Interagency Work Group 1997b).

Natural winter mortality may reduce the KAS population by nearly 50%-75% (Table 1): the lowest KAS populations are observed in March, indicating high winter mortality rates. March floods may result in a lower total take of KAS because there are fewer total KAS prior to reproduction, but the proportional take may be approximately equal in any month from January through July. Additional factors to consider regarding differences in take between months are (1) that a BHBF when watercress is abundant and in the middle of its growth phase may result in increased proportional take, and (2) a BHBF from mid-May through July is likely to result in take of reproductively active snails, potentially affecting annual reproductive output. Therefore, although BHBF's later in the growing season may take an equal proportion of KAS, later high flows may exert different impacts on the KAS population.

Mr. Tim Randle (personal communication) recently extrapolated the Randle and Pemberton (1987) cross sectional stage-to-discharge model at Vaseys Paradise up to the 60,000 cfs stage (Table ES1.1). This extrapolation is crudely estimated to be 4.5', and probably falls within ± 1.5' of the actual 60,000 cfs stage elevation. Using this estimated 60,000 cfs stage elevation, as well as the known stage to discharge relationship up to 45,000 cfs, and the vegetation area mapped on 28 September 1998, Stevens estimated KAS habitat and population size at Vaseys Paradise. This estimate also assumes that the estimated total primary habitat upslope from the approximate 70,000 cfs stage in March 1999 will be 416.3 m^2 (77.2% of that mapped in 1994 by Stevens et al. 1997b). Measurement of the area of the upper zone at Vaseys Paradise takes place in November, and results will be available shortly.

Given these estimates and assumptions, approximately 68.8 m^2 (10.5%) of the estimated total habitat will be inundated during a 45,000 cfs BHBF. This value is 0.5% more than the B.O.-specified level of habitat take of 10%. A total of 22.7 m^2 of the habitat lying below the 45,000 cfs stage in the September 1998 survey consists of mixed vegetation patches dominated by horsetail (*Equisetum* spp.), reed (*Phragmites australis*) and other species. These patches are little used by KAS, and are extremely resistant to scour, having persisted through the 1996 BHBF and the high flows of 1997 and 1998. If this area is subtracted, a 45,000 cfs flow would inundate 7.3% of the total habitat.

Under the same assumptions as above, a BHBF of 60,000 cfs may inundate an estimated 162.3 m^2 of KAS habitat, 24.8% of the estimated total available habitat. If the low zone *Phragmites* and *Equisetum* patches are removed from consideration, 139.6 m^2 of habitat would be inundated, 22.1% of the total habitat.

Table ES1.1: Estimated KAS habitat and population size at Vaseys Paradise, 28 September 1998.

Estimated KAS habitat at VP, 28 Sept. 1998

	Stage Zone					
Patch Type	<33K	<45K	<60K	Total Low Zone	Est. Tot. High Zone	VP Total
Mica	0.0	26.8	88.9	108.7	410.6	519.3
Naof	0.0	12.3	19.4	32.9	5.6	38.6
Mix	27.0	29.7	54.1	95.8	0.0	95.8
Total	27.0	68.8	162.3	237.3	416.3	653.6
% of Total	4.1	10.5	24.8	36.3	63.7	100.0

Estimated KAS population at VP, 28 Sept.1998

	Stage Zone					
Patch Type	<33K	<45K	<60K	Total Low Zone	Est. Tot. High Zone	VP Total
Mica	0	866	4645	5653	23203	28856
Naof	0	1711	2583	5537	1029	6566
Mix	540	592	2177	5099	2922	8021
Total	540	3170	9405	16289	27154	43443
% of Total	1.2	7.3	21.6	37.5	62.5	100.0

If the above habitat assumptions are accurate, if KAS densities are equivalent across stage elevation (as suggested by the Kanab Ambersnail Interagency Work Group, 1997b), and if winter mortality is negligible and not different among stage zones, an estimated 3,170 KAS (7.3% of the 28 September 1998 estimated total population of 43,443 KAS) may be lost during a 1999 BHBF of 45,000 cfs. Similarly, an estimated 9,405 KAS (21.6% of the September 1998 estimated total population) may be taken by a 60,000 cfs BHBF in 1999. For reference, the 1996 BHBF removed 119.4 m2 of habitat and would have eliminated an estimated 2,126 KAS had not 1,275 KAS been moved to higher stage elevations.

The stage-to-discharge model above 45,000 cfs for Vaseys Paradise is still approximate, and the present estimates are ± approximately 20%. Additional modeling may refine the impacts of flows >45,000 cfs on these KAS habitat and population estimates.

Recently, a meta-population of *Oxyloma haydeni* has been discovered near the type locality ("the Greens"), in the Kanab Creek drainage near Kanab, Utah (V. Meretsky, personal communication). Dr. S.K. Wu (personal communication) conducted a taxonomic analysis of three subpopulations from this group and identified them as KAS.

With this taxonomic verification, at least 3 populations of KAS presently are recognized in the Southwest.

In addition, the Arizona Game and Fish Department and the National Park Service have introduced Vaseys Paradise KAS to three remote inner canyon springs in Grand Canyon. Such an introduction may eventually resolve the Service's 1996 B.O. requirement that at least one additional population of KAS be discovered or established in Arizona prior to conduct of another BHBF of 45,000 cfs. A 1998 B.O. on these secondary KAS population establishment efforts indicates that the involved parties (NPS, AGFD, BR) need to determine what constitutes successful establishment (FWS 1998).

Conclusions

BHBF flows are of sufficient magnitude that they may alter habitat availability and KAS recolonization rates; however, the KAS population at Vaseys Paradise survived and recovered from innumerable flows equal to or higher than BHBFs in the pre-dam era. No planned flood will be of sufficient magnitude to threaten the integrity of KAS as a population. The introduction of non-native watercress and the construction of Glen Canyon Dam have increased primary KAS habitat area at Vaseys Paradise by nearly 40%, and has undoubtedly substantially increased the snail population. Since 1963, the KAS population at Vaseys Paradise has survived seven flows of ≥45,000 cfs (i.e., 1965, 1980, 1983-1986, and 1996). Although incremental take from repeated high flows is a concern, KAS and its habitat require the >2 yr recovery period at Vaseys Paradise (Kanab Ambersnail Interagency Work Group 1997b), indicating that the KAS population has existed in a state of recovery from high flows (≥45,000 cfs) for at least 16 of the past 35 years (≥45% of post-dam time). Not withstanding these considerations, the KAS habitat lying in the BHBF flood zone is likely to be adversely affected by flows of 45,000 cfs or more in 1999.

Reclamation concludes that: 1) the Vaseys Paradise KAS population appears to be relatively large and self-sustaining; 2) approximately 40% of the present primary KAS habitat at Vaseys Paradise lies below the pre-dam 10-year flood stage of 125,000 cfs and is new, post-dam habitat; 3) the KAS population has survived numerous larger floods both before and after dam construction; 4) the estimated loss KAS habitat and population may exceed permitted levels of take if all habitat downslope from the 45,000 cfs stage is considered; and 5) the vegetation and the KAS population will re-colonize the scoured area in >2 yr. In order for Reclamation to meet its commitments under the three previous biological opinions for operations of GCD, and prior to definition of successful second population establishment criteria, BHBFs in 1999 should be restricted to flows <45,000 cfs, and higher flows should be avoided.

The 1996 B.O. incidental take statement allowed for mitigation of take through relocation of KAS to a position within the habitat above the 45,000 cfs stage. Moving of snails may be a reasonable strategy for BHBF's of up to 45,000 cfs. Despite concerns about detrimental effects on moved KAS resulting from disturbance due to handling and the potential for increased competition, the Kanab Ambersnail Interagency Workgroup (1997a) reported few if any negative impacts of the 1996 BHBF related to translocation within the habitat. However, that strategy will be impractical for higher BHBF's. Other mitigation options include moving KAS in the BHBF flood zone to the Phoenix Zoo, or to second population sites in Grand Canyon or elsewhere. The "no action" alternative is most likely to result in reduced take of this snail population.

HUMPBACK CHUB
CYPRINIDAE: *Gila cypha* Miller

Condition Factor

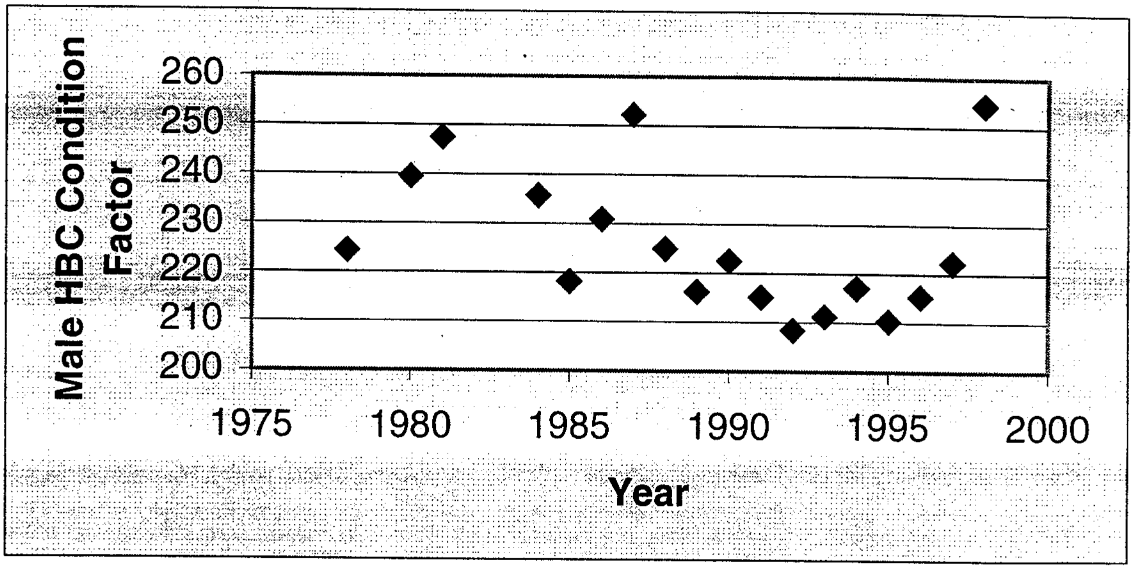


Fig. ES2.1: Modeled condition factor (CF) of male humpback chub in the lower Little Colorado River during the spring spawn in May 1978-1998. Data from all years did not include spawning condition (pre-versus post-spawning condition). No data on gender was available from 1997-1998, and the CF values for those years include female HBC at various stages of spawning. Data from AGFD and USFWS, and analyses courtesy of V.J. Meretsky, Indiana University. Updated 981206.

Humpback Chub Species Account

Distribution and Abundance

The endangered humpback chub (HBC; Cyprinidae: *Gila cypha)* is an endemic fish species in the Colorado River basin (Valdez and Ryel 1997). The HBC was taxonomically described by Miller (1946), and was listed as an endangered species in 1968. Stream alteration, including flow modification, diversion for irrigation, channelization, and the introduction of non-native fish species, have been suggested as responsible for declining populations of HBC throughout the Colorado River basin (Valdez 1995). Five HBC populations remain in canyon-bound reaches of the upper Colorado River basin: Black Rocks (upper Colorado River), Westwater Canyon (upper Colorado River), Cataract Canyon, Desolation/Gray canyons (Green River) and in the Yampa River (Valdez and Williams 1993, Valdez and Ryel 1997).

The Grand Canyon supports the only successfully reproducing HBC population in the lower Colorado River basin (Kaeding and Zimmerman 1983, Valdez 1995, Valdez and

Ryel 1997). Valdez and Ryel (1995) identified nine distinct aggregations in the mainstream Colorado River downstream from Glen Canyon Dam, including: 30-Mile, the Little Colorado River (LCR) confluence area, Lava/Chuar to Hance Rapids, Bright Angel Creek mouth, Shinumo Creek mouth, Stephens Aisle, Middle Granite Gorge, Havasu Creek mouth and Pumpkin Spring. From 3000 to 3500 adult HBC occupy the mainstream Colorado River, and these are largely concentrated within ± 4.2 miles of the mouth of the Little Colorado River (Mile 61.5), the largest and only self-sustaining sub-population. The mainstream HBC in the LCR aggregation use the LCR for spawning, while other HBC appear to be resident in the LCR. The distribution of HBC in the mainstream has not changed over the past two decades (Valdez and Ryel 1997); however, HBC density may have declined in the LCR during the past decade (Douglas and Marsh 1996).

Habitat use by HBC varied between age classes and by time of day. Young HBC in the Colorado River mainstream commonly use return current channels and other backwater habitats (Maddux et al., 1987, Arizona Game and Fish Department 1996, Valdez and Ryel 1997); however, HBC use of backwater habitats in Grand Canyon has been compromised by fluctuating flows and cold-stenothermic releases which reduce warming and create unstable conditions. In addition, backwater habitat area has been reduced and backwaters have aggraded through siltation under Interim Operations in Grand Canyon (McGuinn-Robbins 1997).

