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MEMORANDUM

To: Regional Director, Bureau of Reclamation, Salt Lake City, Utah

From: Regional Director, Region 2

Subject: Final Biological Opinion on the Operation of Glen Canyon Dam (2-21-93-F-167)

This memorandum transmits the Fish and Wildlife Service's final biological opinion on the preferred alternative for the Environmental Impact Statement on the operation of Glen Canyon Dam. This memorandum, with my signature, becomes an integral part of the biological opinion.

We appreciate your assistance in the conservation of endangered species and look forward to continued association with your staff in the implementation of this biological opinion. If you have any questions, please phone James Young, Assistant Regional Director, Ecological Services, at (505) 766-2324, or Sam Spiller, Supervisor, Arizona State Ecological Services Office, at (602) 640-2720.

John G. Tor

Attachment

cc:
Director, Fish and Wildlife Service, Washington, D.C. (AES/TE)
Regional Director, Region 6
Supervisor, Ecological Services State Office, Arizona
Project Leader, Pinetop Fisheries Resource Office, Arizona

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FINAL

BIOLOGICAL OPINION

OPERATION OF GLEN CANYON DAM

AS THE MODIFIED LOW FLUCTUATING FLOW ALTERNATIVE

OF THE FINAL ENVIRONMENTAL IMPACT STATEMENT

OPERATION OF GLEN CANYON DAM

2-21-93-F-167

December 21, 1994

Prepared by

Ecological Services

Arizona State Office

U.S. Fish and Wildlife Service

Phoenix, Arizona

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FINAL BIOLOGICAL OPINION
MODIFIED LOW FLUCTUATING FLOW ALTERNATIVE
DRAFT ENVIRONMENTAL IMPACT STATEMENT
OPERATION OF GLEN CANYON DAM

INTRODUCTION

This biological opinion is in response to Bureau of Reclamation's (Reclamation) original request of February 5, 1993, for formal section 7 consultation, under the Endangered Species Act (Act) of 1973, as amended, with the Fish and Wildlife Service (Service) on the proposed action to operate Glen Canyon Dam according to operating and other criteria of the Modified Low Fluctuating Flow Alternative (MLFF), selected as the preferred alternative for the Final Environmental Impact Statement (EIS), and described in the January 1994 Draft EIS, Operation of Glen Canyon Dam and modified by memorandum dated June 17, 1994 (U.S. Bureau of Reclamation 1994). Glen Canyon Dam, shown in Figure 1, is located in Coconino County, Arizona.

The species of concern in this opinion are the endangered bald eagle (*Haliaeetus leucocephalus*), humpback chub (*Gila cypha*), Kanab ambersnail (*Oxyloma haydeni kanabensis*), peregrine falcon (*Falco peregrinus anatum*), and razorback sucker (*Xyrauchen texanus*). Critical habitat was listed for the humpback chub and the razorback sucker on March 21, 1994 (U.S. Fish and Wildlife 1994a). A document providing additional information about the designation of critical habitat was made available in September 1993 (U.S. Fish and Wildlife Service 1993a). In addition, the southwestern willow flycatcher (*Empidonax traillii extimus*) was proposed as an endangered species with critical habitat on July 23, 1993. Because Reclamation is still evaluating the effect of the proposed action on the southwestern willow flycatcher, the Service will address the section 7 responsibilities for that species in a later conference report.

Formal consultation began on February 8, 1993, the date your request was received by the Service. Reclamation and the Service agreed to an extension of time to prepare the draft biological opinion which was provided to Reclamation on May 20, 1993. Reclamation and the Service discussed the draft reasonable and prudent alternative on May 21, 1993. Reclamation requested a technical review of the recommended flows which was conducted by the Glen Canyon Environmental Studies (GCES) Senior Scientist and Program Manager on June 11.

Reclamation confirmed on June 10 the mutual agreement to extend the consultation period to coincide with the final EIS and provided comments to the Service on the May draft biological opinion on August 16. The Service provided a final draft biological opinion on October 13 and Reclamation made the draft available for public review. A technical review of the final draft, requested by Reclamation, was facilitated by the GCES Senior Scientist on March 2, 1994.

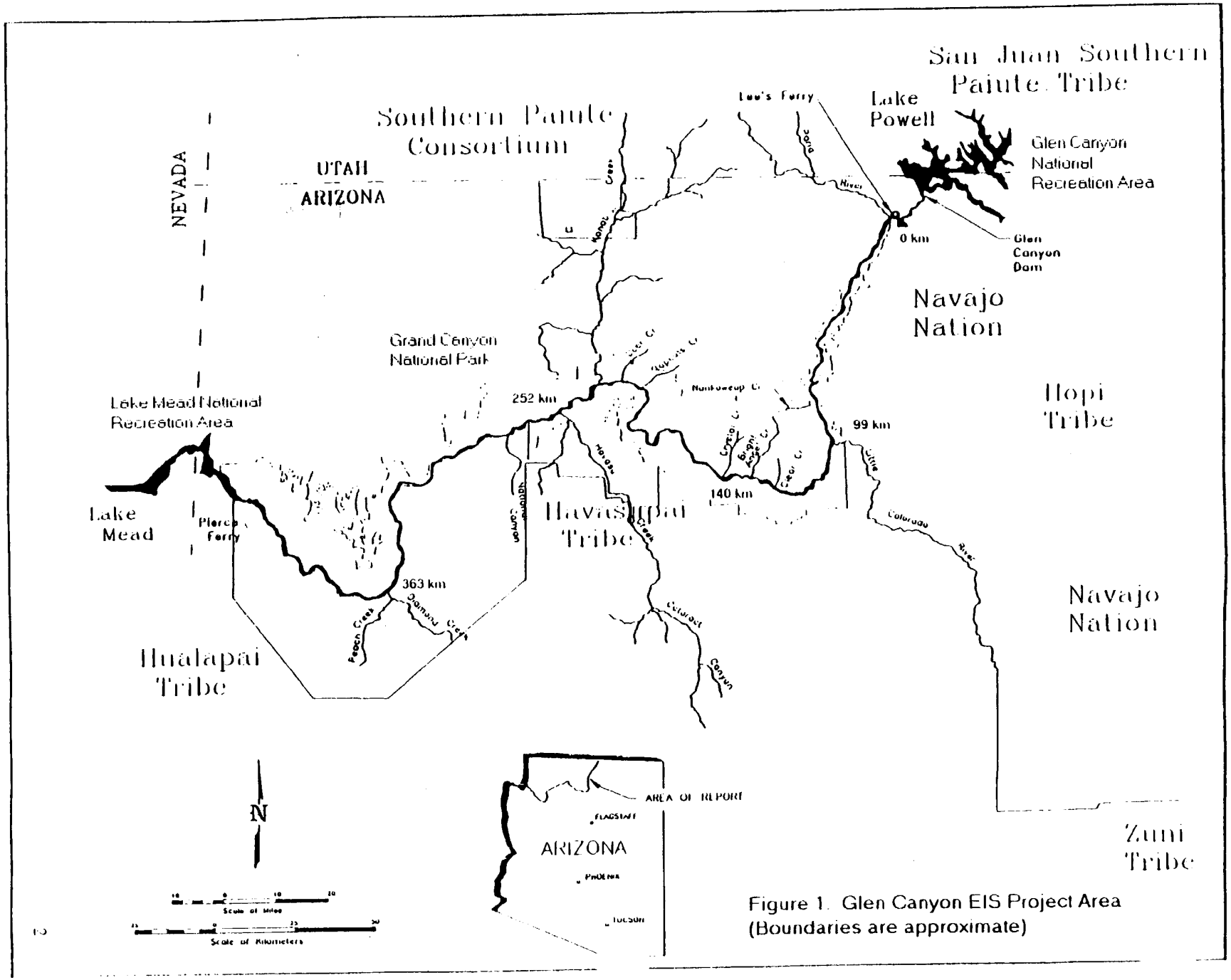

Figure 1. Glen Canyon EIS Project Area
(Boundaries are approximate)

The following biological opinion is based on information provided by the GCES including endangered fish annual research reports for Conservation Measure Five, information in the Draft EIS dated January 1994, a June 17, 1994, memorandum from Reclamation modifying the preferred alternative of the draft EIS (U.S. Bureau of Reclamation 1994), data in our files, and other sources of information. Additionally, because final GCES technical and integration reports, or their summaries, were not available to the Service, the benefit of those analyses was not available for this biological opinion.

BIOLOGICAL OPINION

It is my biological opinion that the proposed operation of Glen Canyon Dam according to operating and other criteria of the MLFF, as described in the Draft EIS and further modified by Reclamation's June 17, 1994, memorandum, is likely to jeopardize the continued existence of the humpback chub and razorback sucker and is likely to destroy or adversely modify designated critical habitat. It is my biological opinion that the proposed operation of Glen Canyon Dam according to operating and other criteria of the MLFF, as described in the Draft EIS and June 17 memorandum, is not likely to jeopardize the continued existence of the bald eagle, Kanab ambersnail, or peregrine falcon. This biological opinion supports maintenance of biological diversity associated with the historic hydrograph and the dependent ecosystem components including other native fishes.

