# DOWNSTREAM RESOURCE CRITERIA FOR SEDIMENT CONSERVATION FLOWS

# GLEN CANYON DAM, AZ

## FEBRUARY 1998

## Introduction

In the October 1996 Record of Decision (ROD) for the Glen Canyon Dam Environmental Impact Statement (EIS), the Secretary of the Interior selected the Modified Low Fluctuating Flow (MLFF) Alternative for operations of Glen Canyon Dam. The MLFF includes provisions for doing special springtime releases, either a habitat maintenance flow (HMF) or a beach/habitat-building flow (BHBF). While sediment conservation is a primary and common objective of the two special flows, there are important differences between them (see Table 1).

Habitat maintenance flows were to be within powerplant capacity (usually somewhere between 31,000 - 33,200 cfs) and were designed with the objective of maintaining existing camping beaches and fish habitat from year-to-year. In contrast, BHBF's were defined as high sustained flows with the objectives of moving and depositing more sediment at higher elevations than HMF's and completing a more extensive reforming of riparian and backwater fish habitats, while restoring some of the natural system dynamics along the river corridor. The frequency of BHBF's was to be 1 in every 5 years. For the MLFF alternative, it works out that a BHBF would always be above powerplant capacity, (something in the range of 40,000 - 45,000 cfs).

Both flows were restricted to years when the level of Lake Powell was 19 million acre-feet, or less, as of January 1. At levels above 19 maf, it's more likely that scheduled releases would be at or above powerplant capacity, and increasing the releases even more would represent an undesirable bypass of the powerplant. Also, neither flow was to be scheduled in a year when there was concern about adverse impacts to sensitive downstream resources, such as sediment or endangered species.

Recognizing uncertainies about the best time to do HMF's, the best time, duration and magnitude for BHBF's, the EIS/ROD left it to the Adaptive Management process to test and confirm those elements.

In the EIS, antecedent criteria for BHBF's included the requirement that there be enough sediment available to replenish sandbars to an elevation that makes them several feet above the water surface for use by wildlife and for camping purposes. Leopold (1969) and Andrews (1991) estimated the magnitude of sufficient discharge to be between 40,000 and 50,000 cfs to initiate movement of substantial amounts of sand and subsequently rebuild sandbars.

A test of a BHBF took place in late March/early April of 1996, prior to completion of the EIS and ROD. The seven-day test flow of 45,000 cfs demonstrated that while sandbars were rebuilt, the other objectives were not met (GCMRC 1997). Research results indicated that flows of this magnitude conserve sediment by moving it from the channel and depositing it on the channel margins (Parnell et al 1996), but flows of this magnitude were insufficient to scour and rejuvenate backwaters, or to reset successional clocks associated with marsh communities. Other resources showed no subsequent adverse affects (6 months later) to this discharge (Kearsley and Ayers 1996; AZGF 1996; Shannon et al 1996).

In order to meet all of the objectives for a BHBF, the scientific community recommended that discharges from Glen Canyon Dam should be of higher magnitude (> 55,000 cfs), and of shorter duration (2-4 days). Based on the information learned to date, it is probably not appropriate to continue referring to a flow of 45,000 cfs, as a Beach/Habitat Building Flow. Rather, a discharge of 45,000 cfs, while above power plant capacity, may simply be a further stage in habitat maintenance flows (GCDEIS, 1996). This document will refer to the flow being considered as a Sediment Conservation Flow.

Because a springtime flow of 45,000 cfs primarily benefits one resource, sediment, with little positive effect on other downstream resources, then the development of resource criteria for use in considering doing 45,000 cfs sediment conservation flows at times other than the spring will be directed at providing information related to whether such a flow might cause an adverse impact to those resources. Flows of higher magnitude, such as the 55,000 cfs or greater recommended by scientists for accomplishing the objectives of a BHBF, would require different criteria, not necessarily developed herein.

Concern has now developed over potential downstream losses of sediment due to high sustained releases from Glen Canyon Dam during high water conditions (i.e., 25,000 cfs - 27,000 cfs). Sediment lost downstream due to such high sustained flows is unavailable for deposit during subsequent HMF or BHBF events. That concern led to the formation of a Subgroup to the Technical Work Group (TWG) to develop some hydrological triggering criteria for conserving sediment when faced with sustained high flows.

Two hydrological triggers, or decision mechanisms, were developed for use as a basis for consideration in doing a sediment conservation release from Glen Canyon Dam. The hydrologic criteria are very straightforward, based on the Annual Operating Plan and Lake Powell inflow forecasts, and apply only to the months of January - July.

The Adaptive Management Work Group (AMWG) agreed that a BHBF (for sediment conservation) should be recommended when one of the triggers occurred, but only if the flow was also appropriate from an environmental perspective (effects to other downstream resources would be within acceptable limits). The AMWG has further charged the TWG to work with scientific and resource management authorities to develop resource-based criteria, to be used in addition to the hydrologic triggers, in deciding whether to recommend a BHBF directed at conserving sediment. The hydrologic triggers are dependent on water year estimates, the annual operating plan and subsequent dam operations, and resource criteria are necessarily dependent on dam operation scenarios.

Reclamation will use the information developed to do an environmental assessment, and related formal consultations for endangered species and cultural resources, in making a decision about scheduled releases for sediment conservation.