Young-of-year and subadult HBC in the Colorado River mainstream often use irregular shorelines as habitat, and adult HBC often occur in or near eddies (Valdez and Ryel 1995, 1997). Adult radio-tagged HBC demonstrated a consistent pattern of greater near-surface activity during the spawning season and at night, and day-night differences decreased during turbid flows (Valdez 1997).

Life Requisites

The life history and ecology of HBC in Grand Canyon has been intensively studied (Suttkus and Clemmer 1977, Kaeding and Zimmerman 1983, Carothers and Minckley 1981, Maddux et al., 1987, Gorman 1994, Valdez 1995, Arizona Game and Fish Department 1996, Douglas and Marsh 1996, Valdez and Ryel 1997). A key issue is the lack of recruitment to the adult population, which is reflected by low survivorship of young fish (Valdez and Ryel 1995). Individual adult HBC demonstrate high microsite fidelity (Valdez 1995), but young HBC may drift for relatively long distances (Tuegel 1995). Mainstream Colorado River HBC in Grand Canyon spawn primarily in the lower nine miles of the LCR from March through May. Adult fish initially stage for spawning runs in large eddies in February and March, and make spawning runs that average 17 days into the LCR from March through May, as LCR flows decrease, warm and clear (Valdez 1995). Spawning runs of up to 25 miles have been reported for this species. After spawning, many adult chub apparently return to specific microsites in the mainstream. Young HBC remain in the LCR, or move into the mainstream where mortality due to thermal stress (Lupher and Clarkson 1993) and predators (Valdez 1995) appears to be extremely high. During the summer the young HBC that survive in the mainstream tend to occupy low-velocity, vegetated shoreline habitats; however, low winter survivorship virtually eliminates the young-of-the-year HBC in the mainstream. Therefore, few if any HBC spawned during the previous year are present in the mainstream in the following spring.

Limited breeding of HBC occurs among other sub-populations in the Colorado River. Valdez (1995) documented limited spawning success at 30-Mile Spring in upper Marble Canyon. Arizona Game and Fish Department (1996) reported young HBC as well as 14 mm fish from Mile 192-208, suggesting that limited spawning also may occur in the lower Grand Canyon.

Dietary analyses reveal HBC to be opportunistic feeders, selectively feeding on aquatic and terrestrial invertebrates (Valdez and Ryel 1995, 1997). HBC diet changes over the course of the year in response to food availability and turbidity-related decreases in benthic standing biomass over distance downstream from Glen Canyon Dam (Stevens et al. 1997, Valdez and Ryel 1997). Non-native *Gammarus lacustris* occasionally comprise a large proportion of HBC diet, especially after high mainstream flow events (Valdez and Ryel 1995, 1997; Arizona Game and Fish Department 1996). *Gammarus* selectively feeds on epiphytes (i.e., diatoms) associated with *Cladophora glomerata*, the dominant alga particularly in the upper reaches, where clearwater conditions often prevail (Shannon et al. 1994).

Impact of BHBF(s)

High flows, such as the 1996 BHBF, had little detectable effect on the movement patterns or distribution of adult HBC, and the 1996 BHBF did not appear to serve as a spawning cue (Valdez 1997). The increased drift associated with that BHBF resulted in an increase in Gammarus in HBC gut contents, an effect which is not surprising given the opportunistic foraging behavior of this species (e.g., Tyus and Minckley 1988). Given that this species evolved under the highly variable flow regimes that characterized the pre-dam Colorado River, it is unlikely that short-duration BHBF flows of 45,000 cfs would affect subadult or mature HBC.

In contrast, high mainstream flows may affect younger HBC. High flow impacts are likely to be most pronounced in mid to late summer as larval and young HBC emerge from the LCR and occupy mainstream near-shore and backwater habitats, with timing dependent on the strength of the spawn and on the severity of the winter. Although a 2-4 day 45,000 cfs BHBF may briefly create additional pool area at the mouth of the LCR, that effect is unlikely to substantially benefit drifting HBC, which would subsequently be flushed into the mainstream. Flows of 45,000 overtop existing bars in the LCR area, and subject shoreline and backwater habitats to cold temperatures and high velocity flows. Thus, high flows stress and displace young HBC in those habitats. Therefore, even brief BHBFs in June and July may negatively affect young HBC in the mainstream.

The Reasonable and Prudent alternatives of the 1994 Fish and Wildlife Service Biological Opinion (BO) include BHBF's; however, the Service determined some HBC may be taken during high flow events. Their discussion of incidental take considered testing and studies to determine impacts of flows on young HBC. One goal of a BHBF is the redistribution of channel-stored sediment to rejuvenate margin and current return channel nursery habitats for young life stages of HBC along the mainstream. This hypothesis will continue to be tested through possible 1999 BHBF(s).

The 1996 B.O. indicated that little impact on mature HBC was anticipated, and this conclusion was supported by data collected in association with that event (Valdez 1997). The 1996 BHBF did not serve as a spawning cue for movement into the mouth of the Little Colorado River. High flows did result in substantial additional drift of benthos, and radio-tagged HBC shifted location to the low velocity portions of eddies. Although some scour of the benthos occurred, rejuvenation of return current channels and other mainstream backwater habitats was brief and persisted for < 6 months. Therefore, there was little additional recruitment habitat for young HBC by the late summer in 1996. In conclusion, the 1996 BHBF had little effect on HBC, and apparently did not adversely affect them.

The Service's B.O. on Reclamation's 1997 HMF expressed concern regarding the high levels of winter mortality sustained by Grand Canyon HBC. That B.O. permitted Reclamation to proceed with the flow event, but stipulated that Reclamation initiate a study of the causes of HBC winter mortality, and support the recovery process.

Conclusions

BHBF's from May through July may affect the HBC population. The timing of high flow events may adversely affect larval and young HBC, through stress and displacement of young fish, depending on the spawning peak in any given year. High flows from January through March are believed to be unlikely to affect young HBC because high winter mortality apparently results in low populations of young fish during winter and spring. High flows that occur during the spawning and drift phase of the HBC life history cycle in the LCR may reduce annual survivorship and recruitment in the mainstream, and may flush refugial backwater habitats along the mainstream. Spring spawning activity from 1995 through 1998 appears to have resulted in rather normal levels of recruitment (Tuegel 1995; Grand Canyon Monitoring and Research Center 1997; T. Hoffnagle, personal communication), and the cold spring conditions in 1998 appeared to have depressed or extended spawning acitivity (Hoffnagle, personal communication). The great improvement in condition factor (Fig. ES2.1) may be related to inclusion of ripe females in the data set. The extent of HBC spawning in 1999 will not be determined until at least June 1999.

A >45,000 cfs BHBF in 1999 may affect, but is not likely to adversely affect subadult or adult HBC during any month between January and July, because HBC appear to be well-adapted to high flow events.

A middle winter to early spring 1999 BHBF appears to be preferable to late spring or summer high flow events for HBC. Reclamation will also continue to support the Service's recommendations regarding research and recovery efforts on this species, including analyses of winter mortality and establishment of a self-sustaining second population. For a proposed May through July BHBF, Reclamation would support analysis of HBC mortality in relation to ponding and predator responses at the LCR mouth, stress and displacement from mainstream shoreline and backwater habitats, and drift in the mainstream.

ENDANGERED RAZORBACK SUCKER
CATOSTOMIDAE: *Xyrauchen texanus*

Fig. ES3.1: Analyses in preparation 3 December 1998.

Razorback Sucker Species Account

Distribution and Abundance

Razorback sucker (RBS; Catostomidae: *Xyrauchen texanus*) is a widely distributed, endemic, warm water Colorado River fish. RBS formerly occurred throughout the Colorado River, but has declined since 1930 with the regulation of the Colorado River (Dill 1944, Minckley 1991). The decline of RBS has been attributed to thermal regime changes, altered spawning habitat, blockage of migration routes, and introduction of non-native fish species, which have cumulatively resulted in wide-scale recruitment failure (Bestgen 1990, Minckley 1991). This species was listed as an endangered species by the U.S. Fish and Wildlife Service in 1991 (U.S. Fish and Wildlife Service 1991).

The largest RBS population in the Lower Colorado River Basin exists in Lake Mohave, where it was estimated to be approximately 60,000 fish in 1989 (Marsh and Minckley 1989). Other, smaller lower basin RBS populations occur in Lake Mead, downstream from Hoover Dam, and in Senator Wash Reservoir. In the Upper Colorado River Basin, RBS occur regularly in the upper Green and lower Yampa rivers, and individual RBS have been collected at rare intervals in the Colorado River near Grand Junction, Colorado, and in the major tributary arms of Lake Powell. RBS are long-lived (20 to 50 yr), but most wild-caught RBS are old individuals, and recruitment failure may lead to the rapid demise of this species (McCarthy and Minckley 1987, Minckley 1991). Experimental releases in the Upper Basin, and attempts to propagate RBS in Lower Basin reservoirs are encouraging, but the mainstream Colorado River populations continue to decline.

RBS are extremely rare in Grand Canyon. Recent observations include those of Carothers and Minckley (1981) who reported four RBS from the Paria River in 1978-1979; Maddux et al. (1988) reported one blind female RBS at Upper Bass (Colorado River Mile 107.5) in 1984; and Minckley (1991) reported records of three additional RBS captured in the lower Little Colorado River from 1989-1990. Putative hybrids between flannelmouth sucker (Catostomus latipinnis) and RBS have been reported from the Little Colorado River (Suttkus and Clemmer 1979, Carothers and Minckley 1981, Minckley 1991). RBS have not been observed since 1991 in this system.

Life Requisites

RBS are generally associated with calm river reaches, particularly man-made lakes (Tyus 1987); however, river spawning typically occurs in riffle habitats over gravel and cobble substrata (Mueller 1989). Larval RBS drift downstream from the spawning habitat, and concentrate in warm, low-velocity areas (e.g., flooded bottoms). These areas also support post-larval RBS, and channel and mid-stream river habitats floored by fine-grained alluvium are important to subsequent RBS life stages (Minckley 1983, Tyus and Karp 1989, Minckley 1991). Springtime concentrations of adult RBS have been noted in side-channels, off-channel impoundments, and in tributaries (Bestgen 1990, Minckley 1991), in temperatures of 22 to 25°C (Bulkley and Pimentel 1983); however, RBS occur in widely varying temperatures. RBS habitats in the Upper Colorado River Basin are ice-covered during winter, while the temperatures of mainstream habitats in the Lower Colorado River exceed 90°F (Dill 1944).

RBS diet varies by age class and habitat type, but few data are available on the diet of larval and juvenile RBS (Bestgen 1990). Larval RBS are known to feed on phytoplankton and zooplankton, and (in fluvial habitats) on chironomid larvae. Adult RBS in lentic habitats feed on benthic and planktonic algae and macroinvertebrates, while adult RBS in rivers feed primarily on benthic algae and invertebrates.

RBS spawn earlier in the season than do most other native, warm water Colorado River fish (Minckley 1973, 1991). Lake Mohave RBS spawn from November into May, with the peak of spawning activity between January and March when water temperatures were stable (50 to 54°F) or rising from 50 to 59°F (Bozek et al., 1984). In riverine situations in the Upper Basin, RBS begin spawning on the rising limb of the spring (April-May) hydrograph, and spawn for an extended period through the spring runoff. Although it occurred throughout the day, spawning activity is most intense at dusk.

RBS are susceptible to parasitic bacteria, protozoa and copepods. Minckley (1983) and others have reported a high incidence of blindness in one or both eyes; however the reasons for this condition are not clear (Bestgen 1990).

Impacts of BHBF(s) and Conclusions

The 1996 BHBF had no detectable effect on the remaining RBS population in the Colorado River in Grand Canyon. If RBS remain in this portion of the Colorado River, they are likely to be mature or senile fish, which survived comparable or higher mainstream flows in 1965, 1973, 1980, and 1983-1986, and possibly those of the late pre-dam era. These older fish are capable of finding suitable refugia, and the lack of recruitment of this species indicates that no young razorback sucker are likely to be in the system or at risk during any 1999 BHBF's. Because RBS spawn somewhat earlier than HBC, earlier (February-April) BHBF's may stimulate some additional RBS spawning activity; however, the rarity of this species precludes testing of such hypotheses.

THREATENED BALD EAGLE
BUTEONIDAE: *Haliaeetus leucocephalus*

Fig. ES4.1: Analyses underway, 3 December 1998.

Bald Eagle Species Account

Distribution and Abundance

The bald eagle (Accipitridae: *Haliaeetus leucocephalus*) has suffered population declines from habitat loss, mortality from shooting and poisoning, and reduced reproductive success from ingestion of contaminants (U.S. Fish and Wildlife Service 1983), and was recognized as a threatened and declining species in 1967. This species occurs throughout North America from Alaska to northern Mexico, and commonly breeds in the northern portion of its range (Stahlmaster 1987). Although bald eagles face numerous threats throughout the 48 states, they have recovered from dramatic population declines over the past several decades. Consequently, the U.S. Fish and Wildlife Service downlisted the bald eagle from endangered to threatened status (U.S. Fish and Wildlife Service 1995).