DESCRIPTION OF PROJECT

BACKGROUND

Glen Canyon Dam was completed in 1963 as a feature of the Colorado River Storage Project (CRSP). At Reclamation's request, a biological opinion was prepared on May 25, 1978, on the effects of the dam on the Colorado River. That opinion found that past, present, and future operations of the dam jeopardized the continued existence of the humpback chub and limited recovery of the humpback chub and Colorado squawfish (*Ptychocheilus lucius*). The Service recommended studies to determine the potential impact of warming the release water, the ecological needs of the species, methods to reduce known constraining factors of low temperature and frequent fluctuations, and relationship between mainstem and tributaries and utilization by species. Jeopardy was not included for the Colorado squawfish since it was considered extirpated from Grand Canyon in 1978, and it remains in that status today. The bonytail chub (*Gila elegans*) and razorback sucker were not listed in 1978 and, therefore, were not included in the opinion. The bonytail chub, a species closely related to the humpback chub, was listed as endangered in 1980, but is considered extirpated from the Grand Canyon. The razorback sucker was listed as an endangered species in 1991.

A late 1970's program to increase peaking power at Glen Canyon Dam was terminated in 1980, but uprating and rewinding of the hydroelectric generators was determined to be feasible by Reclamation. The Service on April 2, 1982, while concurring with Reclamation's biological assessment that the incremental increase in uprated operations did not further increase jeopardy, restated that the 1978 jeopardy opinion was still in effect.

Concern for degradation of the ecosystem downstream from Glen Canyon Dam resulted in the formation of the GCES program in December 1982, and the agreement not to use the uprated capacity of the powerplant until studies and appropriate National Environmental Policy Act (NEPA) compliance was completed (U.S. Bureau of Reclamation 1982). In 1987, Reclamation requested consultation on the existing operation of Glen Canyon Dam which resulted in a draft jeopardy opinion on August 25, 1987 (consultation 2-21-87-F-23). In 1988, the Department of the Interior directed further studies (GCES Phase II) on low fluctuating flows, and Reclamation, Arizona Game and Fish Department (AGFD), National Park Service, Navajo Nation Natural Heritage Program, and Service developed seven conservation measures that would support the successful completion of both Section 7 consultation and NEPA compliance (U.S. Fish and Wildlife Service 1990a).

The preparation of an EIS on operations of Glen Canyon Dam was announced July 27, 1989, by the Secretary of the Interior (Secretary), and the cooperating agencies formed an EIS Team with Reclamation as lead. The Service has participated as a cooperating agency and is on the EIS Team. In 1992, the Grand Canyon Protection Act (P.L. 102-575, Title XVIII) was passed directing the Secretary of the Interior to develop alternatives "... in such a manner as to protect, mitigate adverse impacts to, and improve values for which Grand Canyon National Park and Glen Canyon National Recreation Area were established ...."

With guidance from other cooperating agencies, Reclamation selected the MLFF in January 1993 as the preferred alternative for the Draft EIS. Reclamation reaffirmed that choice in their June 17 memorandum and proposed two increases in the operating limits and the removal of endangered fish experimental flows from the preferred alternative (U.S. Bureau of Reclamation 1994).

OPERATION

From 1963 to 1980, Glen Canyon Dam was operated under the filling criteria. These criteria ended when the dam spilled for the first time in 1980. Since 1980, the objective has been to produce the greatest amount of firm capacity and energy practicable while adhering to the releases required under legislative mandates. Minimum allowable flows were 1,000 cubic feet per second (cfs) from Labor Day until Easter and 3,000 cfs from Easter until Labor Day. Maximum allowable flow was 31,500 cfs. No restrictions existed on daily fluctuations and ramp rates. Historically, daily fluctuations exceeded 12,000 cfs more than 58% of the days, and 20,000 cfs 15% of the days. Provisions also were established for system emergencies and system regulation.

Hourly and daily releases were modified in June 1990 when a schedule of research flows was initiated. These flows were for the purposes of allowing the GCES researchers to evaluate the impacts of current and alternative dam operations on the downstream resources for the EIS. Following the research flows, the Secretary implemented interim operating criteria on November 1, 1991, following a 3-month testing of the proposed interim flow criteria. Interim flows were designed to ameliorate the rate of adverse change on downstream resources resulting from past dam operations pending a final decision on permanent long-term operating criteria. These criteria, known as Interim Flows, are still in operation today.

The annual volume of water released is influenced by regional hydrology and legal requirements. In general, the types of water years and annual discharge in million acre-feet (maf) are classified as: Low - e.g. 8.23 maf, 1989 (the minimum discharge); Moderate - e.g. 13.6 maf, 1987; and High - e.g. 19.3 maf, 1985.

Low water years are considered normal and likely to occur more than 50% of the time. Full pool for Lake Powell is defined as 1,128 meters (m) and 24.3 maf of storage. Flood flows (flows greater than 45,000 cfs) are estimated to occur for the No Action Alternative at a rate of 1 in 40 years.

Monthly volumes of releases vary depending on the type of water year and the Annual Operating Plan. Under other than high water conditions, the greatest monthly releases have historically occurred during peak energy requirement periods (summer and winter). Daily and hourly discharge rates are primarily a function of power generation requirements. Daily fluctuations are generally highest during low volume years (power is generated during high use periods of day and reduced at night to save limited water supply) and decrease as yearly release volumes increase (essentially extending peak period throughout day and into night).

The MLFF is similar to the original interim operating criteria with the exceptions that it does not include the financial exception criteria allowed under Interim Flows but would include habitat maintenance flows, increased flood protection, higher maximum flows, and increased up-ramping rates (Table 1.). EIS elements common to all alternatives also would be included.

Table 1. Modified Low Fluctuating Flow Alternative [1]

Monthly Release Vol.(ac-ft)	Minimum release (cfs)	Habitat Maint. Flow (cfs)[2]	Maximum release (cfs)	Daily Fluctuation (cfs/24 hr)	Ramp rate (cfs/hr)
Low <600,000	8,000 between 7am & 7 pm 5,000 night	30,000 to 33,200	25,000 Exceeded during hab. maint flows	5,000	4,000 up 1,500 down
Medium 600,000 to 800,000	same	same	same	6,000	same
High >800,000	same	same	same	8,000	same

[1] Description of preferred alternative from January 1994 Draft EIS and Reclamation's June 17, 1994, memorandum (U.S. Bureau of Reclamation 1994).

[2] Steady flows with minor fluctuations of ± 1,000 cfs.

Habitat maintenance flows are defined as high, steady releases within powerplant capacity (33,200 cfs maximum) for 7 to 14 days in March or April. Other months could be considered under the Adaptive Management Program. Habitat maintenance flows would occur every year in which lake Powell is not expected to spill and would not occur when beach and habitat building flows are scheduled. Beach and habitat building flows would be of greater magnitude (40,000 to 45,000 cfs) and occur less frequently, 1 in 5 years when Lake Powell is low (60% of time), for an occurrence in all years of 1 in 8 years or 12% (Tim Randle, personal communication). Neither maintenance nor building flows would occur in a year when there is special concern for a sensitive resource, for example, a good year class of humpback chub in the upper reaches of the mainstem. The Adaptive Management Program would coordinate such recommendations.

Figure 2 shows a plot of monthly releases for the proposed action during a minmum release year. The habitat maintenance flow is included in March, but could occur in April.

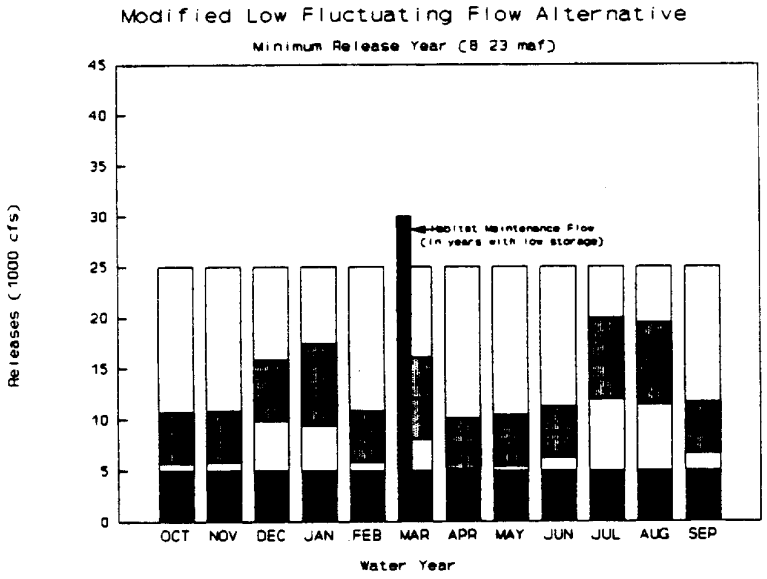

Figure 2. Monthly releases of preferred alternative with minimum (solid), mean (single line), and range (arrows and stiple)(Craig Phillips, Reclamation, Written Communication).