Downstream resources are categorized into the following elements:

1. Biological

2. Cultural

3. Physical

4. Socio-economic

Managers and stakeholders have identified 43 resources within these categories that should be considered when making decisions concerning operations associated with Glen Canyon Dam.

In contrast to the straightforward hydrologic triggering criteria, the development of criteria for other resources requires more consideration than just whether the resources are there or not. Many resources of concern are inherently dynamic and are continually responding and reacting to local as well as system-wide inputs. Evidence of the effects of input (catastrophic or otherwise) for many resources in the river corridor can be immediate, like the loss of a whole population due to a rock fall, or the effects may take a generation or more to be recognized (e.g., endangered fish populations). With this in mind, a criterion for most biological, physical and cultural resources directly affected by releases (i.e., resources found within the anticipated stage), is a knowledge of the antecedent conditions and subsequent conditions.

Developing decision criteria for dam releases pertaining to resources associated with the Colorado River corridor downstream of Glen Canyon Dam requires defining the purpose for the criteria. In some cases the purpose may be to develop criteria that helps determine how to do the most good for all resources. Conversely, the purpose may be to help one resource and "do no harm" to the other resources. In light of anticipated high-sustained releases, the AMWG has agreed that sediment conservation is desirable. Efforts for sediment conservation includes staging something like the BHBF described in the EIS/ROD, with the magnitude and duration being approximately 45,000 cfs for 2 to 4 days, sometime between the months of January and July.

Aspects associated with the identified resources that require consideration are:

- Legislative/legal compliance issues (e.g., endangered species and biological opinion requirements, SHPO requirements)
- Temporal issues (i.e., critical timing for biological processes like spawning, nesting, flowers, or seed dispersal), and
- Safety and economic issues (whitewater rafting, sport fishing, loss of revenues).

The sequence in which one deals with these aspects can vary from a single resource perspective, with each resource carrying equal weight, or from a more holistic perspective, recognizing that resources are interdependent and work in a "bottom-up" and "top-down" interactive fashion. In other words, some resources may be keystone resources in the system and require more consideration than others for the health or integrity of the system.

To some extent, a relative weighting of resources might be done by considering the force and effect of various laws and regulations. There are no fewer than 48 Federal and State statutes, compacts, executive orders, court decisions, treaties and decrees that apply or affect how Glen Canyon Dam is operated. As explained on page 8 of the final EIS, "Federal statutes establish a number of responsibilities for the Secretary of the Interior. Many responsibilities are specifically mandated, while discretionary authority is given for dealing with others."

For example, the 1973 Endangered Species Act and the 1966 National Historic Preservation Act are very clear in their direction to Federal agencies to fully consider and mandate that certain actions be taken to avoid or alleviate impacts to threatened and endangered species and cultural resources, beyond that provided for in the 1970 National Environmental Policy Act and other laws. With perhaps somewhat less emphasis, the 1968 Colorado River Basin Project Act (43 U.S.C. 1501 et seq.) includes provisions for □improving conditions for fish and wildlife□ and that the annual operating plan for the Colorado River reservoirs □shall reflect appropriate consideration of the uses of the reservoirs for all purposes, including.....enhancement of fish and wildlife and other environmental factors.□ The 1992 Grand Canyon Protection Act reiterates the need to comply with the 1968 Act and other applicable laws in the operations of Glen Canyon Dam.

If it is agreed that legal issues spearhead the criteria development process, then perhaps the logical path to follow is to begin with those resources that are most closely related in a biological and physical context to endangered species and cultural properties. The rationale being that to do no harm to these priority resources, one must also determine the impacts to those resources utilized by endangered species or cultural properties. The sequence in which resources are considered in this resource criteria for a sediment conservation flow at discharges of 45,000 cfs are:

I. Legal/legislative compliance

II. Resources integral to the health of endangered and cultural properties

III. Resources that are secondarily associated with the former two categories

## I. Legal Compliance Issues

### Endangered Species Act Compliance

The Colorado River and its riparian environments in Marble and Grand Canyon serve as habitat for federally listed endangered species including the humpback chub, razorback sucker, bald eagle, peregrine falcon, southwestern willow flycatcher, and the Kanab ambersnail. In addition, the flannelmouth sucker is a candidate species being considered for listing. Other Arizona species of concern in Grand Canyon are the southwestern river otter, osprey, and belted kingfisher. Each of these species has needs associated with habitat or life stage that must be considered before a BHBF can be implemented.