Wintering bald eagles were first observed to congregate in Grand Canyon in the early 1980's and the winter population there increased dramatically after 1985 (Brown et al., 1989, Brown and Stevens 1991, Brown and Stevens 1992). The wintering bald eagle population has been monitored since 1988, and it occurs primarily throughout the upper half of the Grand Canyon (in Marble Canyon) and on both Lakes Powell and Mead. Density of the Grand Canyon bald eagles during the winter peak (in late February and early March) ranged from 13 to 24 birds between Glen Canyon Dam and the LCR confluence from 1993 to 1995 (Sogge et al., 1995). A concentration of wintering bald eagles occurs in late February at the mouth of Nankoweap Creek, where bald eagles forage on spawning rainbow trout (Brown et al., 1989, Brown 1993). Bald eagle density there ranged from 6 in 1987 to 26 in 1990, and 18 bald eagles occurred at Nankoweap Creek in 1995 (Sogge et al., 1995). Eagle density was correlated with trout density in the lower 0.5 km of Nankoweap Creek, and trout density was correlated with tributary stream water temperature (Leibfried and Montgomery 1993). Apparent territorial behavior, but no breeding activity, has been detected in Grand Canyon.

Life Requisites

Bald eagles are opportunistic feeders, preying on fish, waterfowl, rabbit and road-killed game (Stahlmaster 1987). Wintering bald eagles frequent rivers, reservoirs and lakes, including western reservoirs (Detrich 1987), and their distribution is dependent on prey availability, perch suitability, weather and human disturbance intensity (Ohmart and Sell 1980, Brown and Stevens 1997). Their wintering range extends from northern Mexico throughout the western United States.

At Nankoweap Creek in Grand Canyon, wintering bald eagles preferentially capture rainbow trout in the shallow creek, rather than in the mainstream where foraging success is low (Brown 1993, Sogge et al., 1995). Bald eagles at Nankoweap Creek prefer roosting and feeding areas that are relatively free of vegetation. The eagle population there consists of all age classes, with considerable piracy and other interactions between individuals (Brown and Leibfried 1990, Brown and Stevens 1991). The ease and relative safety of foraging in Nankoweap Creek affords wintering bald eagles at Nankoweap Creek the opportunity to accumulate energy reserves needed for their long, northward migration flights and initiation of nesting.

Bald eagle distribution in Glen and Grand canyons appears to be negatively related to human disturbance (Brown and Stevens 1997). Although bald eagles are widely known as opportunistic foragers, they are rare in the Glen Canyon and uppermost Grand Canyon reaches. This is surprising given that those reaches contain the most abundant aquatic foodbase and trout populations (Stevens et al. 1997c). Those reaches support the highest intensity of recreation and other human uses, and Brown and Stevens (1991) reported that bald eagles in Grand Canyon are extremely sensitive to human disturbance, often abandoning their foraging sites when human came within 0.5 km. For these reasons, Brown and Stevens (1997) concluded that human disturbance is responsible for the general rarity of bald eagles in the upper reaches.

Impacts of BHBF(s) and Conclusions

Wintering and migrant bald eagles have largely left the Grand Canyon region by late March (Stevens et al. 1997b). The few remaining eagles in April forage opportunistically and may continue to catch trout in the mainstream. The rainbow trout conclude their spawning run in Nankoweap Creek in April as water temperatures warm (Leibfried and Mongomery 1993), and remaining bald eagles no longer have access to that food source. Short-duration BHBF's in January through March may have slight adverse effect on bald eagle foraging at Nankoweap Creek, if the trout spawn is robust. BHBFs from late March through July will have no adverse effect on the bald eagle population in the Colorado River in Grand Canyon because this migratory species is unlikely to be present.

ENDANGERED PEREGRINE FALCON (PROPOSED FOR DELISTING)
FALCONIDAE: *Falco peregrinus anatum*

Fig. ES5.1: Analyses underway, 3 December 1998.

Peregrine Falcon Species Account

Distribution and Abundance

The peregrine falcon (Falconidae: *Falco peregrinus anatum*) is a federally listed endangered raptor, which declined dramatically as a result of the biological concentration of pesticide residues in prey species, and resulting eggshell thinning (U.S. Fish and Wildlife Service 1984). The population in the Rocky Mountain/ Southwest region declined from 180 pairs prior to 1975 to 55 pairs in 1983, largely as a result of DDT/DDE thinning of eggshells (U.S. Fish and Wildlife 1984).

The Grand Canyon peregrine population was thought to be low in the mid-1970's (Ellis and Monson 1989), but apparently increased dramatically in the 1980's, following recovery efforts by the U.S. Fish and Wildlife Service (1984; Glinski 1993). At present, the Grand Canyon supports the largest breeding population of peregrine falcons on a single land management unit in the coterminous United States (Brown et al. 1991a, 1992). Surveys for nesting peregrine falcons in 1988 and 1989 revealed 28 and 58 pairs, in 15% and 24% of the park, respectively. Habitat-based estimation of the potential number of peregrine falcons in Grand Canyon suggested that as many as 96 pair existed in Grand Canyon in 1989.

Life Requisites

Peregrine falcons feed on more than 40 species of birds and several small mammals (Porter and White 1973, Stevens et al. 1998). Hunting areas included marshes or narrow tongues of streamside vegetation, and peregrine falcons may forage up to 17 miles from nest sites. Peregrine falcon diet at nest sites in national parks in southern Utah included small and medium-sized birds, especially including white-throated swifts, large shorebirds and Clark's nutcracker (Burnham 1987).

In Grand Canyon, peregrine falcons feed on waterfowl, swifts, swallows and bats (Brown 1991a, Stevens et al. 1998), many of which feed on invertebrate species (especially Diptera) that emerge out of the Colorado River (Stevens et al. 1997c). Therefore, dam operations that influence aquatic macro-invertebrate populations exert, at most, only indirect impacts on peregrine falcons.

Peregrine falcons breed up to 3,130 m elevation, typically on ledges on steep cliff faces (U.S. Fish and Wildlife Service 1984). The mean distance between nest sites along the South Rim of Grand Canyon varied from 3.5 to 5.0 linear miles, with minimum distances of 1.8 linear miles (Brown 1991a, 1992). The breeding season in Grand Canyon extends from February to July.

The primary reason for the national decline of the peregrine falcon population has been eggshell thinning from DDE and other environmental contaminants, which are biologically concentrated through the food chain (U.S. Fish and Wildlife Service 1984). DDE sources to peregrine falcons are derived from their prey, many of which are migratory insectivores. Burnham (1987) reported that swifts, shorebirds, and other migratory insectivores contained 5.8 ppm DDE (wet weight), while mean DDE levels in granivorous migrants, such as grosbeaks and mourning doves, was only 0.14 ppm DDE. Peregrine eggshells from southern Utah parks from 1985 to 1987 were 21% thinner than those from the pre-DDE era, indicating poor viability of eggs (Burnham 1987). Brown (1991b) reported that peregrine falcon eggshells from the Grand Canyon in 1988 were 11.4% to 12.7% thinner than pre-DDE controls.

In addition to pesticide concentrations, competition with other raptors has been considered as a possible cause of peregrine falcon population declines; however, Porter and White (1973) examined peregrine and prairie falcon interactions and concluded that competition was not important.

Impacts of BHBF(s)

Most wintering waterfowl on which peregrine falcons feed will have migrated from Grand Canyon by late March; however, mallard and late migrating gadwall and American widgeon are still likely to be common (Stevens et al. 1997a, 1998). Springtime food sources (swifts, swallows and bats) should be present in large numbers at that time of year (Stevens et al. 1998), and are only indirectly influenced by dam operations. Therefore, peregrine falcons will not lack food resources during the proposed high release. BHBFs at any time of the year will have no effect on peregrine falcons in the Colorado River downstream from Glen Canyon Dam.

ENDANGERED SOUTHWESTERN WILLOW FLYCATCHER
TYRANNIDAE: *Empidonax trailli extimus*

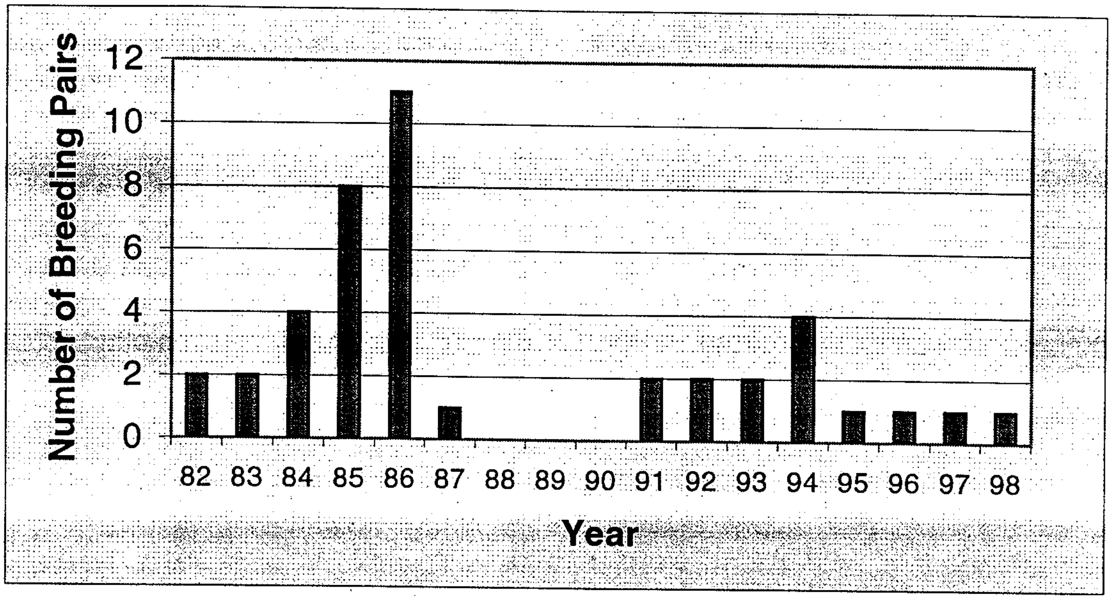


Figure ES6.1: The number of breeding southwestern willow flycatcher pairs detected along the river corridor in Grand Canyon 1982-1997. No surveys were conducted from 1988-1990 (Sogge 1998).

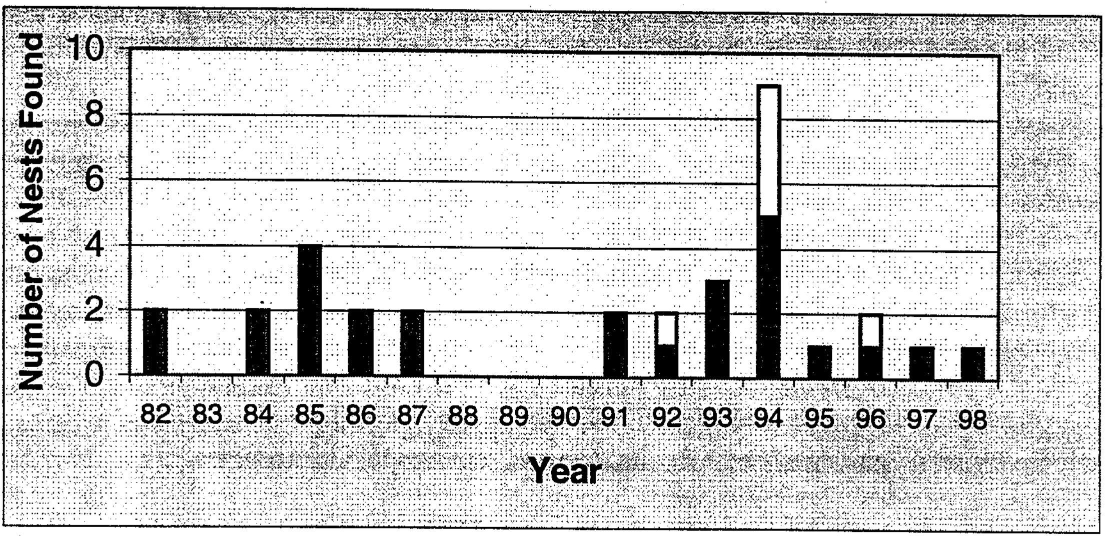


Figure ES6.2: The number of willow flycatcher nests detected along the river corridor in Grand Canyon 1982-1997. Lighter areas represent known renesting attempts (following failed previous nests) within the same territory. No surveys were conducted from 1988-1990 (Sogge 1998).

Southwestern Willow Flycatcher Species Account

Distribution and Abundance

The southwestern willow flycatcher (SWWF; Tyrannidae: *Empidonax traïlii extimus*) is a Neotropical migrant. Overall, the willow flycatcher species has a broad breeding range, extending from Nova Scotia to British Columbia and south to Baja California. The SWWF is an obligate riparian insectivore (Hunter et al., 1987), preferring habitat near open water (Gorski 1969; Sogge 1995). The historic breeding range of the SWWF includes Arizona, New Mexico, southern California, and southern portions of Nevada, Utah, and perhaps southwestern Colorado, and extends east into western Texas (U.S. Fish and Wildlife Service 1993). It probably winters from Mexico to Panama, with historical accounts from Colombia (Phillips 1948). The SWWF is distinguished from other subspecies by distribution, morphology and color, nesting ecology, but not by song dialect (Phillips 1948, Aldrich 1953, King 1955, Sogge 1995).