The MLFF also includes the following elements:

- Flood protection limiting the frequency of floods greater than 45,000 cfs to no more than 1 in 100 years.
- An Adaptive Management Program including long-term monitoring and research.
- Further study of a Selective Withdrawal Structure (multi-level intake structure).
- Beach and habitat building flows - a controlled flood between 40,000 and 45,000 cfs (may be greater, still being defined).

Further description of the alternative is found in the Draft EIS.

STATUS OF SPECIES

ENDANGERED COLORADO RIVER FISHES

The seven-State Colorado River Basin watershed is 1/12 of the continental United States, receiving the majority of its yield from Rocky Mountain runoff in the spring and early summer and transporting that flow to the mouth of the Colorado River (U.S. Bureau of Reclamation 1946). Historically, seasonal variations in the free flowing River were considerable, with extremes at the Grand Canyon gauge ranging from an estimated 300,000 cfs on July 8, 1884, to 700 cfs on December 28, 1914 (Boner et al. 1991). Flows between years also varied from wet to dry climatic periods. Fish that evolved in the basin were subject to the concomitant variations in sediment and food resources (U.S. Fish and Wildlife Service 1980; Minckley 1991).

The fish fauna of the basin represent the highest number of endemic fish species (32 species of which 75% are endemic) of any basin in North America (reviewed by Minckley 1991), with the larger streams and rivers historically dominated by native minnows (cyprinids) and suckers (catostomids) (Minckley et al. 1986). As the southwest rivers became more arid and seasonal in flow, the fish evolved with high year-to-year variability and with long-term droughts (Moyle and Herbold 1987). The four "big river" endangered fish of the basin: bonytail chub, Colorado squawfish, humpback chub, and razorback sucker; all occurred in the Grand Canyon before and shortly after Glen Canyon Dam began operating (reviewed by Minckley 1973, 1991; U.S. Fish and Wildlife Service 1994a).

Widespread and sudden declines of the endemic fishes have been related to physical and biotic changes in the habitat of these fishes (Deacon and Minckley 1991; U.S. Fish and Wildlife Service 1994a). Miller (1961) chronicled 100 years of drastic changes in the native fishes and rivers of western North America by such factors as deterioration of stream flow, construction of barrier dams, and the introduction and establishment of a host of non-native fish species.

HUMPBACK CHUB

General Status

The northern extent of humpback chub's range is the Yampa River, Colorado and the Green River, Utah. The southern extent (historical) is Catclaw Cave, a 750-1100 A.D. archeological site, 24 kilometers (km) south of Hoover Dam on the Colorado River, Arizona (Miller 1955). The species occurs in widely separated, swift water canyon reaches.

In the upper basin, humpback chub were found in pre-impoundment surveys of the Flaming Gorge basin (Guafin et al. 1960) along with two other species of *Gila*. Populations of humpback chubs are now found in the areas of (1) Yampa Canyon (Yampa River) and Whirlpool Canyon (Green River) of Dinosaur National Monument, (2) Desolation Canyon and Gray Canyon of the Green River, (3) Black Rocks area of the Colorado River, (4) Westwater Canyon of the Colorado River, and (5) Cataract Canyon of the Colorado River above Lake Powell (U.S. Fish and Wildlife Service 1994a).

The Grand Canyon is the location of the species' (1) original description - a specimen taken at or near mouth of Bright Angel Creek at River Mile (RM) 87.8 (Miller 1946); (2) oldest record - 4,000 years B.C., from archeological remains in Stanton Cave at RM 31.6 (Euler 1978); (3) current southern distribution - at RM 222 (Valdez et al. 1992a), and (4) the largest population (Marsh and Douglas 1992).

The Grand Canyon population of the humpback chub is found in Marble Canyon and Grand Canyon, including several tributaries to the mainstem river. Recent mainstem studies have found the humpback chub to be more abundant in the reaches immediately upstream and downstream of the Little Colorado River (LCR) (Kaeding and Zimmerman 1983; Maddux et al. 1987; Valdez et al. 1992a). The Grand Canyon population of humpback chub may be composed of a resident LCR group that is supplemented by individuals in the spring and summer that overwinter in the mainstem or there may be a more complex relationship between use of the mainstem and LCR depending on environmental conditions in each river (Angradi et al. 1992). The number of mainstem humpback chub that migrate to the LCR is not known.

The possibility exists that humpback chub in the middle and lower Grand Canyon may represent a separate population. The genetic identity of the humpback chub throughout the Grand Canyon is being investigated in a basin-wide taxonomic study of the genus *Gila* (U.S. Fish and Wildlife Service 1991a).

Humpback chub have been aged to 22 years using otoliths, but the relationship of age to length is not well known (Hendrickson 1993). In warm water of the LCR, humpback chub were found to grow to approximately 100 millimeters (mm) the first year and then 250-300 mm in three years (Kaeding and Zimmerman 1983). Few individuals are found greater than 450 mm total length (Kubly 1990; Valdez et al. 1992a). The size of the Grand Canyon population has been estimated by several researchers, and all researchers have recognized the inherent limitations of those numbers. Kaeding and Zimmerman (1982) estimated 7,000 to 8,000 humpback chub greater than 200 mm in the LCR; AGFD estimated 5,000 to 18,000 humpback chub in the lower reach of the LCR from 1987-1989 (Kubly 1990); Valdez et al. (1992a) estimated 2407 humpback chub greater than 175 mm near the LCR with a wide confidence interval of 1,102 to 6,564; and Douglas and Marsh (1992), working with humpback chubs greater than 150 mm total length in the LCR, placed 2031 new passive integrated transponder (PIT) tags, recaptured 1814 old PIT tags, and recaptured 61 old Carlin or floy tags for a total of 3906 individuals humpback chubs.

Adults

Locations of humpback chub listed above identify the species' canyon-bound macrohabitat which usually includes swift water and boulders. Within the canyons, Miller and Hubert's (1990) review found shoreline-eddy habitats were the most frequently utilized by adult humpback chub, with backwater-eddy and pools also identified. Kaeding et al. (1990) considered the similarity of humpback chub habitats to be "... dynamic flow vectors that result from water moving rapidly among large, angular boulders and shoreline rock outcrops" and suggested that "... the unusual morphology of this species is an adaptation to life in such habitats." Substrates ranged from bedrock and boulders to sand and silt (Miller and Hubert 1990). Humpback chub select low

velocity water current microhabitats such as areas behind boulders, eddy channels, and eddy fences (the zone of water between eddy and mainchannel) (Valdez and Nilson 1982).

In the Grand Canyon, habitat use by the humpback chub has been reported by Kaeding and Zimmerman (1983), Maddux et al. (1987), and the present GCES Phase II work by AGFD and BIO/WEST. Over 80% of the adult humpback chub captured or contacted by radio-tracking were found by Valdez and Hugentobler (1993) to be from eddy complexes (active recirculating eddies and eddy return channels). Surface mapping (flows from about 4,000 to 16,000 cfs) showed the availability of those same habitats was 20% for eddies, less than 1% for return channels, and 56% for runs (Valdez, et al 1992a). Boulders and sand were the dominant substrate, water velocities were low, and depths ranged from 1.2 to 12 m (n=11).

Preliminary information from the on-going studies in the Grand Canyon and from studies conducted in the upper basin (Valdez and Nilson 1982; Kaeding et al. 1990) found humpback chub to have an affinity for specific locations. In the Grand Canyon, movement of 48 humpback chub over a period of 5 to 149 days was an average of 1.3 kilometers from release site to last contact site. Movements of humpback chub in response to daily changes in flow (ramping) may be due to feeding behavior or to changes in habitat (Valdez et al. 1992a).

Migratory movements such as those observed for the Colorado squawfish have not been reported for the humpback chub. In the Black Rocks radio-tracking study, adult humpback chub rarely moved from the area suggesting that habitat requirements, including spawning, are met in that area (Archer et al. 1985). The longest movement recorded for the humpback chub in the Grand Canyon was an individual PIT and radio-tagged near the LCR and captured 261 days later about 98 kilometers downstream (Valdez et al. 1992a).