Table 1. COMPARISON OF BHBF AND HMF (from the GCDEIS)

| | HABITAT MAINTENANCE FLOW | BEACH/HABITAT BUILDING FLOW |
|---|---|---|
| PURPOSE | --Reform backwaters<br>--Maintain sandbars (important for camping beaches and fish habitat) | --Deposit sediment at high elevations<br>--Re-form backwater channels<br>--Deposit nutrients |

| | | |
|---|---|---|
| | | --Restore some of the natural system dynamics along the river corridor<br><br>--Help the National Park Service manage riparian habitats |
| MAXIMUM RELEASE | --Within PP capacity (33,200cfs); steady release, plus or minus 1,000 cfs for power | --45,000 cfs, plus or minus 1,000 cfs for power. The EIS provided for flows at least 10,000 cfs above the maximum allowable release in a minimum release year. For the MLFF alternative, that maximum release is 30,000 cfs, so the BHBF would be at least 40,000 cfs |
| DURATION/FREQUENCY | <u>Duration</u>: 7-14 days<br><br><u>Frequency</u>: Annually, as hydrology provides | <u>Duration</u>: 7-14 days<br><br><u>Frequency</u>: 1 in every 5 years, as hydrology provides |
| HYDROLOGY | --When projected storage in Lake Powell on January 1 is less than 19 maf. If projected storage is greater than 19 maf, releases are likely to be at or more than PP capacity | --When projected storage in Lake Powell on January 1 is less than 19 maf (the intent being to minimize releases above PP capacity) |
| TIMING | March:<br><br>--reform backwater channels prior to humpback chub spawning<br><br>--more sediment likely available from tributaries in March<br><br>--prior to peak recreational season<br><br>--however, other months to be considered through adaptive management | --In the spring (to coincide with the May/June peak in the natural hydrologic cycle) or in late summer when, due to local thunderstorms, tributaries are expected so supply large quantities of sediment (especially silt and clay) and nutrients<br><br>--The exact season and duration would be determined through adaptive management and scheduled through the Annual Operating Plan process |
| OTHER CONSIDERATIONS | --Would not be scheduled in a year when there is concern for a sensitive resource, such as sediment or an endangered species | --Must be sufficient quantities of sediment available<br><br>--Would not be scheduled following a year in which a large population of young humpback chub is produced |

## Effects Matrix Process and Assumptions

In the November Technical Work Group Meeting (November 4-5 1997) a portion of the meeting was devoted to discussion about potential high inflows to Lake Powell and subsequent releases from Glen Canyon Dam higher that 25,000 cfs. Included in this discussion was the possibility of implementing short duration, experimental high flows (Beach Habitat Building Flows: BHBF) as a resource management strategy. The course of the discussion led to the recognition that the TWG needed to develop a process to evaluate the resources and a rating to establish the effects between January to June 1998 of a 45,000 cfs release, to assist in the decision-making process concerning which month to run a BHBF.

The recommended process involved compiling the expert opinions and research citations supporting that opinion of scientists experienced with the Colorado River ecosystem, and providing a matrix that used a 7-point rating scale (positive, negative, no effect). In addition, resource impacts should be considered relative to the hydrologic trigger before and after the BHBF, because most spills and BHBF will occur during high flow years. Comments were made by some TWG members that the matrix needed to be more comprehensive, however, the degree to which the matrix should be further developed was not defined by TWG members and is an issue that need further development and consideration. The TWG recommended that GCMRC use this process to develop a Resource Effects Matrix for the months of January to June.

## Assumptions

Based on the above criteria, the assumptions for a resource effects matrix are as follows:

- A short duration (2-4 days) high flow of 45,000 cfs could take place in months January - June 1998.
- BHBF occur in high flow years, so expect flows prior to and after a BHBF event to be high (20-25 cfs, at least).
- Hydrologic conditions meeting the triggering criteria indicate that there is a high probability of a dam safety related spill. The decision for or against a BHBF does not significantly change the risk of an emergency release later in the season. By implementing a BHBF, the beneficial effects of a spill (e.g., sand storage) can be maximized and the deleterious effects (e.g., biological disturbance) can be mitigated through advanced planning.

## Directions to Developers of Resource Matrix

- Utilize a 7-point scale that varies from +3 to -3 with 0 representing no effect, +3 being strongly positive and -3 being strongly negative.
- The matrix was only for consideration for the year 1998 and it was not intended that a BHBF would be conducted every year.

An event such as this is unlikely because the hydrologic trigger would not be met every year. The intent and structure of the matrix only allows for a high flow scenario to be evaluated, as was the recommendation of the TWG to GCMRC (see November minutes). The effects of a steady flow (20k cfs, for example) was not evaluated beyond the patterns associated with the current operations since February 1997.

The process associated with the matrix and accompanying supporting citations involved contacting researchers that had been directly involved with the 1996 BHBF (attachment a) as well as researchers recommended by program managers. Because funds limited the ability to bring researchers together for a workshop and the time of year also limited people's ability to participate, we decided to compile researcher opinions via fax and mail. A mailing was sent out in November 13, 1997 and researchers were asked to reply by December 3, 1997.

Comments from scientists were received and scores for the matrix were averaged and provided to the TWG in their December 1997 meeting with a review provided by Barry Gold. The scientists rated effects to resources in a range from -3 (negative) to +3 (positive). The TWG recommended that that matrix be sent out again to the researchers for review and evaluation with a revised matrix available by January 15, 1998 to TWG and AMWG. It was discussed that a meeting of the scientists providing information might be required to fully describe potential effects on resources.