The regional SWWF population has declined over the past 50 years, corresponding with loss and modification of riparian habitats (Phillips 1948). Southwestern riparian ecosystems support a rich avian fauna (Johnson and Haight 1987) and habitat changes have resulted in reduction or extirpation of many avian species (Hunter et al., 1987). Modification and fragmentation of these systems through development and livestock grazing have precipitated devastating changes to SWWF populations. Destruction of native willow/cottonwood vegetation has provided opportunity for invasion by non-native plant species, notably saltcedar. Habitat fragmentation and modification has been beneficial to some southwestern avian species, especially cowbirds (*Molothrus* spp.), which parasitize SWWF nests, contributing to the precipitous population declines of SWWF (Brown 1994, Johnson and Sogge 1995, Sogge et al. 1995). SWWF habitat loss in Central and South America has also undoubtedly contributed to recent SWWF population declines, although little information is available.

The SWWF has been extirpated from much of its range (Hunter et al. 1987). Population reduction since 1950 was so dramatic that it was proposed (U.S. Fish and Wildlife Service 1992) and listed, with critical habitat, under the Endangered Species Act, on July 23, 1993 (U.S. Fish and Wildlife Service 1993). The SWWF is more rare than most other currently listed avian species (Unitt 1987). An estimated 300-500 breeding pairs remain in the United States, including 115 pairs in California and approximately 100 pairs in New Mexico (U.S. Fish and Wildlife Service 1993). Limited information exists for Colorado, Utah, Nevada, and Texas. It has been given special protection status by the Game and Fish Departments in Arizona, New Mexico and California.

Arizona has experienced the sharpest decline in SWWF numbers. SWWF formerly bred throughout the state at high and low elevations. For example, a 1931 breeding record exists from the south rim of the Grand Canyon (Brown et al., 1984), indicating that this taxon bred at high elevations, even at the northern edge of its range. By 1987, the State population was estimated at less than 25 pairs (Unitt 1987; U.S. Fish and Wildlife Service 1993), but much habitat was not surveyed. At least 52 territories or active nests were reported during extensive surveys in 1993 in Arizona (Muiznieks et al. 1994), and at least 62 active nests were located during a more thorough inventory in 1994 (Sferra et al. 1995). In Arizona, there were approximately 113 SWWF pairs in 1996 (Sferra et al. 1997).

From 1974 through 1996 the Grand Canyon population was detected between Colorado River miles 47 and 71 (Unitt 1987, Sogge et al. 1995, 1997). In its recent proposal the Service included the Colorado River from River Mile 39 to River Mile 71.5 as critical habitat U.S. Fish and Wildlife Service 1993), and stipulated in a subsequent final rule that defines such habitat as that "within 100 meters of the edge of areas with surface water during the May to September breeding season and within 100 meters of areas where such surface water no longer exists owing to habitat degradation but may be recovered with habitat rehabilitation" (U.S. Fish and Wildlife Service 1997). The boundary of this area in Grand Canyon includes the main Colorado River channel and associated side channels, backwaters, pools and marshes.

SWWF were common in Glen Canyon and the lower San Juan River prior to impoundment by Glen Canyon Dam (Woodbury and Russell 1945, Behle and Higgins 1959). This area was inundated by Lake Powell and no singing male SWWF were detected in a 1991 survey below Glen Canyon dam, although weather may have been a factor (Brown 1991a). SWWF were rather commonly reported along the pre-dam Colorado River at Lees Ferry, with records at Lees Ferry in 1909, 1933, 1935, and 1961, and near Lava Canyon in 1931 and near the Little Colorado River confluence in 1953 (reviewed by Sogge et al. 1997); however, the pre-dam distribution of SWWF in Marble Canyon and through Grand Canyon is poorly known. Carothers and Sharber (1976) reported only one pair of SWWF in Grand Canyon in the early 1970's surveys. Brown (1988) noted a brief population increase in the Grand Canyon from two in 1982, to a maximum of 11 (two in Cardenas Marsh), with a subsequent decline to seven in 1987. Brown (1991a) detected two pairs in 1991, with nests located at River Mile 50.7 and at River Mile 71.1 (Cardenas Marsh). Surveys in 1992 detected seven SWWF, three unpaired males and two breeding pairs in Cardenas Marsh (Sogge et al. 1995a). A total of five SWWF were detected in Grand Canyon in 1995: three territorial but non-breeding males and one breeding pair that fledged a single young (Sogge et al. 1995a). The unpaired male SWWF established territories between Colorado River miles 50.5 and 65.3, and the breeding pair nested at mile 50.5. In 1996 Sogge et al (1997) reported three singing SWWF, but only one successfully breeding pair along the Colorado River in upper Grand Canyon. The single pair apparently fledged two young. In 1997, the single nest in upper Grand Canyon was parasitized by brown-headed cowbirds and failed. A single SWWF nest near mile 265 in 1997 produced two young (Grand Canyon Monitoring and Research Center 1997). In both 1997 and 1998 SWWF failed to nest successfully in upper Grand Canyon because of cowbird brood parasitism (M. Sogge, U.S. Geological Survey Biological Resources Division, personal communication). The single nesting pair of SWWF at Mile 50.5L in upper Grand Canyon failed to produce young successfully in 1998 (N. Brown, personal communication). Other 1996-1997 reports of SWWF breeding in the lower Colorado River basin have stimulated additional research there.

The Service's 1996 B.O. on the BHBF defined several measures to mitigate impacts on the SWWF in Grand Canyon. Stevens et al. (1996) studied habitat changes at four historic SWWF nest sites in Grand Canyon. Fluvial marshes associated with these sites were dominated by common reed, horsetail and cattail. SWWF research activities associated with that BHBF included verifying stage-to-discharge relations, quantifying flow depth and velocity at nest sites, and determining nest site and foraging habitat structure, litter/understory characteristics, and nesting success.

The 1996 BHBF impacts on Grand Canyon SWWF habitat were reported by Stevens et al. (1996). Nest stand vegetation impacts were nominal: two stands were slightly scoured, and three sites sustained a slight reduction in ground cover and/or branch abundance at <0.6 m above the ground; however, no reduction in branch abundance or alteration of stand composition occurred, and the BHBF did not inundate the bases of any historic nest trees. Impacts on marsh foraging habitats were more severe, with decreases in area of 1% to >72%. Two of four SWWF sites regained vegetated area during the summer of 1996, while two other marshes sustained slight additional losses in cover through the 1996 growing season. The 50.05L marsh has not recovered appreciably since the 1996 BHBF (Stevens personal communication).

Life Requisites

SWWF arrive in the Grand Canyon area in mid-May, but may be confused with another subspecies, the more common *E.t. brewsteri*, which migrates through to more northern breeding grounds (Aldrich 1951; Unitt 1987). *E.t. brewsteri* sings during migration, making sub-specific distinctions difficult until mid-June (Brown 1991b). Males arrive earlier than females and establish territories. The characteristic territorial song is a "fitz-bew," most frequently heard in the morning before 10 AM (Tibbitts et al., 1994).

SWWF are highly territorial. Nest building begins in May after breeding territories are established. The nest is placed in a fork or horizontal branch 1-5 meters above ground (Tibbetts et al. 1994). A clutch of three or four eggs is laid from late May through July (Unitt 1987), but in Grand Canyon two or three eggs (usually three) are usually laid (Sogge 1995). Breeding extends through July and singing ceases at the end of the breeding season.

After a 12-14 day incubation, nestlings spend 12 or 13 days in the nest before fledging (Brown 1988; Tibbetts et al., 1994). The breeding season (eggs or young in nest) in Grand Canyon extends from early June to mid-July, but may extend into August. One clutch is typical, however re-nesting has been known to occur if the initial nest is destroyed or parasitized (Brown 1988).

Riparian modification, destruction and fragmentation provided new foraging habitat for brown-headed cowbirds (*Molothrus ater*) and populations of brown-headed cowbirds continue to expand (Hanka 1985, Harris 1991). Brood parasitism is currently the greatest threat to SWWF and probably many other Neotropical migrants as well (Bohning-Gaese et al., 1993; Sogge et al., 1995). Over half the nests in Brown's study (1988) contained brown-headed cowbird eggs. Cowbirds may remove prey eggs, their eggs hatch earlier, and the larger nestlings are more competitive in the nest. Cowbirds fledged from Sierra Nevada SWWF nests while SWWF nestlings died shortly after hatching (Flett and Sanders 1987). Brown-headed cowbirds occur extensively around mule corrals on the rim of the canyon and travel down to the Colorado River.

SWWF may remove cowbird eggs or, more commonly, abandon the nest if the parasite's eggs are deposited. The second nesting attempt is energetically expensive, requiring a new nest to be built (Sogge 1995), although Brown (1988) noted that a SWWF pair covered a cowbird egg with fresh nesting material and laid a new clutch. The second nest, already at a temporal disadvantage, is often parasitized as well. Cowbird parasitism could be largely responsible for the absence of SWWF in otherwise suitable habitat in the Grand Canyon (Unitt 1987). Bronzed cowbirds (*Molothrus aenus*) have recently been reported colonizing the Grand Canyon and represent another threat (Sogge 1995).

The SWWF in Grand Canyon occupy sites with average vegetation canopy height and density (Brown and Trossett 1989). SWWF commonly breed and forage in dense, often multistoried, riparian vegetation near surface water or moist soil (Whitmore 1977, Sferra et al., 1995), along low gradient streams (Sogge 1995). Nesting in the Grand Canyon typically occurs in non-native *Tamarix* approximately 4-7 m tall (13-23 feet), with a dense volume of foliage 0-4 m from the ground (Tibbetts et al., 1994). SWWF commonly and preferentially nest in saltcedar in upper Grand Canyon (Brown 1988), and nested in saltcedar in Glen Canyon before completion of the Glen Canyon Dam (Behle and Higgins 1959). Although habitat is not limiting in Grand Canyon (Brown and Trossett 1989), required patch size is not known. The 1997 nesting record from lower Grand Canyon demonstrates that this species can colonize new habitat; however, that habitat is influenced by Lower Basin Lake Mead management and is not within the purview of this Biological Assessment.

Proximity to water is necessary and is correlated with food supplies. Little is known of SWWF food preferences but it is probably a generalist feeder. It typically flycatches (sallys) from conspicuous perches, but also hovers and gleans insects from foliage (Stevens personal communication). SWWF also forage on sandbars, backwaters, and at the waters edge in the Grand Canyon (Tibbetts et al., 1994).

SWWF return to wintering grounds in August and September (Brown 1991b), but neither migration routes nor wintering areas are well known. Birds sing and perhaps defend foraging territories in Central America during winter, and winter movement may be tied to water availability (Gorski 1969). Threats to SWWF on the wintering grounds are poorly documented, but habitat losses in Latin America may be a major factor in the decline of this species.

Impact of BHBF(s)

A BHBF between May and July may affect the southwestern willow flycatcher and it's critical habitat along the Colorado River in Glen, Marble and upper Grand Canyons. GCMRC GIS coverage of 3 of the 4 sites will be used to model BHBF stage elevations above 45,000 cfs and the results incorporated into subsequent revisions to this BA.

We believe there is support for a determination of an "unlikely to adversely affect" SWWF critical habitat, based on the following logic. Nesting sites for SWWF would not be affected because SWWF nest several meters up in tamarisk trees that stand at or above the 45,000 cfs stage. In upper Grand Canyon, SWWF generally nest in saltcedar trees and nest trees typically lie at or above the 45,000 cfs stage. The saltcedar stands in which SWWF nest are unlikely to sustain direct damage from BHBF(s). Stevens and Waring (1988) demonstrated that saltcedar is exceptionally tolerant of flooding in the Grand Canyon, persisting through many weeks of inundation. The saltcedar trees in which the SWWF presently nest survived the >92,600 cfs flows of 1983 as well as the 1996 BHBF (Stevens et al. 1996), and are therefore unlikely to be scoured by one or more brief, <45,000 cfs BHBF's in 1999.

Although little is known of SWWF food preferences, it is probably a generalist feeder. It typically hovers and gleans insects from foliage, or flycatchers from conspicuous perches (Stevens personal communication). SWWF also forage on sandbars, backwaters, and at the water's edge in the Grand Canyon (Tibbetts et al., 1994).

As generalist feeders, SWWFs likely forage on both adult aquatic flying invertebrates, and terrestrial (non-aquatic) flying invertebrates. Although aquatic species could be impacted by the BHBF, populations of terrestrial flying invertebrates are unlikely to be affected by the flow, and any that are affected are likely to recover promptly after the event. Stevens (1985) reported that riparian invertebrate populations increased rapidly following a flow comparable to a BHBF in 1980 (U.S. Bureau of Reclamation 1990), a condition which would seem to provide required food needs for any SWWF present during or following a BHBF. Stevens (1985) also documented that tamarisk and willow, the dominant shrub/tree species in the Grand Canyon SWWF nest stands, support abundant invertebrate populations.