Humpback chub feed on aquatic and terrestrial invertebrates throughout the water column including the bottom of eddies or other such areas where food organisms may collect (Minckley 1991). Mormon crickets (*Anabrus simplex*) were a significant food item in one upper basin study (Tyus and Minckley 1988). Kaeding and Zimmerman (1983) sampled stomachs of humpback chub from the LCR (n=26 with 12 empty) and Colorado River (n=18 with 5 empty) and found immature Chironomidae and Simuliidae larvae dominant. They noted that the amphipod *Gammarus* was uncommon in stomachs although abundant in the mainstem. Two stomachs from the LCR contained fish, including a fathead minnow (*Pimephales promelas*). Mainstem collections had a larger number of organisms than those from the LCR. Valdez et al. (1992a) evacuated eight stomachs (non-lethal pumping) from mainstem humpback chub and found primarily aquatic invertebrates; the dominant species was *Gammarus* with the algae *Cladophora glomerata* also represented. In 1992, stomachs of 43 humpback chub were sampled in the mainstem, and Simulids were 62% of all food items, amphipods were 24%, and chironomids were 13% (Valdez and Hugentobler 1993).

Spawning

Environmental variables important to the reproductive process of the humpback chub are believed to be hydrology, water temperature, and photoperiod, but endogenous factors such as stage of maturity and genetic lineage appear influential but undefined (Tyus and Karp 1989).

Nesler et al. (1988) found agreement in the literature that temperature and photoperiod combine as mechanisms influencing gonad maturation, particularly in cyprinids, but that the final phase of maturation and the release of gametes also may be controlled by water velocity and quality, substrate, barometric pressure, or pheromones.

For the Grand Canyon population, gonadal development of humpback chub estimated to be three to four years of age or older began in December and February and increased rapidly until April; during April and May the gonadosomatic index (relationship of gonad weight to whole-body weight) quickly declined indicating spawning had occurred (Kaeding and Zimmerman 1983). From specimens collected from 1967 to 1976, including one from just below Glen Canyon Dam, Suttkus and Clemmer (1977) judged that spawning occurred during June and July. Based on collections of larvae, AGFD found spawning from April to July (Angradi et al. 1992; AGFD 1993). In the upper basin, Black Rocks populations have spawned from May to July (Valdez and Clemmer 1982; Archer et al. 1985; Kaeding et al. 1990) and Yampa Canyon populations from mid-May to mid-June (Tyus and Karp 1989).

The foregoing research generally found the humpback chub to spawn when the hydrograph of the river was at its peak or descending. Streamflow was often variable between years at the same site. Maximum daily water temperatures reported by the above researchers were at Black Rocks 11.5 to 23 °C, at Yampa Canyon 16 to 23 °C, and in the LCR 18 to 22 °C. Suspected spawning areas in Yampa Canyon were shoreline eddy and run habitat (Tyus and Karp 1989).

Caution should be used when evaluating reported spawning conditions because some physical attributes of sexually mature humpback chubs such as tubercles are often not closely related to the actual spawning event (Archer et al. 1985) and required temperatures may be more a function of degree-days and allowable fluctuations of temperature rather than daily maximum temperatures. A further problem in identifying spawning requirements is that the actual spawning site for humpback chub has not been documented.

Hamman (1982) found humpback chub eggs adhered to rock substrate in the study raceway and hatched in 5-7 days at 19 to 20 °C with 84% success. Hatching success diminished at lower temperatures (16 to 17 °C = 62%; 12 to 13 °C = 12%) and higher temperatures (21 to 22 °C = 79%). Comparative conclusions with an optimum temperature of 20 °C were found by Bulkley et al. (1982) and Marsh (1985). Temperatures colder than optimum increase hatching time; for example, Marsh (1985) reported 372 hours at 15 °C versus 166 hours at 20 °C and significant sublethal effects such as stunted or deformed larvae with the increased hatching time.

Larvae and Juveniles

Life history information is limited for larval humpback chub in the wild compared to other life stages. In the hatchery, larvae were about 7 mm total length at hatching, swam up in 3 days, and begin feeding on zooplankton near the surface for two weeks (Hamman 1982). Larval humpback chub have been collected from the mainstem in total lengths as small as 16 mm (AGFD 1993). In the LCR, guts of 40 humpback chub from 13 to 35 mm total length were examined during May 1990 and chironomid larvae were most frequent (62.5%) (Angradi et al.

1992). An analysis of larval humpback chub collections and habitat is the subject of ongoing GCES research being conducted by the AGFD.

Young-of-year humpback chubs, including larvae, use backwaters, eddies, and runs (reviewed by Miller and Hubert 1990). Holden (1977) sampled those habitats in Desolation Canyon and Gray Canyon on Green River in proportion to their occurrence and reported young-of-year humpback chubs (30 to 70 mm total length) preferred backwaters with no current, a firm silt bottom, and 0.6 m maximum depth. Deeper eddies and slow runs also received some use. Kaeding and Zimmerman (1982) commonly collected young-of-year and juvenile life stages from shoreline/run and shoreline/eddy LCR habitats. Valdez (1990) collected larvae and young-of-year humpback chubs from backwaters (most occurrences), along shorelines, and in isolated pools in Cataract Canyon on the Colorado River. Valdez et al. (1990), using humpback chub data from the Green River (1500 observations), found larvae (<21 mm) at a mean depth of 0.4 m (range 0.03 to 2.5 m) and in water velocities less than 0.03 m/s (range <0.0 to 0.09 m/s). Young-of-year were found in mean water depths of 0.6 m and mean velocities 0.06 m/s.

Juvenile humpback chub are frequently found in eddy habitats and also in other low to moderate velocity areas (Kaeding and Zimmerman 1982; Tyus and Karp 1989). Valdez et al. (1992a) captured juvenile humpback chub along Grand Canyon mainstem shoreline habitats with talus slopes, earthen banks with root wads, and near large standing boulders. Pockets of sand were prevalent in those habitats, but few juvenile humpback chubs were captured on sand beaches. Including data from upper basin studies, Valdez et al. (1992a) report for humpback chub a "... transition in habitat use with size or age from shallow, protected areas such as backwaters or stable shorelines to areas with moderate depth and velocity and uneven substrate."

Critical Habitat

Critical habitat is defined in the Endangered Species Act to include areas, occupied or not, that are essential to the conservation of the species. Conservation is defined as that needed to bring about the complete recovery of the species. Thus, critical habitat preserves options for a species' eventual recovery. Of the 610 km of critical habitat designated for the humpback chub in the Colorado River basin, 291 km are found in the project area (U.S. Fish and Wildlife Service 1994a). This includes the lower 13 km of the LCR and from Natuloid Canyon (about RM 34) to Granite Park (about RM 208) on the Colorado River.

In determining which areas to designate as critical habitat, the Service considers those physical and biological attributes (constituent elements) that are essential to species conservation. Known constituent elements for the Colorado River endangered fishes include water, physical habitat, and biological environment as required for each particular life stage. These primary elements include, but are not limited to the following:

> Water - This includes a quantity of water of sufficient quality (i.e., temperature, dissolved oxygen, lack of contaminants, nutrients, and turbidity) that is delivered to a specific location in accordance with a hydrologic regime that is required for the particular life stage for each species.

Physical Habitat - This includes areas of the Colorado River system that are inhabited by fish or potentially habitable for use in spawning, nursery, feeding, and rearing or corridors between these areas. In addition to river channels, these areas also include bottomlands, side channels, secondary channels, oxbows, backwaters, and other areas in the 100-year floodplain, which when inundated provide spawning, nursery, feeding, and rearing habitats.

Biological Environment - Components of this element include food supply, predation, and competition. Food supply is a function of nutrient supply, productivity, and availability to each life stage of the species. Predation and competition, although a normal component, may be out of balance because of non-native fish species.

RAZORBACK SUCKER

General Status

The razorback sucker was listed as an endangered species throughout its range on October 23, 1991 (U.S. Fish and Wildlife Service 1991b). Once one of the most abundant and widespread fishes of the mainstem rivers in the Colorado River Basin, successful recruitment to adult of this monotypic genus is now virtually nonexistent in all natural riverine environments (reviewed in Minckley et al. 1991; U.S. Fish and Wildlife Service 1991b). Archaeological and historical information reported by the above reviewers identified lower basin records of razorback suckers in Arizona in the San Pedro River, the Gila River near Phoenix, the upper Verde River, Colorado River near Lee's Ferry, and the Salton Sea (California) and Colorado River delta (Mexico). Historic range in Arizona includes all of the mainstem Colorado River, most of the Verde River and San Pedro River, the lower portion of the Salt River, and almost the entire Gila River (Minckley et al. 1991).

The razorback sucker now inhabits about 25% of its former range, and of the four "big river" endangered fish, only the bonytail chub is believed to be more rare (U.S. Fish and Wildlife Service 1991b). In the upper basin, the species persists in the San Juan and Colorado River arms of Lake Powell, the Grand Valley area of the Colorado River, and the lower Yampa River and Green River, with the largest concentration in this last area. In the lower basin, the formation of Lake Mohave on the Colorado River in 1954 retained a large number of razorback suckers that now comprise the largest population of the species which Marsh and Minckley (1992) estimated at approximately 60,000. Minckley et al. (1991) report that limited numbers of razorback suckers have been found in Lake Havasu, the Central Arizona Project aqueduct (near the Lake Havasu intake), and from the Colorado River downstream of Parker Dam in irrigation ditches and in Senator Wash Reservoir but that an approximate 10-year reintroduction program in central Arizona rivers has had little success.