The matrix was sent out again prior to winter holidays with a request that evaluations be returned by January 9, 1998. Revised scores and comments were incorporated into the matrix and accompanying text. Included in the text were concerns voiced by researchers that pertain to resources such as sediment, the aquatic food base, Kanab ambersnail, and vegetation. The revised matrix, comments, notes and a summary of details were provided to the TWG in the January meeting by Barbara Ralston. Barbara explained how the values for the resources were obtained--via average scores and provided comments to the TWG member from the researchers regarding specific resources. Among the comments by the researchers was vagueness of the scale associated with the matrix and a desire by the researchers to have an idea of what the anticipated flow volumes following a high flow event might be. The TWG and GCMRC agreed that researchers should be gathered to discuss the scale and to further develop the assumptions associated with the matrix.

Researchers in areas that had negative impacts (-1 or greater) associated with the resource were requested to come to GCMRC to discuss the rating scale and to clarify the assumptions. Prior to the meeting, the researchers were provided the previous matrices and text as well as a copy of the hydrologic trigger document, "BHBF Triggering Criteria" developed by the TWG Spike Flow Subgroup. Three groups of researchers were convened: sediment, aquatic biology, and terrestrial biology. In these discussions, the following assumptions were developed for the resources.

**Assumptions**

- A high flow would occur in the event that hydrologic triggering criteria were met.
- A high flow would likely only be triggered in high water years so that flows preceding and flows following a BHBF would be high (e.g., 20-25,000 cfs).

**Directions to Developers of the Resource Matrix**

- The primary intent of the BHBF is sediment conservation with no harm to other resources. In effect, if sediment criteria are not met, then it is unlikely that a

BHBF would proceed.

- Sediment effects should include the variable high sediment storage in the channel vs. low sediment storage in the channel.

- Sediment storage should be divided into the sections of major sediment input (i.e., the Paria River to the LCR and LCR and below). This division covers the Marble Canyon reach which is considered a sediment starved or reduced sediment input reach compared to reaches below the LCR. In this iteration, the Glen Canyon reach was not separated.

- Biological resources should be evaluated on the biology/life history of an organism without Endangered Species considerations over-riding scale factors.

- The scale for the biological resources were defined in terms of recovery, because a flood is a disturbance and the effect of the disturbance is evaluated in the response/recovery and long-term benefits to a resource in some cases in addition to the immediate impact to the resource. The scale for biological resources were 0 - no effect, -1 the resource would be affected but recover within the a year at the most; -2 the resource might be affected and recovery would take longer than a year; -3 the resource would be affected and recovery would be unlikely.

**Additions to the Resource Matrix**

The biological researchers felt that the matrix was too general to explain the values assigned to particular resources and suggested that a narrative be developed to accompany the matrix for the biological resources. The intent of the narrative was to describe life history patterns associated with identified resources and to point out months that coincide with developmental stages or potentially critical times associated with an organism's reproductive effort. A narrative was written based on material generated from GCES phase I and II and was distributed to the researchers for comments, corrections and additions. The researchers were also asked to re-evaluate their previous values. The narrative and matrix were sent out February 20, 1997 and responses were requested by March 12, 1998.

A presentation of this last iteration was made on March 18, 1997 by Barbara Ralston at the TWG meeting. During this presentation, questions concerning the process used to develop the matrix were brought up, who was contacted and how the values for the numbers that were associated with the matrix were derived. A lack of time provided to the TWG members to review the document was noted. The TWG members were given a week to review the document and submit comments concerning either the matrix or the narrative for incorporation into the document. Comments from Debra Bills and Norm Henderson has since been received and will be incorporated into the comments portion of the document. Accompanying their comments will be an explanation of why some of their concerns might not be able to be addressed via the matrix.

**Attachment A Researchers receiving matrix and providing comments**

| Name | 1st mailing (11/13/98) | 2nd mailing (12/15/98) | meeting/email |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Jan Balsom | yes | no | -- |
| Dean Blinn | yes | yes | yes |
| Bryan Brown | yes | no | yes |
| Steve Carothers | no | no | -- |
| Kerry Christensen | yes | no | no |
| Mike Douglas | no | no | -- |
| David Foster | yes | yes | yes |
| Owen Gorman | yes | no | no |
| Dave Harpman | yes | no | -- |
| Bob Hart | yes | no | -- |
| Joe Hazel | yes | yes | yes |
| Tim Hoffnagle | yes | no | yes |
| Linda Jalbert | yes | no | -- |
| Matt Kaplinski | yes | yes | yes |
| Lisa Kearsley | -- | -- | yes |
| Michael Kearsley | yes | yes | yes |
| Dennis Kubly | no | yes | no |
| Signa Larralde | no | no | -- |
| Bill Leibfried | yes | no | yes |
| Margaret Matter | no | no | -- |
| Carole McIvor | no | no | -- |
| Ted McKinney | no | no | yes |
| Vicky Meretsky | yes | yes | -- |
| Wendell Minckley | no | no | -- |
| Tom Moody | no | yes | no |
| Lars Niemi | yes | no | -- |
| Clayton Palmer | no | no | -- |

| | | | |
|---|---|---|---|
| Rod Parnell | no | no | no |
| Duncan Patten | no | no | -- |
| Bill Persons | no | no | yes |
| Jim Peterson | -- | -- | no |
| Art Phillips | yes | no | no |
| Andre Potochnik | yes | no | no |
| Dave Rubin | no | no | -- |
| Jack Schmidt | yes | no | no |
| Mark Sogge | no | no | -- |
| Jeff Sorenson | no | no | yes |
| John Spence | yes | yes | no |
| Larry Stevens | yes | no | yes |
| Julie Stromberg | no | no | -- |
| Tim Tibbets | -- | -- | no |
| David Topping | yes | no | yes |
| Richard Valdez | no | no | yes |
| Bill Vernieu | yes | no | -- |
| Dave Wegner | -- | -- | no |
| Steve Wiele | yes | no | no |
| Michael Yeatts | yes | no | -- |
| Ben Zimmerman | yes | no | no |
| Helen Yard | -- | no | no |
| Michael Yard | -- | -- | yes |

-- indicates that these researcher were not contacted.