The wetlands and low-lying areas near SWWF nesting habitats and in which they occasionally forage, are likely to continue to be affected by BHBFs. Impacts to associated wetlands ranged from 1% to >72% from the 1996 BHBF, and impacts on those sites persisted through the 1996 growing season (Stevens et al. 1996). Although those habitats were strongly affected by the 1996 flood, actual impacts on SWWF food resources remain undocumented. It is unlikely that the 1996 BHBF affected SWWF foraging, but impacts are impossible to document with so few birds to study. SWWF forage on adult, terrestrial (non-aquatic) flying invertebrates, populations which are unlikely to be affected by a brief 45,000 cfs BHBF, and which are likely to recover promptly after the event. Stevens (1985) reported that riparian invertebrate populations increased rapidly following a flow comparable to a BHBF in 1980 (U.S. Bureau of

Reclamation 1990). Invertebrate population may require a longer recovery period after higher stage BHBFs.

The habitat and population in lower Grand Canyon is influenced by Lower Colorado River basin management of Lake Mead, and is not part of this Reclamation Office's purview. Even if that section of the river corridor is considered, present data indicate no impacts of a BHBF on SWWF habitat there. Results of Hualapai Indian Tribal analyses on riparian resources in lower Grand Canyon indicate that the impacts of the 1996 BHBF extended no farther than Mile 255 (Christensen 1997). This point lies approximately 10 miles upstream from recently reported SWWF nesting areas on upper Lake Mead. Therefore, this, and the shorter duration of the proposed 1998 BHBF, suggest that a planned high flow should have no effect on potential SWWF habitat in lower Grand Canyon .

In conclusion, BHBF(s) in 1999 may affect the SWWF. Foraging habitat of SWWF may be adversely affected, but flows ≥45,000 cfs will have an unknown impact on nest trees. High flows are likely to continue to reduce marsh areas associated with nest site stands, while higher stage BHBF's may eliminate those marshes (Stevens et al. 1995). However, the impacts on SWWF foraging success are unlikely to be nominal or undetectable.

NON-ENDANGERED ARIZONA STATE SPECIES OF CONCERN

Niobrara Ambersnail

Niobrara Ambersnail (*Oxvloma h. haydeni*) in this region is known from one site along the Colorado River (-9L, upstream from Lees Ferry) and at Indian Gardens. The ambersnail population at the riverside spring is unique and is associated with the *Typha* and other wetland vegetation. This population somehow persisted through the 1996 experimental flow. This snail population is not presently being monitored; however, some observations were made in 1998. Although the snail was abundant in May 1998 (Stevens, personal observation), flows in excess of 20,000 cfs inundate the habitat. Flows exceeded 22,000 cfs for extended periods in the summer of 1998, and no snails were found during two searches in late summer and autumn (Stevens and Meretsky, personal communications). This population is one of several under genetic analysis by Keim and Stevens.

Northern Leopard Frog

Northern Leopard Frog (*Rana pipiens*) in the Grand Canyon region is presently known from one site along the Colorado River (-9L, upstream from Lees Ferry). The frog population at -9L is apparently native, and was monitored before and after the 1996 test flow. The population was active at the time of that flow, and apparently was little affected by the flow and recovered quickly (Spence 1997). However, higher BHBF's may exert greater impacts on this population.

Other Avifauna

Wintering passerines and waterbirds are a concern in lower Glen and Grand canyons, and are being monitored. Migratory osprey and belted kingfisher populations are additional species of concern in Arizona. Those populations were apparently not affected by the 1996 test flow, and spring and fall 1997 and 1998 populations of those species appeared to be approximately normal (Stevens et al. 1997a, J. Spence, Glen Canyon National Recreation Area, personal communication).

GCMRC Monitoring and Research Projects in 1998

Hyperlink to GCMRC Home Page

CULTURAL RESOURCES

New Findings

Background

Past Studies

EIS Studies

PA Program

GCM RC Studies

1996 Test Flow Impacts

Cultural Resources Work in 1997 and 1998

Archeological Sites

Ethnobotanical Resources

Summary

New Findings

Cultural resources along the Colorado River corridor include archaeological sites and traditional cultural resources such as springs, landforms, sediment and mineral deposits, and traditional plant locations and animals. All of these resources have the potential to be affected by the operations of Glen Canyon Dam. The ultimate goal of the cultural resource efforts related to Glen Canyon Dam operations is *in-situ* preservation, with minimal impact to the integrity of the resources and when preservation is not possible data recovery efforts, as appropriate.

Background

The current information concerning cultural resources is based on a number of previous investigations within the Colorado river corridor in the Glen and Grand Canyons. Comprehensive overviews of previous investigations are included in Ahlstrom et al. (1993) and Fairley et al. (1994).

Past Studies: Archaeological remains were first noted in the river corridor by Euro-Americans during the Powell expeditions in the 1800s (Powell 1875). Traces of archaeological remains were noted in the vicinity of Bright Angel Creek and the Unkar Delta area. In later years, archaeological investigations were noted in the river corridor and on the rims of the canyon (Hall 1942; Haury n.d.). In the 1950s and 1960s, investigations became more focused under the direction of the NPS, in part due to anticipated dam development in areas of the Canyon (Euler 1967; Euler and Taylor 1966; Taylor 1958). In the late 1960s and early 1970s the School of American Research and the NPS conducted excavations in the river corridor and adjacent areas to investigate the prehistoric settlement pattern (Jones 1986; Schwartz 1965; Schwartz et al. 1979, 1980, 1981). Together, these studies provided the initial information that suggested that numerous cultural resources existed within the river corridor.

EIS Studies: Intensive archaeological inventories were conducted by the NPS during 1990 to 1991 in preparation of the GCDEIS to assess a range of dam operations (Fairley et.al 1994). These inventories located approximately 475 sites within the assessed area extending from Glen Canyon Dam to Separation Canyon, about 255 river miles and up to the 300,000 cfs flood level. Of the sites within this area, approximately 336 had identifiable impacts that were believed to be related to dam operations. Impacts were categorized as direct, indirect, or potential. Direct impacts included sites where inundation or bank cutting had occurred within the site in recent years. Indirect impacts included: 1) bank slumpage or slope steepening adjacent to the site, 2) arroyo cutting or other erosion phenomena related to base level lowering from river eroded sediments within the site, and 3) effects of visitor impacts at sites due to recreational use patterns. Potentially impacted sites include those within the 300,000 cfs flood level without direct or indirect impacts currently identifiable.

Participating Native American tribes have also conducted cultural resource inventories to identify resources that have important cultural values to them. These studies were conducted by the Hopi Tribe, the Hualapai Tribe, the Navajo Nation, the Southern Paiute Consortium, and the Zuni Pueblo during the development of the GCEIS. Numerous locations of cultural importance were identified and assessed including important biological cultural resources, physical features and locations, and archaeological resources. Assessments were conducted by these tribes to identify potential impacts resulting from dam operations and to formulate possible treatment options. These studies were subsequently utilized by the BOR for the identification and evaluation of traditional cultural properties within the area of potential effect as defined by the PA program.

PA Program Work: Using the above resource inventories to establish baseline conditions, monitoring activities have been conducted to identify changes in resource conditions under the stipulations of the PA program. The NPS conducts monitoring throughout the year and produces annual monitoring reports for the Glen Canyon and Grand Canyon areas. Tribal groups conduct monitoring trips several times a year and assess changes to their traditional cultural resources and to assess the general health of the ecosystem through their own traditional value system.

Current monitoring activities conducted under the PA program include site visits, photographs, instrument mapping of sites, and remedial activities. Results of these monitoring activities indicate that physical and visitor-related impacts constitute the majority of impacts to the cultural resources. Based on the NPS FY 98 field work, two river corridor areas, Reaches 5 (RM 61.5-77.4) and 10 (RM 159.8-213.9), appear to have the highest frequencies of physical and visitor related impacts (Leap et. al. 1998).

Recommendations from monitoring efforts include a combination of preservation options (such as trail obliteration and retrailing, revegetation, and construction of checkdams to halt erosion) and recovery options (such as surface collection, mapping, testing, and data recovery) at features or sites (Leap et.al. 1998).

GCMRC Studies: Three on-going GCMRC projects are providing information that complements data collected under the PA program. This information includes a data synthesis of previously collected information under the PA program, mainstem flow and deposition modeling, and testing of a geomorphic erosional hypothesis. Compilation of existing data from a number of sources will identify data gaps in previously collected data. In addition, analysis currently underway will provide information on changes in site conditions over time. Empirical data has been collected for the projects addressing mainstem flow modeling and geomorphic hypothesis testing. Project data from the three efforts is expected in FY 99.

1996 Test Flow Impacts on Cultural Resources

Many of the archaeological resources along the river corridor are contained in the sediment deposits which form the alluvial terraces. Since the completion of Glen Canyon Dam, the sediment resource has declined, and the alluvial terraces have eroded. A system-wide method for regenerating the river terraces and redistributing sediment is generally considered an essential component to maintaining integrity for cultural resources.

The 1996 Test Flow presented an opportunity to study the effects of high flow discharge from Glen Canyon Dam on alluvial terraces and margin deposits along the river corridor. The effects of these flows on the margin deposits and terraces is an important area of study since many of the terraces are of relatively recent origin and contain archaeological materials.

The 1996 Test Flow was expected to provide system-wide mitigation to most cultural sites in the Colorado River corridor through the accumulation of additional sediment. A positive effect was presumed but not guaranteed. As a result, some mitigation and monitoring of archaeological sites and other kinds of cultural resources, ethnobotanical resources, beaches, and sediment accumulation at the mouths of arroyos was undertaken to assess the results of the Flow. Terraces were studied in the Glen Canyon reach to determine whether terrace erosion occurred in this area as the loss of terrace deposits would impact the archaeological materials contained in the sediments.

The overall findings of the cultural resources studies done in conjunction with the 1996 Test Flow strongly suggest that the 45,000 cfs flow had either no effect, no adverse effect, or a beneficial effect on cultural resources. These findings support the original contention that habitat building flows can offer a system-wide mitigation for cultural resources. Some locations, especially in the Glen Canyon Reach, did experience loss of sediments or redeposition of sediments in a way that, in the long run, could be detrimental to cultural resources.

Cultural Resources Work In 1997 and 1998: Archaeological Sites

Archaeological site monitoring and management was conducted along the river corridor by the NPS (Leap et al. 1998). In Grand Canyon National Park (GCNP) and Glen Canyon National Recreation Area (GCNRA), monitoring was conducted at a total of 141 sites along the corridor and remedial activities were undertaken at 44 sites. The sites were selected based on protocols established under the Programmatic Agreement (PA) and the Historic Preservation Plan (HPP). Remedial activities at these sites included mapping, maintenance and construction or erosional controls such as check dams, and small data recovery (excavation) efforts.

Physical and visitor impacts were observed at many of the sites. Physical impacts are divided into eight categories that include surface erosion, gullying, arroyo cutting, bank slumpage, eolian/alluvial erosion or deposition, side canyon erosion, animal- caused erosion, and others. Impacts directly related to dam operations include bank slumpage, gullying and arroyo cutting in locations where drainage systems are actively changing to achieve the dam-induced, lowered river baselevel. At GCNP, eighty-one percent of the sites (N=80) monitored in FY 98 had some form of physical impact (Leap et. al. 1998:14). New physical impacts were observed at 49% of the sites (N=49). Surface erosion and gullying were the most commonly observed impact to archaeological sites. The highest frequency of impacts appears to occur at sites with structures/storage features, artifact scatters, and roasters/hearths, the most common archaeological sites encountered in the river corridor. The majority of the impacts appear to occur within the geomorphic river reaches 5 (Mile 61 to 76) and 10 (Mile 160 to 214).

Visitor impacts are separated into five categories that include trails, collection piles, on-site camping, criminal vandalism and other, undefined impacts. Trails are the most frequent impact 43% of the sites (N=43). Visitor impacts tend to occur at the same site types listed above for physical impacts. The majority of impacts appear to occur within River Reaches 4 (RM 35 to 61), 5 (RM 61.5-77.4) and 10 (RM 159.8-213.9) that have high site densities and popular river camps, where layovers with time for exploration above the beaches is possible.

In the GCNRA, active physical impacts are present at less than half of the 42 monitored sites with surface erosion the most frequent type at 29% (N=12) of the sites. Sites with river based drainages exhibited more active erosion than sites with terrace based drainages (Leap et. al.1998: 85-88). Visitor related impacts were evident at 45% (N=19) of the 42 sites monitored.

Mitigative measures were conducted at five sites under the direction of an Hopi Tribe archaeologist (Yeatts 1998). The data recovery efforts were necessitated at erosional impacts to specific thermal features (roasters) and one cyst. Research questions were concerned with chronological issues, subsistence and subsistence technology, paleoenvironmental conditions and possibly seasonality of site use. Excavation, pollen, and flotation data provided information in the these areas. C-14 dates from datable charcoal indicate that the roasting features range in age from the Basket Maker III period (AD 620 – 775), through Pueblo II (AD 970 – 1195) to modern use (AD 1810- 1930), although the early dates may be somewhat problematic due to the possibility of reuse of older wood. Pollen and macrobotanical remains indicate that local and non-local woods were used as fuel, with mesquite being the dominant wood. Definitive data on the types of materials that were being processed in the roasting features was lacking, although there are remains of cactus, lily and Cheno-Am pollen in some samples. This work provides some information on prehistoric and historic activities from small mitigation efforts.