Minckley (1983) reported that 18 razorback suckers were recorded by investigators at various localities in Lake Mead from 1967 to 1980, and in 1990 Jon Sjoberg (Nevada Department of Wildlife, personal communication) reported sighting and capturing small numbers of razorback suckers in western Lake Mead. Using helicopters to locate aggregations, 36 razorback suckers in western Lake Mead were captured and tagged in 1992 (Heinrich and Sjoberg 1992; Burke

1992). No razorback suckers were reported from a 1991 survey of selected locations in eastern Lake Mead (Baucom 1991).

In the Grand Canyon area, razorback suckers rarely have been collected. Carothers and Minckley (1981) collected one and observed three in or near the Paria River (1978-1979). A razorback sucker was collected in and released near RM 108 in the mainstem (1984) and, at the mouth of the LCR, one was captured in 1989 and five were PIT tagged in 1990 (Dennis Kubly, Arizona Game and Fish Department, personnel communication).

Adults

Because adult razorback suckers are the second largest native fish in the Colorado basin, average total length in Lake Mohave was 550 mm for males and 620 mm for females (Marsh and Minckley 1992), it has been feasible to implant them with radio or ultrasonic transmitters to track movements and habitats utilized. Marsh and Minckley (1991) found radio-tagged individuals transplanted to the Gila River above San Carlos Reservoir, Arizona to use mid-channel habitats that were wide runs with sand substrate. Quieter habitats such as backwaters, eddies, and deep pools were selected by few fish. Radio-tagged razorback suckers (Tyus 1987) used the mid-channel sand bars of the flat-water reaches of the upper Green River and lower Duchesne River in summer rather than deep pools. Velocities of these habitats were slow (0.5 m/s) and depths were about 1.5 m. Of the over 300 razorback suckers captured in the Tyus study, none used the white-water canyon reaches. A study of reintroduced adult and subadult razorback suckers radiotracked in the upper Verde River, Arizona, found these fish occupied habitats with slower mean current velocity (0.03 m/s) and shallower mean depths (0.72 m) than reported from upper basin studies; however, in both studies, preference for sand substrates was similar (Clarkson et al. 1993). Two of the Verde River radiotagged suckers moved more than 60 km downstream after reintroduction.

Recollections of first-hand observers from the early 1900's, reported by Minckley (1973) and Minckley et al. (1991), were that razorback suckers were in eddies, backwaters, or deep holes and were sometimes fished by snagging. Holden and Stalnaker (1975) in a study of the Colorado River from the upper Yampa and Green Rivers down to Glen Canyon, Marble Canyon, and Grand Canyon on the Colorado River found razorback suckers only in "stagnant or quiet-water areas." They identified one concentration site as wash confluences during high water of early summer in Canyonlands National Park. Bestgen (1990) remarked on the greater, perhaps even year-round, use of lentic and backwater habitats by razorback suckers compared to the other "big river" fishes. Further evidence of this apparent preference for "quite-water" may be the success in raising and maintaining razorback suckers in ponds and lakes that has been observed by many who work with the species.

Minckley (1991) described the different adaptations to feeding for the three native Grand Canyon suckers and stated that the razorback sucker possess a "protrusible mouth and special gill rakers for sieving plankton or detritus." Marsh (1987) examined stomachs (n=32) of adult razorback suckers and found planktonic crustaceans, diatoms, filamentous algae, and detritus demonstrating feeding occurs both on plankton and benthic organisms. Dill (1944) found razorback sucker

stomachs (n=4) in a bay below Headgate Rock Dam, Colorado River to be filled with silt "rich in microscopic organisms" and filamentous algae.

By examining otoliths from Lake Mohave specimens, ages of razorback suckers were found to range from 24 to 44 years (McCarthy and Minckley 1987), longevity typical of big river endangered fish.

Spawning

Unlike the humpback chub that successfully recruits young, but actual spawning has not been observed, the recruitment of razorback sucker in historic habitats (rivers) is unsuccessful, but considerable information exists on spawning activities. Reviews of the ample data from Lake Mohave found spawning usually occurs from January to April or May with water temperatures varying from 10.5 to 21 °C, but usually above 15 °C over wave-washed, gravel and cobble shorelines (Minckley et al. 1991; Minckley 1991). Larvae were produced but did not recruit into juvenile stage until recent experimental actions of placing breeding adults into a predator-free backwater was begun (Paul Marsh, Arizona State University, personal communication).

Sigler and Miller (1963) reported spawning to occur in water about 12 to 18 °C in tributary streams and reservoir shorelines over silt, sand, gravel, or rocks. Tyus and Karp (1990) captured ripe razorback suckers in riffles on substrates of cobble, gravel, and sand during the ascending and high limbs of the hydrograph of the Green River and Yampa River from mid-April to early June. Spawning was associated with temperatures of about 14 °C, and migrations of 30 to 106 km were recorded for some individuals but not all. Some ripe female razorback suckers were captured in flooded bottomlands with temperatures ranging from 17 to 19 °C, and habitats and temperatures were found to vary with various water years experienced (Tyus 1987). Marsh (1985) found greater success with experimental hatching of razorback sucker eggs at 20 and 25 °C then at 15 °C and complete loss at 5, 10, and 30 °C.

Larvae and Juveniles

After the adhesive eggs hatch, the larvae settle in spaces between substrate material until swim-up stage; accordingly, spaces free of silt or other sediment were deemed important to their survival (Inslee 1981, Bozek et al. 1984).

Sigler and Miller (1963) reported the behavior of larval razorback suckers, approximately 25 mm total length, as traveling in large schools along river and reservoir margins. They note that two seine hauls on June 15, 1950, collected over 6,000 larval razorback suckers (10 to 35 mm standard length) from the margin of the Colorado River in Nevada in temperatures ranging from 21.7 to 24.4 °C while the mainstem river temperature was 14.4 °C. Tyus (1987) collected larvae (10.6 to 13.6 mm long) (tentatively identified as razorback sucker) in quiet river margins of the Green River downstream of areas where razorback suckers in breeding condition were previously sampled. Extensive collecting in Lake Mohave has not found larvae greater than about 12 mm total length (Minckley et al. 1991).

The inability of larvae to recruit into young-of-year or juvenile life stages in wild populations has been recognized as a major limiting factor for the survival of the razorback sucker, and Minckley et al. (1991) identified three possible explanations: "(1) transport from the system, (2) nutritional constraints resulting in starvation, and (3) loss of early life-history stages to predation" with the last one thought the most probable.

To examine all possible factors, however, food habitat investigations of larval razorback suckers have been initiated to determine whether food may be limiting such as availability of appropriate size food items for larvae that have just consumed their yolk sack or have changed orientation of their mouth (Minckley et al. 1991, Papoulias and Minckley 1992). An intensive study of larval razorback suckers spawned and raised in an isolated cove in Lake Mohave is the subject of an ongoing investigation (Paul Marsh, Arizona State University, personal communication).

Critical Habitat

The total length of critical habitat designated for the razorback sucker within the Colorado River basin is 2776 km. Within the project area, this includes the Colorado River and the 100-year flood plain from the confluence with the Paria River (about RM 1) to Hoover Dam (555 km). Known constituent elements (defined above for the humpback chub) include water, physical habitat, and biological environment as required for each particular life stage of the species.

BALD EAGLE

The Colorado River corridor within the Grand Canyon has become an important winter concentration area for the bald eagle. Although not a separate subspecies, bald eagles in the southwestern United States and northern Mexico are considered a distinct population for purposes of recovery efforts and section 7 consultation (U.S. Fish and Wildlife Service 1982). Prior to 1984, Floyd Thompson (Service, retired) reported locating three possible bald eagle nests in the Grand Canyon region (Hunt et al. 1992). However, whether the wintering bald eagles in the Grand Canyon are part of the southwestern breeding population or migrate from northern latitudes is not known.

Bald eagles were not recorded in concentrations in the Grand Canyon until after the establishment of the mainstem rainbow trout (*Oncorhynchus mykiss*) fishery following construction of Glen Canyon Dam. Prior to Glen Canyon Dam, low winter flows and the presence of large native fishes may have offered similar or even superior conditions to those that exist today for wintering bald eagles, but no documentation exists to support this premise. Wintering bald eagles were first documented (n=4) in the winter of 1985-1986 (Brown et al. 1989), and observations increased to a high of 26 birds counted in a single day at Nankoweap Creek in late February 1990 (National Park Service 1992).