Range of Scores for Resources.

NPS/NRNAU/NRTP-93-10, National Park Service, Washington, D.C.

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.

Dear Researchers,

Enclosed is a draft of narratives for fish, birds, KAS, and plants. Please review this material, edit it and add to this: nothing is sacred. The information was gleaned from various reports and from work provided by Larry Stevens that was composed for Biological Opinion Works. Information that I have tried to include in these narratives are times of years in association with life histories that might be considered critical components of the organisms life cycle. I have also tried to include habitat utilized by different life stages. In some cases, this does not apply, while in other cases, I was unable to find this information.

Could you please return you comments to me by **March 12, 1998**. You can email me your comments, or send a hard copy.

# Narratives For Biological Resources

## Kanab Ambersnail

### Distribution and Abundance

Kanab ambersnail (KAS; Succineidae: Oxyloma haydeni kanabensis Pilsbry 1948), is a landsnail that was proposed for emergency listing (U.S. Fish and Wildlife Service 1991a, 1991b) and officially listed and endangered 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). Extant populations of KAS are presently known to occur at two southwestern springs: one at Three Lakes, near Kanab Utah, and the other at Vaseys Paradise, a spring at Colorado River Mile 31.5R, in Grand Canyon, Arizona (Spamer and Bogan 1993a, 1993b). Two populations formerly occurred in the Kanab area, but one population was extirpated by desiccation of its habitat. The remaining Utah population at Three Lakes 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 the Bureau of Reclamation examined KAS ecology there from 1995 through 1997 (Kanab Ambersnail Interagency Work Group 1997a). Vaseys Paradise is a popular water source and attraction site for Colorado River rafters; however, the dense cover of poison ivy (Toxicodendron rydbergii), and the nearly vertical terrain (Stevens et al. 1997b) limit access. Within Grand Canyon, KAS is apparently restricted to Vaseys Paradise: more than 100 other Grand Canyon springs surveyed from 1991 through 1997 failed to detected the presence of KAS (Stevens, pers. comm., Sorensen and Kubly 1997). Rematched historic 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. Flow regulation by the dam has increased primary KAS habitat area at Vaseys Paradise by more than 40%.

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 habitat occurring from 20 April 1996 through 3 October 1997. The total estimated area of primary habitat was 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.

### Life Requisites

KAS occurs on little-disturbed, saturated soil and associated wetland vegetation at Three Lakes, near Kanab, Utah (Stevens, pers. commun.), where cattail and sedges are the predominant macrophytes. 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 virtually restricted to those species at Vaseys Paradise (Stevens et al. 1997b, Kanab Ambersnail Interagency Work Group 1997a,b).

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 constant 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 affect the watercress life cycle, 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 1.0% to 9.5% of the mature snails expressing sporocysts in mid-summer from 1995 through 1997 (Stevens et al. 1997b, Kanab Ambersnail Interagency Work Group 1997 a,b). 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).

Natural winter mortality may reduce the KAS population by nearly an order of magnitude: the lowest KAS populations observed from 1995 through 1997 occurred during emergence in March, indicating winter mortality rates of 43.5% to 84.7%. March floods may result in a lower total take of KAS, but the proportional take is probably approximately equivalent 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 relatively greater impacts on KAS reproduction.

The Vaseys Paradise KAS population appears to be relatively large and self-sustaining. More than 40% of the present primary KAS habitat at Vaseys Paradise lies below the pre-dam 10-year flood stage of 3540 $m^3/s$ and is new, post-dam habitat. The KAS population has survived numerous larger floods both before and after dam construction. The vegetation and the KAS population will re-colonize the scoured area in $\geq$2 years.

## Bald Eagles

### Distribution and Abundance

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 in 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). 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). Apparently, 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).

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. 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.

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.

**Peregrine Falcons**

**Distribution and Abundance**

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 mi from nest sites.

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.

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.

**Southwestern Willow Flycatcher**

**Distribution and Abundance**

The willow flycatcher (Tyrannidae: Empidonax traili) is a Neotropical migrant with a broad breeding range, extending from Nova Scotia to British Columbia and south to Baja California. The Southwestern Willow Flycatcher is a subspecies (SWWF: Tyrannidae: Empidonax trailii extimus). 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).

From 1974 through 1996 the Grand Canyon population was detected between Colorado River miles 47 and 71 (Unitt 1987, Sogge et al. 1995, 1997). 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). Other recent reports of SWWF breeding in the lower Colorado River basin have stimulated additional research there. Throughout the state, there were approximately 113 pairs of SWWF in 1996 (Sferra et al. 1997) and 166 in 1997 (McCarthey et al, in prep).