In the Spring 1998, additional remediation efforts occurred at Furance Flats. The report of the results of the excavation is currently being drafted.

Ethnobotanical Resources

Ethnobotanical resources were monitored by tribal groups during 1997 and 1998. The Southern Paiute Consortium (SPC) monitored traditional resources to assess the condition of the resources, to educate and train tribal members as monitors, to educate other tribal members and the general public, and to compile resource data bases (Austin et al. 1998).

Twelve locations were monitored by the SPC. The locations included traditional resources such as plants, rock art, and archaeological remains. The assessment of the tribal monitors is that the resources appear to be in good condition with the exceptions of visitor trails at two locations through archeological sites. Plant resources seem to be in very good conditions at three locations.

Hualapai ethnobotanical resources were monitored at five study sites along the river (Phillips and Jackson 1997) during 1997. The trends that were noted during 1997 site visits included: 1) a reworking and erosion of unstable sediment deposits near the shore continued during 1997 resulting from the high water releases from GCD; 2) species and plant recovery following the 1996 test flow was reversed at some sites based on the high water releases from GCD, while vegetation away from the shoreline were less obvious; 3) two exotic species consistently increased in 1997, bermuda grass and camel thorn; and 4) the continual high water releases may erode sediments from the base of the root system of the Goodding Willow at Granite Park; and 5) the species diversity evident following the 1996 test flow may have been reversed with the continual high water releases in 1997. Recommendations where made to continue monitoring these locations to determine the health of these resources with the high water releases anticipated in 1998. The 1998 tribal monitoring report was not available at the time of this report draft.

The Hopi Tribe has initiated an ethnobotanical project to evaluate traditional plant resources. Some results from this project will be available next year.

Summary

Resource monitoring in 1997 and 1998 of archaeological and traditional resources suggests that archaeological resources continue to be impacted by physical impacts such as surface erosion and gullying in both the Grand and Glen Canyon areas. While some surface erosion is related to natural processes, sediment loss from erosional process related to dam operations and mainstem water levels, and head cutting arroyos appears to impact archaeological sites at specific locations. Visitor impacts such as trailing, collection of artifacts have also been noted at archaeological sites and locations of traditional importance.

Assessment of ethnobotanical resources suggests somewhat mixed results. At some locations, the Southern Paiute Consortium have identified good conditions for traditional plant resources, while the Hualapai Tribe has expressed concerns for botanical resources at other locations and the increase in exotic plants such as Bermuda Grass and Camel Thorn. The results from the 1998 Hualapai monitoring season may provide additional information in this area.

SOCIO-ECONOMIC RESOURCES

Recreation

- **Whitewater Boating**
- **Day Use Rafting**
- **Angling**

Power Production

Whitewater Boating

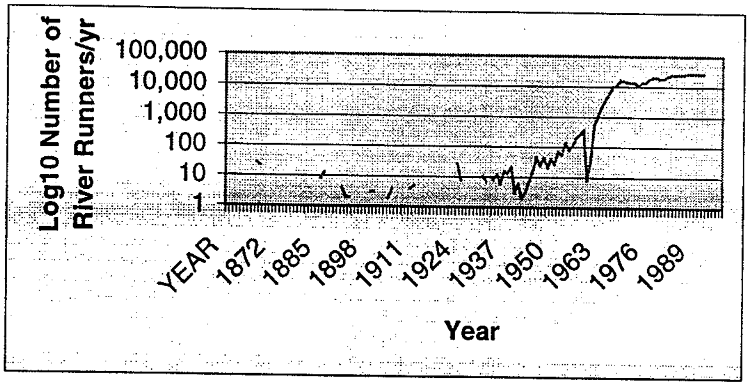


Fig. E1.1: Number of river runners through Grand Canyon, 1869-1998. Data courtesy of Grand Canyon National Park, updated 1 July 1998.

Day Use Rafting

Day-use rafting from Glen Canyon Dam to Lees Ferry typically involves half-day trips. Nearly 40,000 visitors/yr enjoy floating the last free-flowing section of Glen Canyon, a quiet-water river trip offered by Wilderness River Adventures from Page, Arizona.

Angling

Recent data on angling economics have yet to be compiled.
Hyperlink to Trout Section on angler use.

Power Production

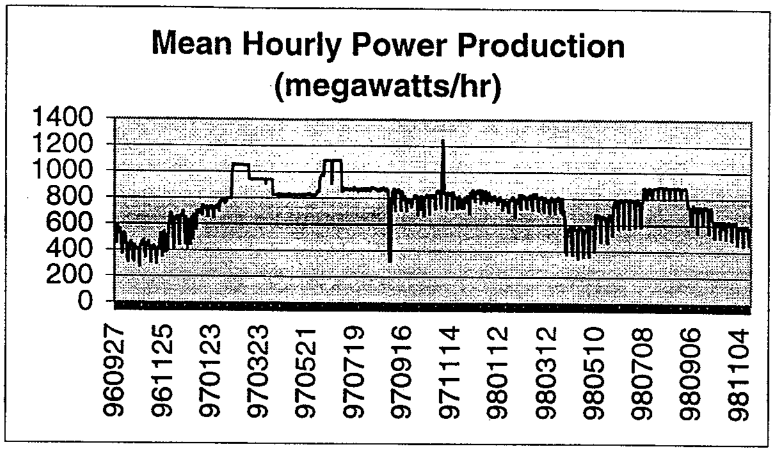


Fig. E2.1: Mean hourly daily Glen Canyon Dam hydroelectric power production, Water Years 1997-1998. Data from the Bureau of Reclamation SCADA data; updated 17 November 1998.

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CITED AND RELEVANT COLORADO RIVER ECOSYSTEM AND MANAGEMENT LITERATURE (Updated 7 December 1998)

Aldrich, J.W. 1951. A review of the races of the Traill's flycatcher. Wilson Bull. 63(3): 192-197.

Aldrich, J.W. 1953. Habitats and habitat differences in two races of Traill's flycatcher. Wilson Bull. 65(1): 8-11.

Angradi. T.R. 1994. Trophic linkages in the lower Colorado River: multiple stable isotope evidence. J. North American Benthological Society 13:479-495.

Angradi, T.R. and D.M. Kubly. 1993. Effects of atmospheric exposure on chorophyll *a*, biomass and productivity of the epilithon of a tailwater river. Regulated Rivers: Research & Management 8:345-358.

Angradi, T. R., R. W. Clarkson, D. A. Kingsolving, D. M. Kubly, and S. A. Morgensen. 1992. Glen Canyon Dam and the Colorado River: responses of the aquatic biota to dam operations. Bureau of Reclamation Glen Canyon Environmental Studies Program, Flagstaff.

Behle, W.H. and H.G. Higgins. 1959. The birds of Glen Canyon. Pp 107-133 in Woodbury, A.M. (ed.). Ecological studies of flora and fauna in Glen Canyon. University of Utah Anthropological Papers 40 (Glen Canyon Series No. 7).

Bestgen, K.R. 1990. Status review of the razorback sucker, Xyrauchen texanus. Colorado State University Larval Fish Laboratory Contribution 44. Fort Collins, CO.

Blinn, D.W., L.E. Stevens and J.P. Shannon. 1992. The effects of Glen Canyon Dam on the aquatic food base in the Colorado River corridor in Grand Canyon, Arizona. Bureau of Reclamation Glen Canyon Environmental Studies Report II-02, Flagstaff, AZ.

Blinn, D.W., J.P. Shannon, L.E. Stevens and J.P. Carder. 1995. Consequences of fluctuating discharge for lotic communities. Journal of the North American Benthological Society 14:233-248.

Bohning-Gaese, K., M.L. Taper, and J.H. Brown. 1993. Are declines in North American insectivorous songbirds due to causes on the breeding range? Conservation Biology 7(1): 76-86.

Bozek, M.A., L.J. Paulson and J.E. Deacon. 1984. Factors affecting reproductive success of bonytail chubs and razorback suckers in Lake Mohave. U.S. Bureau of Reclamation Final Report 14-16-0002-81-251, Boulder City, NV.

Brown, B. T. 1988. Breeding ecology of a willow flycatcher population in Grand Canyon, Arizona. Western Birds 19:25-33.

Brown, B.T. 1991a. Abundance, distribution, and ecology of nesting peregrine falcons in Grand Canyon National Park, Arizona. Grand Canyon National Park Report.

Brown, B. T. 1991b. Status of nesting willow flycatchers along the Colorado River from Glen Canyon Dam to Cardenas Creek, Arizona. Endangered Species Report No. 20, U.S. Fish and Wildlife Service, Phoenix, Arizona. 34 pp.

Brown, B.T. 1993. Winter foraging ecology of bald eagles in Arizona. Condor 95:132-138.

Brown, B.T. 1994. Rates of brood parasitism by brown-headed cowbirds on riparian passerines in Arizona. Journal of Field Ornithology 65:160-168.

Brown, B.T. and W.C. Leibfried. 1990. The effects of fluctuating flows from Glen Canyon Dam on bald eagles and rainbow trout at Nankoweap Creek along the Colorado River, Arizona. 1990 Interim Report to the Glen Canyon Environmental Studies, U.S. Bureau of Reclamation, Upper Colorado Region, Salt Lake City, UT.

Brown, B.T. and L.E. Stevens. 1991. Influences of fluctuating flows from Glen Canyon Dam and effects of human disturbance on wintering bald eagles along the Colorado River in Grand Canyon, Arizona, Final Report. U.S. Bureau of Reclamation Glen Canyon Environmental Studies Report, Flagstaff.

Brown, B.T. and L.E. Stevens. 1992. Winter abundance, age structure, and distribution of bald eagles along the Colorado River, Arizona. Southwestern Naturalist 37:404-435.

Brown, B.T. and L.E. Stevens. 1997. Winter bald eagle distribution is inversely correlated with human activity along the Colorado River, Arizona. Journal of Raptor Research 31:7-10.

Brown, B.T. and M.W. Trossett. 1989. Nesting-habitat relationships of riparian birds along the Colorado River in Grand Canyon, Arizona. Southwestern Naturalist 34(2):260-270.

Brown, B.T., S.W. Carothers, L.T. Haight, R.R.Johnson, and M.M. Riffey. 1984. Birds of the Grand Canyon region: an annotated checklist. Grand Canyon Natural History Association, Monograph Number 1. 54 pp.

Brown, B.T., R. Mesta, L.E. Stevens and J. Weisheit. 1989. Changes in winter distribution of bald eagles along the Colorado River in Grand Can;yon, Arizona. Journal of Raptor Research 23:110-113.

Brown, B.T., G.S. Mills, R.L. Glinski, and S.W. Hoffman. 1992. Density of nesting peregrine falcons in Grand Canyon National Park, Arizona. Southwestern Naturalist 37:188-193.

Brown, B.T., L.E. Stevens and T. Yates. Influences of fluctuating flows on bald eagle foraging behavior. The Condor, in press.

Burnham, W. 1987. Three-year report, Rocky Mountain Peregrine Program. National Park Service, Denver.

Carothers, S.W. and C.O. Minckley. 1981. A survey of the fishes, aquatic invertebrates and aquatic plants of the Colorado River and selected tributaries from Lees Ferry to Separation Rapids, Final Report. Water and Power Resources Service, Salt Lake City, UT.

Childs, M.R., R.W. Clarkson and A.T. Robinson. 1998. Resource use by larval and early juvenile native fishes in the Little Colorado River, Grand Canyon, Arizona. Transactions of the American Fisheries Society 127:620-629.

Christensen, K. The river runs to Mile 254. Pp. 65 in Glen Canyon Dam beach/habitat building flow: abstracts and summaries. Grand Canyon Monitoring and Research Center, April 1997.

Clarke. A.H. 1991. Status survey of selected land and freshwater gastropods in Utah. U.S. Fish and Wildlife Service Report, Denver, CO.

Cole, G.A. and D.M. Kubly. 1976. Limnologic studies on the Colorado River from Lees Ferry to Diamond Creek. Colorado River Research Series Report No. 8, Grand Canyon.

Cooley, M.E., J.W. Harshbarger, J.P. Akers, and W.F. Hardt. 1969. Regional hydrogeology of the Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah. U.S. Geological Survey Professional Paper 521A.

Detrich, P.J. 1987. Effects of water projects on western raptors. Pp. 204-108 in Proceedings of the Western Raptor Management Symposium and Workshop, Boise Idaho, October 26-28, 1987.

Dill, W.A. 1944. The fishery of the lower Colorado River. California Fish and Game 30:309-401.

Douglas, M.E. and P.C. Marsh. 1996. Population estimates/population movements of *Gila_cypha*, an endangered cyprinid fish in the Grand Canyon region of Arizona. Copeia 1996:15-28.

Drost, C.A. and M.K. Sogge. 1995. Monitoring of brown-headed cowbird impact on nesting migrant birds in Grand Canyon National Park: 1995 progress report. National Biological Service Colorado Plateau Research Station, Flagstaff, AZ.