Bald eagle use of the river corridor is opportunistic and currently concentrated around Nankoweap Creek (RM 52) where the birds utilize an abundant food source in the form of winter-spawning trout. These trout have been found to comprise greater than 99% of eagle foraging attempts (Brown and Leibfried 1990; National Park Service 1992). The number of bald eagles at Nankoweap Creek appears to be directly related to the abundance of spawning trout.

The number of trout attempting to ascend and spawn is a function of the number of spawning trout in the river and conditions in Nankoweap Creek. More than 500 trout were recorded at Nankoweap Creek during 1990, with the spawning run peaking at 1,500 fish. Some 70-100 bald eagles may have moved through the Grand Canyon in February and March of 1990 (Brown and Leibfried 1990; National Park Service 1992). Bald eagles took trout stranded by fluctuating discharges in isolated pools along the river near the creek mouth, but most of the feeding activity was in Nankoweap Creek (Brown and Leibfried 1990; National Park Service 1992). The bald eagle concentration at Nankoweap Creek was down in 1991 along with the number of spawning trout. In 1991, low discharges in Nankoweap Creek, low water temperature, and ice may have limited the number of trout attempting to ascend and spawn in the creek (National Park Service 1992). Observations from 1992 to 1994 have found further decreases in trout in Nankoweap Creek during the winter and correspondingly lower numbers of bald eagles (Mark Sogge, National Park Service, written communication).

Daily operations of Glen Canyon Dam influence the migration patterns of spawning trout and availability of this food resource to bald eagles. For example, during a recent survey there was a physical barrier at the mouth of Nankoweap Creek that prevented trout from ascending the creek when river discharge was below approximately 4,000 cfs (Bill Leibfried, personal communication). At discharges between 4,000 and 15,000 cfs, the creek mouth and the lower 30 m of the creek were used most frequently by foraging eagles. At these discharges, trout were distributed over a shallow gravel area and vulnerable to foraging bald eagles. When discharges ranged from approximately 15,000 to 20,000 cfs, these areas were deeply inundated and bald eagles foraged further up Nankoweap Creek.

Operations which enhance the trout fishery or native fish populations should benefit bald eagles. The Service believes it is unlikely that the bald eagle would be adversely affect by the proposed action, and the species will not be considered further in this consultation.

PEREGRINE FALCON

The peregrine falcon is a medium-sized raptor which occurs across much of North America and its various subspecies distributed worldwide. It tends to nest on cliffs near sources of avian prey and has traditionally been associated with cliffs near large bodies of water such as seacoasts, lakes, and large rivers (Ratcliffe 1980). However, the arid southwestern United States has recently been demonstrated to not only support breeding peregrine falcons but to support the largest known concentration in North America, excluding Alaska. Recent studies have documented high densities of breeding pairs in the Southwest, particularly the Colorado Plateau (Burnham and Enderson 1987; Hays and Tibbitts 1989; Tibbitts and Bibles 1990; Tibbitts and Ward 1990a, 1990b; Enderson et al. 1991; Brown 1991). Ellis (1982) reported on habitat preferences of peregrine falcons in Arizona and identified a profile for eyrie locations: elevation less than 2,700 m, extensive tall or very tall cliffs, high topographic relief, and having surface water available. In the Southwest, breeding peregrine falcons are currently found almost anywhere large cliffs ($\geq$ 100 m) are available, with the exception of the hottest and driest desert regions (Tibbitts and Ward 1990a).

Grand Canyon National Park supports the largest known breeding population of peregrine falcons in the contiguous United States, with the majority nesting along the river corridor (Carothers and Brown 1991). Between 1988 and 1990, 71 different breeding areas were identified in Grand Canyon National Park (Brown et al. 1992). Four peregrine falcon territories have been identified in Glen Canyon Recreation Area downstream of the dam (Hetzler 1992). Extrapolation estimates indicate that 96 pairs of peregrine falcon may exist in the project area (Brown 1991).

While peregrine falcons are usually migratory, conditions in the project area may support year-round resident individuals. During river surveys of Glen Canyon Recreation Area downstream of the dam, peregrine falcons were observed throughout the winter feeding on wintering waterfowl (Hetzler 1992).

The peregrine falcon appears to be making considerable progress toward recovery through much of its range. Recovery appears to be greatest in the Colorado Plateau of southern Utah, southwestern Colorado,and northern Arizona; and in adjacent habitats in Arizona, Utah, and Colorado. Recovery in this region is inferred from high total numbers of breeding pairs, high rates of site occupancy, and high reproductive success (Enderson et al. 1991; Tibbitts and Bibles 1990; Tibbitts and Ward 1990a, 1990b; Burnham and Enderson 1987; Brown et al. 1992).

Carothers and Brown (1991) speculate that post-dam changes in emergent marsh and riparian vegetation upon which insects are dependent have caused dramatic increases in insectivorous birds, such as swifts and swallows, and bats. These changes could positively affect the prey abundance for peregrine falcon.

Peregrine falcons also occur in somewhat lower densities, with successful reproduction, throughout the arid Southwest where river conditions differ from that of the regulated Colorado River (Hays and Tibbitts 1989; Burnham and Enderson 1987; Tibbitts and Ward 1990a, 1990b). However, dependent relationships between river flow regime and water turbidity, insect and insectivorous birds, and densities of breeding peregrine falcons in Grand Canyon have not been documented. Seasonal or long-term changes in riparian vegetation and abundance of insects and insectivorous birds closely tied to the river may affect gross abundance of prey available to local peregrine falcons. However, it is unknown but unlikely that changes in prey abundance due to the proposed action would be significant enough to adversely impact peregrine falcon populations. The Service believes it is unlikely that the peregrine falcon would be adversely affected by the proposed action, and it will not be considered further in this consultation.

KANAB AMBERSNAIL

The Kanab ambersnail has been recorded in three locations, two areas being developed near Kanab, Utah, and one in Grand Canyon National Park. The Grand Canyon population is the only one known from a wilderness setting (Spamer and Bogan 1993). Since the listing of the species, one of the Kanab Creek populations is believed extirpated (Larry England, Service, personal communication). The species is associated with permanently wet soil or shallow standing water and the presence of cattails (*Typha* sp.), or at least permanently wet soil which indicates the potential for cattails according to Clarke (1991). Individuals in the Grand Canyon

were found associated with cardinal monkey flower (*Mimulus cardinalis*) and water cress (*Rorippa nasturtium-aquaticum*) (Dennis Kubly, AGFD, personal communication). Maidenhair fern (*Adiantum capillus-veneris*) and poison ivy (*Rhus radicans*) are also common in the area (Larry Stevens, National Park Service, personal communication). Vegetative cover is a necessity for this species (Clarke 1991).

Spamer and Bogan (1993) summarize mollusk surveys of Grand Canyon and vicinity. Virtually no data exist on mollusks from previous resource surveys of the Colorado River and tributaries in the Grand Canyon, and there are no data on river corridor mollusks in literature published before the 1963 closure of Glen Canyon Dam.

For the known population in the Grand Canyon, the Kanab ambersnail is restricted to the wetted area created by a perennial stream flowing from a spring in the wall of the canyon at the base of limestone cliffs. Individuals may occur in the springfed area where cover, vegetation, and moisture conditions are found. The availability of monkey flower or other vegetation and the presence of rock ledges influences the distribution of this species towards the river. The wetted area where this population is currently known to reside is densely vegetated, quite small, and subject to floods from the rim and variable flows from the spring source. Environmental conditions such as loss of springflow due to drought and freezing temperatures may potentially affect Kanab ambersnail numbers or habitat (Dennis Kubly, AGFD, personal communication).

The population was reported by Blinn et al. (1992) to occur above the zone of 40,000 cfs, and the population size to vary widely between seasons. Individuals have recently been found in vegetation near the river's edge at 20,000 cfs (Dennis Kubly, AGFD, and Larry Stevens, Northern Arizona University, personal communication). Daily fluctuations in river level are likely to limit habitat below 20,000 cfs.

ENVIRONMENTAL BASELINE

The environmental baseline includes past and present impacts of all Federal, State, Tribal, or private actions and other human activities in the action area; anticipated impacts of proposed Federal projects in the action area that have already undergone formal or early section 7 consultations; and the impact of State, Tribal, or private actions that are contemporaneous with the consultation in process.

Human actions on the Colorado River in Grand Canyon prior to 1960 were Native American use by Tribes both in and outside of Grand Canyon for sustenance, cultural, and religious uses, and small scale mining and tourist ventures. Non-native fish species such as brook trout (*Salvelinas fontinalis*), brown trout (*Salmo trutta*), and rainbow trout were introduced by Federal and State agencies in the Grand Canyon and other species such as carp (*Cyprinus carpio*) and channel catfish (*Ictalurus punctatus*) were introduced by the same agencies elsewhere in the Colorado River system (U.S. Fish and Wildlife Service 1980).