Stevens et al. (1996) reported on the 1996 BHBF impacts on Grand Canyon SWWF habitat. 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.

**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 set up 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, althought singing will continue in migration and on the bird's winter grounds..

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) along the Colorado River extends from late May, and 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). In addition to habitat destruction, or predation, brood parasitism is a threat to SWWF and probably many other Neotropical migrants as well (Bohning-Gaese et al., 1993; Sogge et al., 1995). The threat of brood parasitism may be locally greater than other threats. 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 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 breed and forage in dense, multistoried riparian vegetation near surface water or moist soil (Whitmore 1977, Sferra et al., 1995, 1997), 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 are commonly found nesting 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 sally-hovers insects from foliage from conspicuous perches (Stevens pers.comm.). 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.

**Impacts of BHBF(s)**

BHBF's that are conducted before May will have no substantial direct effect on the SWWF population along the Colorado River in Glen, Marble and upper Grand canyons because the birds do not establish territories until that time. BHBF's during the breeding season are also unlikely to affect the SWWF population because SWWF nest several meters up in tamarisk trees that stand at or above the 45,000 cfs. In upper Grand Canyon, SWWF generally nest in saltcedar trees and nest trees typically lie above the 45,000 cfs stage. The saltcedar stands in which SWWF nest, are unlikely to sustain direct damage from BHBF(s). 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.

The wetlands and low-lying areas near SWWF nesting habitats and in which they occasionally forage, are likely to continue to be affected by BHBF's. 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. We have little information on how important these backwater habitats may be in producing a sustainable forage base for SWWF while they are feeding young in the nest.

SWWF forage on adult, terrestrial (non-aquatic) flying invertebrates, populations which are unlikely to be affected by a brief BHBF, and which are likely to recover promptly after the event.

**Aquatic Food Base**

The phytobenthic community is dominated by *Cladophora glomerata* and submergent macrophytes with additional constituents including other filamentous green algae and red algae. *Cladophora* and submergent macrophytes provide mucous-free substrates for diatoms that are a food source for macroinvertebrates and fishes (Blinn et al 1992; Hardwick et al. 1992; Stevens et al. 1998). Elements that affect *Cladophora* and aquatic macrophyte densities include discharge patterns (fluctuating vs. steady flows), flow volume, nutrient inflow concentrations from Glen Canyon Dam, time of year, time since last disturbance, and light availability (i.e., turbidity) (Angradi et al, 1992; McKinney et al 1996, 1997; Shannon et al 1996). Each of these separately and in combination can influence biomass of this species and concomitantly associated invertebrate biomass.

The general pattern of growth for *Cladophora*, based on monthly sampling in the Lees Ferry Reach, is that biomass is lowest in January and shows a gradual increase such that by June and July, biomass reaches maximum values (Ayers and McKinney 1996a; Shannon et al 1996). This pattern coincides with increased light availability allowing longer days for photosynthesis and growth. Other algal constituents show a similar pattern. Biomass densities decrease by August and continue to decrease, reaching a low in January. In contrast, biomass of *Chara contrana* and *Potamogeton pectinatum* tends to be highest in winter (Ayers and Mckinny 1996a, McKinney et al 1996, 1997).

Algal growth and discharge patterns indicate that steady flows favor recovery from disturbance compared to fluctuating flows. Rapid recolonization in the Lees Ferry reach is attributed in part to subsequent high steady high flows that may have promoted zoosporogenesis that occurred in the splash zone following the BHBF (Shannon et al 1996).

The BHBF had an significant immediate negative affect on the filamentous green algae: reducing biomass to 15% of the total representation, but one month later had increase to 65% of the ash free dry mass. Recovery time for both phytobenthos and macroinvertebrates occurred within one months time for some monitoring sites. Variables affecting recovery time were light intensity (i.e., clear water with no tributary inputs), and discharges that were steady flows (McKinney et al 1996a, 1997; Shannon et al 1996).

Macroinvertebrates that use the algal community as a substrate follow a similar pattern of productivity. There is a lag time associates with this interaction. 1995-96 data indicate that macroinvertebrate biomass was lowest in February and showed an increase through September (Ayers and McKinney 1996a, McKinney et al 1996; Shannon et al 1996).

Phytobenthic and zooplankton conposition has changed since the implementation of interm flows. Zooplankton densities in the river were consistent throughout Grand Canyon prior to Interim Flows (Haury 1988). Currently patterns show a negative correlation between zooplankton density and biomas with distance from GCD (Ayers and McKinney 1996b; Shannon et al 1996). Variables associated with this charge are potential limnological changes in Lake Powell and changes in the discharge pattern from 1980-86 and present.