Ellis, D.H. and G. Monson. 1989. A historical review of peregrine falcon breeding and summering records for Arizona and the Navajo Indian Reservation. The Southwestern Naturalist 34:565-569.

Ferriss, J.H. 1910. A collecting excursion north of the Grand Canyon of the Colorado. The Nautilus 23:109-112.

Flett, M.A. and S.D. Sanders. 1987. Ecology of a Sierra Nevada population of willow flycatchers. Western Birds 18:37-42.

Glinski, R.L. 1993. Peregrine falcon recovery in the Southwest: the administrative necessity for a survey protocol and the ecological importance of the Grand Canyon, National Park. Pp. 49-55 *in* Rowlands, P.G., C. van Riper III, and M.K. Sogge, editors. Proceedings of the First Biennial Conference on Research in Colorado Plateau National Parks. Transactions and Proceedings Series NPS/NRNAU/NRTP-93-10, National Park Service, Washington, D.C.

Gorman, O.T. 1994. Habitat use by humpback chub, Gila cypha, in the Little Colorado River and other tributaries of the Colorado River: GCES Phase II final report. U.S. Fish and Wildlife Service Arizona Fishery Resources Office - Flagstaff, AZ.

Gorski, L.J. 1969. Traill's flycatchers of the "fitz-bew" songform wintering in Panama. Auk 86:745-747.

Grand Canyon Monitoring and Research Center. 1997. The state of natural and cultural resources in the Colorado River ecosystem. U.S. Department of the Interior, Grand Canyon Monitoring and Research Center, Flagstaff.

Grams, P.E. and J.C. Schmidt. 1998. Synthesis of geomorphic data in the Point Hansbrough and Little Colorado River confluence study reaches: draft final report. Grand Canyon Monitoring and Research Center, Flagstaff, AZ.

Hamman, P.L. 1982. Spawning and culture of humpback chub. Progressive Fish Culturist 44(4):213-216.

Hanka, L. R. 1985. Recent altitudinal range expansion by the brown-headed cowbird in Colorado. Western Birds 16:183-184.

Harris, J.H. 1991. Effects of brood parasitism by brown-headed cowbirds on willow flycatcher nesting success along the Kern River, California. Western Birds 22:13-26.

Howard, A.D. and R. Dolan. 1981. Geomorphology of the Colorado River. Journal of Geology 89:269-298.

Johnson, M.J. and M.K. Sogge. 1995. Cowbird concentrations at livestock corrals in Grand Canyon National Park. Pp. 275-284 in Van Riper, C., III (ed.). Proceedings of the Second Biennial Conference on Research in Colorado Plateau National Parks. National Park Service Transactions and Proceedings Series NPS/NRNAU/NRTP-95/11.

Johnson, R.R. 1991. Historic changes in vegetation along the Colorado River in the Grand Canyon . Pp. 178-206 *in* Marzolf, G.R., ed. Colorado River ecology and dam management. National Academy Press, Washington.

Johnson, R.R. and L.T. Haight. 1987. Endangered habitats versus endangered species: A management challenge. Western Birds 18:89-96.

Kaeding, L.R. and M.A. Zimmerman. 1983. Life history and ecology of the humpback chub in the Little Colorado and Colorado rivers of the Grand Canyon. Transactions of the American Fisheries Society 112:577-594.

Kanab Ambersnail Interagency Monitoring Group. 1997a. The impacts of an experimental flood from Glen Canyon Dam on the endangered Kanab ambersnail at Vaseys Paradise, Grand Canyon, Arizona. Grand Canyon Monitoring and Research Center, Flagstaff.

Kanab Ambersnail Interagency Monitoring Group. 1997b. The endangered Kanab ambersnail at Vaseys Paradise, Grand Canyon, Arizona: 1997 draft annual report. Grand Canyon, Arizona. Grand Canyon Monitoring and Research Center, Flagstaff.

Kaplinski, M.,.J.E. Hazel, M.F. Manone, R.A. Parnell and A. Dale. 1998. Colorado River sediment storage in Grand Canyon during calendar year 1997: final report. GCMRC, Flagstaff, AZ.

Karp, C. A., and H. M. Tyus. 1990. Humpback Chub (*Gila cypha)* in the Yampa and Green Rivers with observations on other sympatric fishes. Great Basin Naturalist 50:257-264.

Kearney, T.H. and R.H. Peebles (editors). 1960. Arizona flora, 2nd edition. University of California Press, Berkeley.

Kearsley, L.H., J.C. Schmidt and K. D. Warren. 1994. Effects of Glen Canyon Dam on Colorado River sand deposits used as campsites in Grand Canyon National Park, USA. Regulated Rivers: Research & Management 9:137-149.

Kerns, B.K. 1993. Alluvial chronology, malacology, and archaeology in middle Grand Gulch, southeast Utah. Northern Arizona University Geology Department Master's Thesis, Flagstaff.

King, J.R. 1955. Notes on the life history of Traill's flycatcher (*Empidonax traillii*) in southeastern Washington. Auk 72:148-173.

Kubly, D. M. 1990. The endangered humpback chub (*Gila cypha*) in Arizona. A review of past studies and suggestions for future research. Bureau of Reclamation report, Glen Canyon Environmental Studies Program, Flagstaff.

Leap, L.M., T. Burchett, J.L. Kunde, N.B. Andrews and D.C. Hubbard. 1998. Summary report: archaeological site monitoring and management along the Colorado River corridor below the Glen Canyon Dam. Grand Canyon National Park, Flagstaff.

Leibfried, W.C. and W.L. Montgomery. 1993. Regulated flows, trout spawning, and abundance of bald eagles on the Colorado River, Grand Canyon National Park. Pp. 37-48 *in* Rowlands, P.G., C. van Riper III, and M.K. Sogge, editors. Proceedings of the First Biennial Conference on Research in Colorado Plateau National Parks. Transactions and Proceedings Series NPS/NRNAU/NRTP-93-10, National Park Service, Washington, D.C.

Lupher, M.L. and R.W. Clarkson. 1994. Temperature tolerance of humpback chub (*Gila cypha*) and Colorado squawfish (*Ptychocheilus lucius*), with a description of culture methods for humpback chub. Arizona Game and Fish Department Report, Cooperative Agreement 9-FC-40-07940, Phoenix, AZ.

Maddux, H.R., D.M. Kubly, J.C. DeVos Jr., W.R. Persons, R. Staedicke, and R.L. Wright. 1987. Effects of varied flow regimes on aquatic resources of Glen and Grand canyons. U.S. Bureau of Reclamation Glen Canyon Environmental Studies Report, National Technological Information Series PB88-183439/AS.

Marsh, P. C. 1985. Effect of incubation temperature on survival of embryos of native Colorado River fishes. The South western Naturalist 30(1):129-140.

Marsh, P.C. and W.L. Minckley. 1989. Observations on recruitment and ecology of razorback sucker: Lower Colorado River, Arizona-California-Nevada. Great Basin Naturalist 49:71-78.

McCarthy, M.S. and W.L. Minckley. 1987. Age estimation for razorback sucker (Pisces: Catostomidae) from Lake Mohave, Arizona and Nevada. Journal of the Arizona-Nevada Academy of Sciences 21:87-97.

McElroy, D.M., and M.E. Douglas. 1995. Patterns of morphological variation among endangered populations of *Gila robusta* and *Gila cypha* (Teleostei: Cyprinidae) in the upper Colorado River Basin. Copeia 1995:636-649.

McGuinn-Robbins, D.K. 1997. Comparison of the number and area of backwaters associated with the Colorado River in Glen, Marble and Grand canyons, Arizona. Arizona Game and Fish Department Report, Phoenix.

Miller, R.R. 1946. *Gila cypha*, a remarkable new species of cyprinid from the Colorado River in Grand Canyon, Arizona. Papers of the Michigan Academy of Sciences and Arts Letters. 40:125-136.

Minckley, W.L. 1973. Fishes of Arizona. Arizona Game and Fish Department, Phoenix, AZ.

Minckley, W.L. 1983. Status of the razorback sucker, *Xyrauchen texanus* (Abbott), in the Lower Colorado River Basin. Southwestern Naturalist 28:165-187.

Minckley, W.L. 1991. Native fishes of the Grand Canyon region: an obituary? Pp. 124-177 in Marzolf, G.R. (lead editor). Colorado River ecology and dam management. National Academy Press, Washington, D.C.

Mueller, G. 1989. Observations of spawning razorback sucker (*Xyrauchen texanus*) utilizing riverine habitat in the Lower Colorado River, Arizona-Nevada. Southwestern Naturalist 34:147-149.

Muiznieks, B.D., T.E. Corman, S.J. Sferra, M.K. Sogge and T.J. Tibbitts. 1994. Arizona Partners in Flight southwestern willow flycatcher survey 1993. Arizona Game and Fish Department report, Phoenix, AZ.

New Mexico Department of Game and Fish. 1986. Handbook of species endangered in New Mexico, Santa Fe, New Mexico.

Ohmart, R.D. and R.J. Sell. 1980. The bald eagle of the Southwest, with special emphasis on the breeding population of Arizona. U.S. Water and Power Resources Service, Denver.

Patten, D.T., D.A. Harpman, M.I. Voita, and T.M. Randle. A Managed Flood on the Colorado River: Background, Objectives, Design, and Implementation. Ecological Applications, in press.

Patten, D.T., J.C. Schmidt, E.D. Andrews, L.E. Stevens, W.L. Minckley, G.R. Marzolf and J.A. Stanford. 1994. Experimental high discharge release from Glen Canyon Dam through Grand Canyon National Park: draft work plan. Bureau of Reclamation Glen Canyon Environmental Studies, Flagstaff.

Phillips, A.R. 1948. Geographic variation in Empidonax traillii Auk 65:507-514.

Phillips, A.M. III and L. Jackson. 1997. Monitoring Hualapai ethnobotanical resources along the Colorado River, 1997 Annual Report. Hualapai Cultural Resources Division, Peach Springs.

Pilsbry, H.A. 1948. Land Mollusca of North America. The Academy of Natural Sciences of Philadelphia Monographs II(2):xivi,521-1113.

Pilsbry, H.A. and J.H. Ferriss. 1911. Mollusca of the southwestern states, V: the Grand Canyon and northern Arizona. Proceedings of the Academy of Natural Sciences of Philadelphia 63:174-199.

Porter, R. D., and C. M. White. 1973. The peregrine falcon in Utah, emphasizing ecology and competition with the prairie falcon. Brigham Young University Biology Series 18:1-74.

Rubin, D.M., J.M. Nelson and D.J. Topping. 1998. Relation of inversely graded deposits to suspended-sediment grain-size evolution during the 1996 flood experiment in Grand Canyon. Geology 26:99-102.

Rubin, D.M., J.C. Schmidt and J.N. Moore. 1990. Origin, structure, and evolution of a reattachment bar, Colorado River, Grand Canyon, Arizona. Journal of Sedimentary Petrology 60:982-991.

Salzer, M.W., V.A.S. McCord, L.E. Stevens and R.H. Webb. 1996. The dendrochronology of *Celtis reticulata* in the Grand Canyon: assessing the impact of regulated river flow on tree growth. Pp. 273-281 *in* J.S. Dean, D.M. Meko and T.W. Swetnam (editors). Tree Rings, Environment and Humanity. Radiocarbon.

Schmidt, J.C. and J.B. Graf. 1990. Aggradation and degradation of alluvial sand deposits, 1965-1986, Colorado River, Grand Canyon National Park, Arizona. U.S. Geological Survey Professional Paper 1493.

Schmidt, J.C. and D.M. Rubin. 1995. Regulated streamflow, fine-grained deposits, and effective discharge in canyons with abundant debris fans. Pp177-195 *in* Costa, J.E., A.J. Miller, K.W. Potter and P.R. Wilcock, editors. Natural and anthropogenic influences in fluvial geomorphology. AGU Geophysical Monograph 89.

Schmidt, J.C., R.H. Webb, R.A. Valdez, R. Marzolf and L.E. Stevens. 1998. Science and values in river restoration in the Grand Canyon. BioScience 48:735-747.

Sferra, S.J., R.A. Meyer and T.E. Corman. 1995. Arizona Partners in Flight southwestern willow flycatcher survey 1993. Arizona Game and Fish Department Final Technical Report 69, Phoenix, AZ.

Shannon, J.P., D.W. Blinn, and L.E. Stevens. 1994. Trophic interactions and benthic animal community structure in the Colorado River, Arizona, U.S.A. Freshwater Biology 31:213-220.

Sogge, M.K. 1995. Southwestern willow flycatchers in the Grand Canyon Pp. 89-91 *in* LaRoe, E.T., G.S. Farris, C.E. Puckett, P.D. Doran, and M.J. Mac, editors. Our living resources: a report to the nation on the distribution , abundance, and health of U.S. plants, animals and ecosystems. U.S. Department of Interior National Biological Service, Washington.

Sogge, Mark K. 1998. Status and distribution of the southwestern willow flycatcher along the Colorado River in the Grand Canyon - 1997. U.S. Geological Survey Biological Resources Division, Colorado Plateau Field Station, Flagstaff.