Beneficial consumptive use of the Colorado River was apportioned between upper and lower basins in 1922; however, use of water depends on development of projects and features. Glen Canyon Dam was built as part of CRSP to provide storage with the responsibility of the upper

basin to provide minimum releases to the lower basin (7.5 maf) including the Mexican treaty obligation (0.73 maf) for a total of 8.23 maf. Depletions are uses of water that are not returned. In 1992, the estimated total depletion of the upper basin was 3.8 maf (exclusive of evaporation) of the 15 maf which is estimated to be the long-term natural annual average flow based on an 80-year period from 1906 to 1985 at Lee's Ferry, Arizona (U.S. Bureau of Reclamation 1991). Upper basin depletions are scheduled to increase to a total of 4.9 maf by the year 2020 and 5.4 maf by 2040.

Glen Canyon Dam closed in March 1963 and, as a structure, is a barrier to fish migration and movement and to the river's substantial sediment load. During most operations, cold water is released from the hypolimnion of the reservoir. Figure 3 shows mean monthly temperatures of the mainstem at Lee's Ferry from 1955 to 1985.

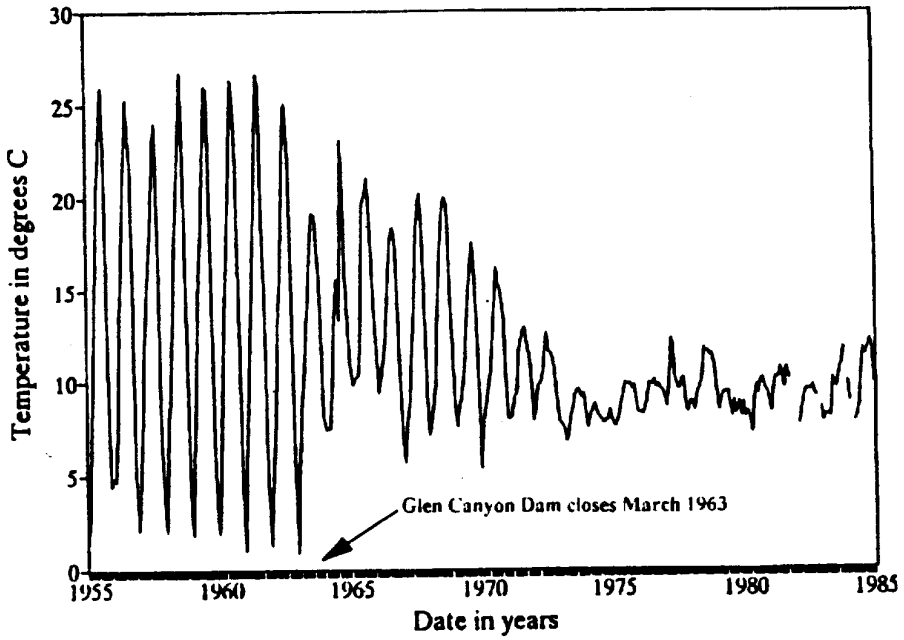

Figure 3. Mean monthly temperature of the Colorado River at Lee's Ferry (Weiss 1993)

The National Park Service conducts activities on the Colorado River for reaches within their jurisdiction under various management plans at Glen Canyon National Recreation Area and Grand Canyon National Park. These plans include activities such as commercial and noncommercial river trip permits, research permits, regulations on recreational use, and monitoring and management actions of the National Park Service. The AGFD also conducts actions such as regulating fishing and stocking of trout in the Colorado River at or above Lee's Ferry in Glen Canyon National Recreation Area.

The potential exists for the humpback chub or its habitat to be seriously impacted by a catastrophic event, such as hazardous material spill at the LCR bridge at Cameron, Arizona, or an adverse chronic event such as a limited release of some pollutant from upstream locations in the LCR drainage, such as oils, heavy metals, pesticides, or uranium compounds.

Native American use of the Colorado River in Grand Canyon continues for cultural, religious, and recreational purposes, but no impacts have been identified.

Depletions affect endangered fish by influencing the quantity of water available for regulation from Glen Canyon Dam. The impacts of depletions on endangered fish and their habitats above Glen Canyon Dam are addressed by section 7 consultations with the Service and Reclamation in the upper basin.

Introductions of non-native fish species have been long recognized as one of the principle reasons for declines in native fishes. Non-native fish species other than rainbow trout are no longer stocked in the Colorado River downstream of Glen Canyon Dam to Lake Mead (see below discussion on fish stocking).

Since construction of Glen Canyon Dam, there has been a decreasing number of native fish species in the Grand Canyon (U.S. Fish and Wildlife Service 1978; Minckley 1991). Now, of the eight native fish species of the Grand Canyon, three have been extirpated, and only four have reproducing populations. Extirpated species include the bonytail chub, Colorado squawfish, and roundtail chub (*Gila robusta*) - a candidate category 2 species. Reproducing populations include the bluehead sucker (*Pantosteus discobolus*), humpback chub, flannelmouth sucker (*Catostomus latipinnis*) - a candidate category 2 species, and speckled dace (*Rhinichthys osculus*). As discussed previously, the razorback sucker occurs in the Grand Canyon but not as a reproducing population. Candidate category 2 species are taxa for which the Service is considering adding to the threatened and endangered species list but insufficient information exists to support listing. The decreasing trend in native fish species also is evident in ranges of the remaining species. For example, since Glen Canyon Dam, the range of the humpback chub has contracted. The last date the species was collected above Lee's Ferry (RM 0) was 1967 (Stone and Rathbun 1968); at RM 17.8, 1980 (Kaeding and Zimmerman 1983); and at RM 29.9, 1993 (Valdez et al. 1993). Reduced range may be directly related to loss of mainstem spawning and nursery areas resulting from cold water releases, daily fluctuations, and fragmentation of habitat due to Glen Canyon Dam.

While Glen Canyon Dam closed in 1963, cold water releases as we know them today, did not occur until the early 1970's, and sub-adult flannelmouth suckers were still collected in the mainstem near Lee's Ferry in the middle of that decade along with non-native species such as channel catfish (Weiss 1993). Thus, Weiss suggests that non-native fish species were not the primary cause that eliminated young flannelmouth suckers from the Glen Canyon and Marble Canyon reaches of the mainstem, but he attributed the cause to low water temperatures and lack of turbidity for cover.

Barriers to fish migration and movement have been identified as a possible cause for severe declines of species such as the Colorado squawfish. Movement of the razorback sucker between lentic habitats and the canyons of the river also may have had been important for the species. The decrease in sediment load is typical for large dams, and downstream impacts to endangered fish habitats are immense.

Impacts of the various management plans of the National Park Service, addressed in section 7 consultations, include monitoring and managing visitor use of endangered species habitats. AGFD regulations include protection of endangered fish from fishing and, together with National Park Service, prohibitions from fishing at the confluence area of the LCR and mainstem. Stocking of non-native fish species may impact native fish species, and no stocking is done in Grand Canyon National Park. Rainbow trout are stocked between Lee's Ferry and Glen Canyon Dam in Glen Canyon National Recreation Area, but documented movements of those rainbow trout into Grand Canyon are limited. Maddux et al. (1987) reported few of the approximately 40,000 dye marked rainbow trout fingerlings moving downstream after stocking in the Lee's Ferry area during the first phase of GCES. However, they speculated that if fluctuations had been predominate during that study period, more fingerlings may have been moved downstream. They also found that the average distance moved by all tagged rainbow trout that were recaptured at least 1.5 km from release site (to separate from local movements) was 7.1 km (n=565).

Reduction in the quality or vitality of the only significant breeding and nursery area for the Grand Canyon humpback chub, the LCR, through catastrophic or adverse chronic event is a considerable threat to the survival of the Grand Canyon population.

EFFECTS OF THE ACTION

DIRECT

Endangered Fish

The MLFF, as a restricted fluctuating flow alternative, increases flood protection and minimum flow and reduces magnitude of daily flows, daily fluctuations, and ramp rate, compared to the No Action Alternative (NA).

The Services's preliminary review of the effect of floods on the humpback chub population in the Grand Canyon do not show any obvious long-term adversity or catastrophic impact after the high flow years 1983 to 1986, all size classes that were in the river before still remain. Evidence that high flows affect humpback chub was reported by several investigators. Floods in the LCR may have moved larvae and post-larvae humpback chub into the mainstem in late summer (Angradi et al. 1992) and adult humpback chubs from the LCR inflow area to mainstem (Valdez et al. 1993). High mainstem flows were suggested by Maddux et al. (1987) to have transported early life history stages of humpback chub to lower reaches in the Grand Canyon. However, the actual consequences of these floods depends on impacts to the population structure of the humpback chub in the Grand Canyon. Although the population structure remains unknown, ongoing research is directed at answering that question.

Throughout GCES and especially after the recent floods, the basic question concerned the short and long-term prognosis for various downstream resources based on the sediment budget. The concern for endangered and native fish was that sediment be available for short and long-term development and maintenance of backwaters and other channel margin habitats.