**Native Fish**

**Flannelmouth suckers**

Flannelmouth sucker spawn in the spring in warm water tributaries (Paria, Little Colorado River, Havasu Creek, Kanab Creek). Greatest CPUE for adult flannelmouths has occurred in the Lees Ferry Reach caught most often in eddy return channel with sandy substrates and vegetation present. Adults were also caught in runs with highest CPUE reported for the Lees Ferry Reach and the LCR-Bright Angel Reach (Maddux et al 1987). Lowest CPUE was associated with boulder substrates. Sub-adults were caught most frequently in eddies and runs over sand with higher CPUE when vegetation was present. Larval FMS were found inhabiting mainstem backwaters and nearshore areas (tributaries) with sand/silt bottoms along with larval bluehead suckers. Larval suckers drift from spawning grounds to nursery areas and larvae may drift down to lower reaches to utilize those habitats as nursery and rearing areas (Thieme and McIvor 1996). Overall capture of larval FMS (ca 18 mmTL) in Grand Canyon is low. Spawning in the Lees Ferry reach was documented by McKinney and Rogers (1996), but recruitment in the reach has not been documented and successful recruitment is probably low due to cold water temperatures. Main spawning sites are considered to be the Paria River (Theirme and McIvor 1996), LCR, Kanab Creek and Havasu Creek (AGFD 1996). Return channels below National Canyon and Bright Angel Creek may be important habitats for this life stage. Other critical areas include RM

60-72 and RM 185-205.

Fluctuating river stage in late spring or early summer may affect survivorship of small, larval age-classes. Seasonal use of tributary mouths in the spring has been noted for this fish. Tributary mouths are used primarily by adult and juvenile FMS for feeding, and for staging areas for spawning in the spring.

Movements into the Glen Canyon tailwater occurred throughout the year, but appeared to increase during late fall and winter and decline in spring and summer, and results suggest that peak seasonal migration into the Lees Ferry reach occurred from downstream locations. Timing of seasonal increase in the Lees Ferry reach corresponds with pre-spawning migration to the Paria River and its confluence with the mainstem Colorado River and is coincident with decline in numbers in the Little Colorado River and its confluence area (McKinney et al. In press).

**Bluehead suckers**

Fast current runs and sidechannels appear to be preferred habitats for adult bluehead suckers. Highest capture data indicate that these fish are found in greatest numbers below National Canyon to Diamond Creek (RM 165-205) and below the LCR over rubble substrates and in the absence of vegetation. Sub-adults have been caught most often in runs. Substrate preferences vary with reach but YOY bluehead suckers are often found with YOY FMS in soft substrates (sand/silt), consuming benthic invertebrates. At about 50-80 mm, they develop a cartilaginous scraper and feed on algae and diatoms from rocks.

**Humpback Chub**

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. 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 (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), the largest 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 varies between age classes and by time of day. Young HBC in the mainstream have been collected in return current channels and other low velocity environments (Maddux et al., 1987, Arizona Game and Fish Department 1996, Valdez and Ryel 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 1995, Valdez and Ryel 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 1995, 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, 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, 1995). Individual adult HBC demonstrate high microsite fidelity (Valdez 1995), but young HBC may drift for relatively long distances (Tuegel 1995) during periods of high turbidity, particulary during monsoon flooding in the LCR. In this case, it is unclear if drifting is active or passive and survivorship is estimated as being low. Mainstream Colorado River HBC in Grand Canyon spawn primarily in the lower nine miles of the LCR from March through May, other possible spawning sites include Havasu Creek and upstream of RM 44. 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 (Marsh and Douglas 1997; 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 spawning 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, and rare young HBC have been documented at Kanab Creek, also in Shinumo and Bright Angel Creeks. However, presence of individual juvenile chub in those tributaries does not confirm spawning in the tributaries. These sightings are rare compared with the reproductive success of those HBC that spawn in the LCR.

Dietary analyses reveal HBC to be opportunistic feeders, selectively feeding on aquatic and terrestrial invertebrates and other fish (Valdez 1995, Valdez and Ryel 1997; Dennis Stone, pers. com). 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 1995, Valdez and Ryel 1997; AGFD 1996).

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 could be demonstrated to affect subadult or mature HBC.

In contrast, high mainstream flows may affect younger HBC (YOY, larvae). High flow impacts are likely to most pronounced from May through July, as larval and young HBC emerge from the LCR and occupy mainstream near-shore and backwater habitats. Although a 2-4 day BHBF may briefly create an additional pool area at the mouth of the LCR, that effect is unlikely to substantially benefit drifting HBC, that 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 from May through July may negatively affect HBC recruitment throughout the mainstream.

**Rainbow trout**

Adult rainbow trout distribution varies above and below the LCR, but there appears to be little downriver migration of these fish from the trout fishery at Lees Ferry. The foodbase for trout varies with age. Larvae-fingerlins are reported to consume immature chironomids, cladocerans, and zooplankton. Adult trout consume *Cladophora,* chironomids and *Gammarus* associated with *Cladophora.*

Habitat utilized by adults in descending order include runs, eddies, riffles, pools and backwaters. Fish select for refuge areas during high flows, moving from fast current environments to slow current velocity environments (Agrandi et al 1992; McKinney et al 1996b).

Spawning occurs from November through spring (April) in the Lees Ferry Reach. Steady flows that allow access to spawning bars positively affects spawning, conversely fluctuating releases that dewater shallow gravel bars potentially reduce spawning success at these locations. Trout show an affinity for specific spawning sites (Agrandi et al 1992, so that impacts to spawning sites should be a consideration concerning high flow and fluctuating releases. Stranding occurs most often during spawning periods and when releases fluctuate rapidly. Overtime, high flows may scour or redistribute spawning gravels utilized by this species.