Sogge, M.K. and T. Tibbitts. 1992. Southwestern Willow Flycatcher (*Empidonax traillii* extimus) surveys along the Colorado River in Grand Canyon National Park and Glen Canyon National Recreation Area - 1992 Summary Report. National Park Service Cooperative Park Studies Unit/Northern Arizona University and U.S. Fish and Wildlife Service Report.

Sogge, M.K., T.J. Tibbitts, and J.R. Petterson. 1997. Status and breeding ecology of the southwestern willow flycatcher in the Grand Canyon. Western Birds 28:142-157.

Sogge, M.K., T.J. Tibbitts, C.Van Riper III and T. May. 1995a. Status of the southwestern willow flycatcher along the Colorado River in Grand Canyon National Park - 1995, Summary Report. National Biological Service Colorado Plateau Research Station/Northern Arizona University, Flagstaff.

Sogge, M.K., C.Van Riper III, T.J. Tibbitts, and T. May. 1995b. Monitoring winter bald eagle concentrations in the Grand Canyon: 1993-1995. National Biological Service Colorado Plateau Research Station/Northern Arizona University, Flagstaff.

Sogge, M.K., D. Felley and W. Wotawa. 1998. Riparian bird community ecology in the Grand Canyon – final report. U.S. Geological Survey Biological Resources Division, Flagstaff, AZ.

Spamer, E.E. and A.E. Bogan. 1993a. Mollusca of the Grand Canyon and vicinity, Arizona: new and revised data on diversity and distributions, with notes on Pleistocene-Holocene mollusks of the Grand Canyon. Proceedings of the Academy of Natural Sciences of Philadelphia 144:21-68.

Spamer, E.E. and A.E. Bogan. 1993b. New records of Mollusca for Grand Canyon National Park and Arizona. The Southwestern Naturalist 38:293-298.

Stahlmaster, M.V. 1987. The bald eagle. Universe Books, New York.

Stanford, J.A., J.V. Ward, W.J. Liss, C.A Frissell, R.N. Williams, J.A. Lichatowich, and C.C. Coutant. 1996. A general protocol for restoration of regulated rivers. Regulated Rivers: Research & Management **12**:391-413.

Stevens, L.E. 1985. Invertebrate herbivore community dynamics on *Tamarix chinensis* Loueiro and *Salix exigua* Nuttall in the Grand Canyon, Arizona. Northern Arizona University Masters Thesis, Flagstaff, AZ.

Stevens, L.E. and T.J. Ayers. 1992. The impacts of Glen Canyon Dam on riparian vegetation and soil stability in the Colorado River corridor, Grand Canyon, Arizona: 1992 final report. U.S. Bureau of Reclamation Glen Canyon Environmental Studies Report, Flagstaff, AZ.

Stevens, L.E. and G.L. Waring. 1988. Effects of post-dam flooding on riparian substrates, vegetation, and invertebrate populations in the Colorado River in Grand Canyon, Arizona. U.S. Bureau of Reclamation Glen Canyon Environmental Studies Report, National Technical Information Series PB88-183488/AS.

Stevens, L.E. and D.L. Wegner. 1995. Management of Glen Canyon Dam for environmental purposes: the Colorado River in the Grand Canyon. Proceedings of the Environmental Protection Agency National Symposium on Using Ecological Restoration to meet Clean Water Act Goals 65-74. Chicago.

Stevens, L.E., V.J. Meretsky, J.R. Petterson, J.C. Nagy and F. R. Protiva. 1996. Impacts of a beach/habitat building flow from Glen Canyon Dam on endangered southwestern willow flycatcher in Grand Canyon, Arizona: final report. Grand Canyon Monitoring and Research Center, Flagstaff, AZ.

Stevens, L.E., K.A. Buck, B.T. Brown, and N.C. Kline. 1997a. Dam and geomorphological influences on Colorado River water distribution, Grand Canyon, Arizona, USA. Regulated Rivers: Research & Management 13:151-169.

Stevens, L.E., F.R. Protiva, D.M. Kubly, V.J. Meretsky and J. Petterson. 1997b. The ecology of Kanab ambersnail (Succineidae: *Oxyloma haydeni kanabensis* Pilsbry, 1948) at Vaseys Paradise, Grand Canyon, Arizona: final report. U.S. Bureau of Reclamation Glen Canyon Environmental Studies Program Report, Flagstaff, AZ.

Stevens, L.E., J.P. Shannon, and D.W. Blinn. 1997c. Colorado River benthic ecology in Grand Canyon, Arizona: dam, tributary and geomorphological influences. Regulated Rivers: Research & Management 13:129-149.

Stevens, L.E. J.E. Sublette and J.P. Shannon. 1998. Chironomidae (Diptera) of the Colorado River in Grand Canyon, Arizona, U.S.A., II: Distribution and phenology. The Great Basin Naturalist 58:147-155.

Stevens, L.E., B.T. Brown, and K. Rowell. 1998. Peregrine falcon foraging ecology in Grand Canyon, Arizona. Grand Canyon Monitoring and Research Center, Flagstaff.

Sublette, J.E., L.E. Stevens and J.P. Shannon. 1998. Chironomidae Diptera) of the Colorado River in Grand Canyon, Arizona, U.S.A., I: Taxonomy and ecology. The Great Basin Naturalist:58:97-146.

Suttkus, R.D., and G. J. Clemmer. 1977. The humpback chub, *Gila cypha* , in the Grand Canyon area of the Colorado River, Occasional Papers of the Tulane University Museum of Natural History 1:1-20. New Orleans, La.

Suttkus, R.D. and G.H. Clemmer. 1979. Fishes of the Colorado River in Grand Canyon National Park. National Park Service Transactions and Proceedings Series 5:599-604.

Tibbitts, T.J., M.K. Sogge, and S.J. Sferra. 1994. A survey protocol for the southwestern willow flycatcher (*Empidonax traillii extimus*). U.S. Department of the Interior, National Park Service. Technical Report NPS/NAUCPRS/NRTR-94/04. Colorado Plateau Research Station, Northern Arizona University, Flagstaff, AZ. 24 pp.

Topping, D.J. 1998. Comparison of model predictions and recent measurements of Paria River sediment discharge. Draft USGS report submitted to GCMRC, Flagstaff, AZ.

Tuegel, M., T. Hoffnagle, M. Brouder, K. Tinning and B. Persons. 1995. AGFD & Bio/West native fish interim monitoring study. Arizona Game and Fish Department, Phoenix, AZ.

Turner, R.M. and M.M. Karpiscak. 1980. Recent vegetation changes along the Colorado River between Glen Canyon Dam and Lake Mead, Arizona. U.S. Geological Survey Professional Paper 1132.

Tyus, H.M. 1987. Distribution, reproduction, and habitat use of the razorback sucker in the Green River, Utah 1979-1986. Transactions of the American Fisheries Society 116:111-116.

Tyus, H.M. and C.A. Karp. 1989. Habitat use and streamflow needs of rare and endangered fishes, Yampa River, Colorado. U.S. Fish and Wildlife Service Biological Reports 89:1-27.

Tyus, H.M. and W.L. Minckley. 1988. Migrating Mormon crickets, *Anabrus simplex* (Orthoptera: Tettigoniidae), as food for stream fishes. Great Basin Naturalist 48:24-30.

Unitt, Philip. 1987. *Empidonax traillii extimus*: An endangered subspecies. Western Birds 18:137-162.

U.S. Bureau of Reclamation. 1990. Graphical Detail of Historic Streamflows, Water Releases and Reservoir Storage for Glen Canyon Dam and Lake Powell. Bureau of Reclamation Water Management Section, Denver, CO.

U.S. Bureau of Reclamation. 1995. Operation of Glen Canyon Dam: final environmental impact statement. U.S. Department of the Interior Bureau of Reclamation, Salt Lake City.

U.S. Bureau of Reclamation. 1998. Report of the Spike Flow Subgroup. BOR Memorandum dated 17 January 1998.

U.S. Fish and Wildlife Service. 1983. Endangered Species Technical Bulletin 15(2).

U.S. Fish and Wildlife Service. 1984. American peregrine falcon Rocky Mountain/Southwest population recovery plan. U.S. Fish and Wildlife Service, Denver, CO.

U.S. Fish and Wildlife Service. 1991. Endangered and threatened wildlife and plants: the razorback sucker (*Xyrauchen texanus*) determined to be an endangered species, 50 CFR Part 17, Final Rule, October 23, 1991. Federal Register 56(205):54957-54967.

U.S. Fish and Wildlife Service. 1991a. Endangered and threatened wildlife and plants; emergency rule to list the Kanab ambersnail as endangered. Federal Register 56(153):37668-37671.

U.S. Fish and Wildlife Service. 1991b. Endangered and threatened wildlife and plants; proposal to list the Kanab ambersnail as endangered and designate critical habitat. Federal Register 56(221):58020-58026.

U.S. Fish and Wildlife Service. 1992a. Endangered and threatened wildlife and plants; final rule to list the Kanab ambersnail as endangered. Federal Register 57(75):13657-13661.

U.S. Fish and Wildlife Service. 1992b. 90-Day finding on petition to list the southwestern willow flycatcher and initiation of status review. Federal Register 57:39664-39668, Sept. 1.

U.S. Fish and Wildlife Service. 1993. Proposed rule to list the southwestern willow flycatcher as endangered with critical habitat. Federal Register 58: 39495-39522, July 23.

U.S. Fish and Wildlife Service. 1994. Biological Opinion on the Operations of Glen Canyon Dam. 21 December 1994 Memorandum, Phoenix Field Office.

U.S. Fish and Wildlife Service. 1994. Habitat use by humpback chub, *Gila cypha,* in the Little Colorado River and other tributaries of the Colorado River. Glen Canyon Environmental Studies Phase II Annual Report. 129 pp.

U.S. Fish and Wildlife Service. 1995. Endangered and threatened wildlife and plants: final rule to reclassify the bald eagle from endangered to Threatened in all of the lower 48 states. Federal Register 60(133):36000-36010, July 12, 1995

U.S. Fish and Wildlife Service. 1996. Biological Opinion on a Proposed Beach Habitat Building Flow from Glen Canyon Dam. Memorandum, Phoenix Field Office.

U.S. Fish and Wildlife Service. 1997. Endangered and threatened wildlife and plants: final determination of critical habitat for the southwestern willow flycatcher; correction. Federal Register 62(161):44228.

U.S. Fish and Wildlife Service. 1997. Biological Opinion on the November 1997 - fall test flow from Glen Canyon Dam. 30 October 1997 Memorandum, Phoenix Field Office.

U.S. Fish and Wildlife Service. 1997. Review of Sufficient Progress in implementation of the Elements of the Reasonable and Prudent Alternative from the December 21, 1994, Biological Opinion on the Operations of Glen Canyon Dam. 5 December 1997 Memorandum, Phoenix Field Office.

Valdez, R.A. and R. J. Ryel. 1995. Life history and ecology of the humpback chub (*Gila cypha*) in the Colorado River, Grand Canyon, Arizona: Final Report. Glen Canyon Environmental Studies Report, Salt Lake City.

Valdez, R. 1997. Effects of an experimental flood on fish and backwaters in the Colorado River, Grand Canyon, Arizona. Pp. 60-62 in Grand Canyon Monitoring and Research Center. Glen Canyon Dam beach/habitat-building flow: abstracts and executive summaries, April 1997. Grand Canyon Monitoring and Research Center, Flagstaff.

Valdez, R.A. and R.J. Ryel. 1997. Life history and ecology of the humpback chub in the Colorado River in Grand Canyon, Arizona. Pp. 3-31 in van Riper, C., III and E. Deschler, editors. Proceedings of the Third Biennial Conference of Research on the Colorado Plateau. Transactions and Proceedings Series NPS/NRNAU/NRTP-97/12, National Park Service, Washington, D.C.

Valdez, R.A. and R.D. Williams. 1993. Ichthyofauna of the Colorado and Green rivers in Canyonlands National Park, Utah. Pp. 2-22 in Rowlands, P.G., C. van Riper III, and M.K. Sogge, editors. Proceedings of the First Biennial Conference on Research in Colorado Plateau National Parks. Transactions and Proceedings Series NPS/NRNAU/NRTP-93-10, National Park Service, Washington, D.C.

Webb, R.H., T.S. Melis and P.G. Griffiths. Debris flows and the Colorado River. A chapter *in* Grand Canyon geology. Oxford University Press, in press.

Wiele, S.M., J.B. Graf, and J.D. Smith. 1996. Sand deposition in the Colorado River in the Grand Canyon from flooding of the Little Colorado River. Water Resources Research 32:3579-3596.

Whitmore, R.C. 1977. Habitat partitioning in a community of passerine birds. Wilson Bulletin 89:253-265.

Woodbury, A.M. and H.N. Russell. 1945. Birds of Navajo country. Bulletin of the University of Utah 35:1-157.

Woods, J.O., T.G. Carr, P.W. Price, L.E. Stevens and N.S. Cobb. 1996. Growth of coyote willow and the attack and survival of a mid-rib galling sawfly, Euura sp. Oecologia 108:712-722.

Yeatts, M. 1998. 1997 data recovery at five sites in the Grand Canyon. Hopi Cultural Preservation Office, Kykosmovi.