Fry come off redds from January through May. The number of fry reach maxima in electrofishing samples during the spring and fall, reflecting extended spawning periods. Fingerlings are present throughout most of the year. High flows did not show a significant loss of fingerlings in the Lees Ferry population (McKinney et al 1996b). Small fish (fry and fingerlings) show affinity for low velocity near-shore habitats. High scouring flows may transport small fry downstream, but this has not been documented. Fingerlings and adult seek cover from high velocity flows. Little or no downstream displacement of fish was apparent due to the experimental spate of 1996.

**Avifauna**

Waterbirds are largely found in the Lees Ferry and Marble Canyon Reaches, likely due to the aquatic food base associated with the dam. Mallards and mergansers appear to be resident constituents, while many other waterfowl use the reach for overwintering, or are transient species (Stevens et al 1997). Seasonality and distance downstream influences abundance of waterbirds: winter is reported to be a time of year when waterfowl numbers are greatest, and downstream aquatic foodbase availability decreases (Stevens et al 1997).

Linkages associated with riparian plant communities; insectivorous birds, perigrine falcons have been established. Passerine birds increase in number and diversity when riparian vegetation becomes more productive in March and into early Summer.

When does primary breeding season start for riparian avifauna?

When do young birds fledge?

Are terrestrial or aquatic insects primary food sources?

Are GC birds more seed eaters or insectivores?

What are the birds besides SWWF that should be of concern for months January to July?

**Marsh and Riparian Vegetation.**

Marsh and riparian vegetation has increased in abundance since the closure of Glen Canyon Dam. The regulated flows have resulted in a more stable environment for marsh and shoreline vegetation to become established and expand. The riparian communities are represented by woody plants such as Tamarix chinensis, Pluchea sericea (arrowweed), Baccharis spp., Prosopis glandulosa (mesquite), Salix, goodiingii (Goodings Willow), S. exigua (Coyote Willow), Solidago sp. (Goldenrod) and annual and perennial grasses and forbes (e.g., Stanleya pinnata- princess plume, Salsola iberica- tumbleweed, Schizachrium scoparium-little bluestem). The marsh communities are represented by Equisetum (horestails), Carex aquatilis, Juncus spp, Scirpus spp. (sedges and rushes), Phragmites australis (reed), and Typha domingensis (cattails). The location of these plants relative to the shoreline is dependent on each species water requirement and ability to withstand innudation and dewatering.

Short-term changes in dam operations can affect long term responses to the riparian community. Small fluctuations may enhance sediment accumulation in marsh areas. The build up of sediment alters water relations/availability and may encourage expansion of drier adapted plant species to damp-soil conditions vs wet conditions. Higher discharge events promote scouring and may return an area to a marsh condition or bare sand. The 1996 high flow event had the effect of burying vegetation, rather than scouring. Vegetation closest to the river and at low elevation experience the greatest effects/damage. Most obvious damage is associated with areas upstream of reattachment bars and near the banks of debris fans, both areas are associated with eddy current patterns.

Total foliar cover was lost as a result of the flood, particularly in reaches below Marble Canyon, but no sites showed a significant change in area covered by wetland vegetation (Ayers and Kearsley 1996). Low growing (0.0-0.3 m), perhaps transitional plant species (e.g., broad leafed herbs, and grasses) that occupy damp-soil environments may be most susceptible to short duration high flows. These plants may sustain damage via burial (Ayers and Kearsley 1996).

Distribution of surface organic material occurs with high flows that may contribute to downstream drift, or local redistribution of organics. The redistribution of organics and shifting of sands associated with high flows may contribute to increased marsh plant densities. An increase in the density of some marsh species (e.g., cattails) was noted in lower reaches of Grand Canyon following the flood (Ayers and Kearsley 1996). However, this may be a result of the high sustained releases that followed the BHBF and inundated previously drier habitats.

As with the earlier flood, a 2-day 45 k flow will once again bury the grass / herb layer in New High Water zone patches below 40 kcfs. This layer, made up of herbs and perennial grasses for the most part, as well as some seedlings and saplings of larger species, has shown some recovery in the past two years, given the high summer flows which promote growth. The nutrients in these habitats, mostly locked up in plant tissue, will not be mobilized, since the plants will be buried in place. Larger woody individuals will have some bark and branches (and leaves if the flows occur much after April 1) stripped during the flows, but there will be little uprooting or outright mortality directly attributable to the flows.
**Assessment**: will negatively affect riparian vegetation (but the effects will be less than spectacular).

Similarly, the soil seed bank will be buried again under sterile sand from the channel bottom and elsewhere in the eddy complex. As with the grass / herb layer, the soil seed bank has shown some remarkable signs of recovery in the past two growing seasons. A two-day 45kcfs flood will likely cause another loss on the order of 60% of the individuals and 40% of the species present in New High Water zone vegetation patches. **Assessment**: will negatively affect the soil seed bank.

Marshes in return current channels will likely be buried under ~ 50 cm of sediment again, and green plants will likely be knocked over and flattened. The effects will depend on the timing and subsequent flows.

**Assessment**: will negatively affect the marsh vegetation , but flows before mid-April will have less impact than those after (the investment in green tissue will be lost), and if high flows follow the flood, the impacts will be less visible after 6 months.

Impacts on riparian habitat follow the above assessments.

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