Increased flood protection would increase protection of sediment resources needed to build and maintain backwater and other channel margin habitats used by endangered and other native fishes. Because Glen Canyon Dam has essentially eliminated sediment transport from the river above, the replenishment of sediment in Grand Canyon is now tributary dependent. From the Dam to Paria River (Lee's Ferry) only local input sources are available, and the reach is expected to continue to erode and become increasingly armored. Because of the limited supply from the Paria River, the next most vulnerable reach is Lee's Ferry to LCR. Being contiguous with the LCR makes this reach important to the humpback chub. To redistribute sand from the riverbed to channel margins, some flooding would be necessary (see discussion on habitat maintenance and building flows below), but flows with excessive frequency, magnitude, or duration might result in a net sand loss. Factoring increased flood control with reductions in maximum releases, daily range, and ramp rates, the Draft EIS shows that the probability of a net gain in riverbed sand for the reach between Lee's Ferry and LCR after 20 years would be 64% for MLFF compared to 50% for NA. After 50 years, the probabilities would be 73% for MLFF compared to 41% for NA.

Habitat maintenance and habitat building flows (see DESCRIPTION OF PROJECT - OPERATION) are proposed actions for the purposes of reforming beaches and backwaters to maintain areas for camping and habitats associated with sediment deposits. They would be expected to slightly reduce the probability of net gain in riverbed sand, but analysis of that reduction is not available. Habitat maintenance flows (flows up to 30,000 cfs) would redistribute some sediment from the riverbed to channel margins and areas above normal high flow of 25,000 cfs. The higher and less frequent habitat building flows would be the primary vehicle during low water years to move sediment from storage in the riverbed to channel margins. During years when Lake Powell is expected to fill, powerplant releases greater than 25,000 cfs and floods would be the vehicle to move sediment.

The preferred alternative (without a selective withdrawal structure) does not remove the issue of coldwater temperatures on reproductive success in the mainstem; thus, most eggs or developing larvae would not be expected to survive in the Colorado River below Glen Canyon Dam. Humpback chub eggs, for example, need approximately 2 weeks at 20 °C water for hatching and larval development. As presented earlier, water temperatures 5 °C colder will more than double hatching time and considerably diminish success. Most successful spawning would be restricted to tributaries, although mainstem areas near warm springs and tributaries such as Shinumo Creek might produce some humpback chub. The potential for mainstem spawning and rearing of larval endangered and native fish is evidenced by the recent captures of adult and observations of larval humpback chubs near a warm shoreline spring about RM 30. The temperature of the spring was 19 °C, where the adults were collected was 12 °C, and in the mainstem was 8 °C.

Access to tributaries is an important factor that might be influenced by dam operations. Access to tributaries for spawning humpback chubs and razorback suckers, based on stage height of mainstem, would not be limited at 5,000 cfs minimum releases. Moreover, actual stage height would be slightly higher than what the dam releases show due to transformation of the discharge wave downstream of the dam (bottom of trough rises and top of peak falls).

Tributary confluences and the portion of the tributary immediately upstream will have slower current or become ponded with an increase in river stage. Larval fish that rear in these areas avoid entering the more harsh conditions of the mainstem (Clarkson et al. 1994). Downstream transport of young-of-year humpback chub emerging from tributaries would be reduced compared to NA. During high flow years of GCES Phase I (1983-1986), small humpback chub were collected in the lower reaches of the mainstem, down to RM 217 (Maddux et al. 1987). These humpback chub may have been spawned in a tributary in that lower reach, or they might have originated from the LCR and were swept downstream in the high flows in the mainstem.

Reduced magnitude of flows would allow young-of-year and juvenile fish that exit the LCR to remain in a possibly more productive reach just downstream of the LCR. The AGFD (1993) report in September 1991 they collected 146 humpback chub less than 160 mm total length in the reach of the mainstem downstream of the LCR. They believe an LCR flood event earlier that month was the probable cause for moving the young-of-year and juvenile fish from the LCR to the mainstem.

Reduction in the daily range of fluctuations (5,000, 6,000, or 8,000 cfs, depending on monthly release volume) might increase the food base; therefore, young-of-year humpback chub might experience some increase in growth due to increased food and more stable nearshore habitats. Juvenile humpback chub that remain in area might benefit from possible higher food production and a reduced number of possible predators or competitors compared with downstream reaches. The increase in minimum flows (8,000 cfs day and 5,000 cfs night) also might increase the food base and increase stability of nearshore habitats including backwaters.

Fluctuating flows limit solar warming of backwaters, flush organisms and nutrients important as food resources, and force earlier life stages of endangered and other native fishes out of quiet protected waters into unfavorable mainstem conditions. These conditions might include increased exposure to predation and debilitating effects of cold water and increased velocities. Importance of backwaters as nursery areas for endangered and native Colorado River fishes was reported by Holden (1977,1979), Valdez and Wick (1981), and Archer et al. (1985).

Backwaters are formed from fine-grained sediments within circulation zones; when river stage decreases, eddies often become backwaters (Weiss 1992). Backwaters are dynamically related to discharge and available sediment (Dawdy 1991). Weiss inventoried backwaters at various releases from Glen Canyon Dam using videography and found more at 5,000 cfs than at 15,000 cfs releases from Glen Canyon Dam. The MLFF range of flow in summer months (July and August), when larval or young-of-year humpback chub and other native fishes may be drifting or moving from the tributaries into the mainstem, might be 17,000 to 25,000 cfs based on 8,000 cfs daily fluctuations and maximum release of 25,000 cfs. Daily fluctuations in the reaches upstream and downstream of the LCR were estimated in the Draft EIS to range from 0.8 to

1.0 m. Only a few backwaters would occur in the reach downstream of the LCR under these flow conditions because the stage of the river would overtop the sediment forming the return channel.

Preliminary information from research being conducted under the Interim Flow regime, similar to the preferred alternative, found humpback chubs less than 40 mm total length in the mainstem from May through September (AGFD 1993; Valdez et al. 1992a); however, survival of those small fish is unknown. They may represent fish that have drifted from tributaries into the mainstem at various times during the summer. Growth of fish is reduced in water colder than optimal, and Hendrickson (1993) noted that lower growth rates are usually associated with higher mortalities (see also discussion of temperature in Status of Species).

Although lessened compared to NA, daily fluctuations could cause juvenile humpback chub to move from eddies, nearshore areas, or large backwaters to seek more suitable habitat. Exposure to predation and additional energy expenditure would occur during these movements, but the effect of such movement is unknown.

Kaeding and Zimmerman (1982) discussed the reduction in turbidity due to Glen Canyon Dam and the resulting increased light transmission in the mainstem waters which would alter behavior of young humpback chub. Since Glen Canyon Dam, most GCES fish researchers have observed behavior changes with differences in turbidity, particularly when turbidity levels are high due to tributary flooding events. While turbidity from daily fluctuations of the MLFF may offer some cover for young humpback chubs in shallow channel margin habitats, the significance of this lower level of turbidity has not been established.

Mainstem water temperatures before Glen Canyon Dam were as high as 25 to 29 °C during July and August (Paulson and Baker 1983). Because of hypolimnetic releases from Lake Powell, temperatures from Glen Canyon Dam now vary little throughout or between most years. Water temperatures at Lee's Ferry vary only from 7 to 12 °C (see Figure 3), and temperatures 400 km downstream rarely warm above 16 °C (Kubly 1990). Cold releases occur because the powerplants penstock intakes are located 70 m below full pool elevation (1,128 m). However, releases influence a cone of withdrawal current that may extend 30 m above and below the intake. In 1992, elevations of Lake Powell were about 24 m below full pool elevations, and increases in release temperatures were noted. As the epilimnion approaches the intakes, release of warmer water is possible. Thus, discharge temperatures are dependent on operations as well as location of penstock intakes.

Kanab Ambersnail

Presence of the Kanab ambersnail was not verified in Grand Canyon prior to the 1983 flood. However, individuals identified as *Lymnea* by Cole and Kubly (1976) actually may have been *Oxyloma haydeni kanabensis* (Dennis Kubly, AGFD, personal communication; Spamer and Bogan 1993).

The decrease in maximum flow and daily fluctuations during the early 1990's under interim flows (similar to the preferred alternative) has allowed for the expansion of vegetation and the population down towards the river's edge. Flows above 20,000 cfs and beach and habitat building or maintenance flows would impact potential habitat as estimated by the area of cardinal monkey flower which would be underwater as follows (Frank Protiva, GCES, personal communication):

River level (cfs)	Cardinal Monkey flower area under water (m^2)
15,000	0.0
20,000	1.3
33,000	41.3
45,000	86.0

The entire area of monkey flower or water cress is not known. Although vegetation extends up the redwall, how much of this habitat is likely to be used by the Kanab ambersnail or whether the species is evenly dispersed throughout the vegetation is not known. A survey conducted in September 1994 and habitat evaluations indicate that a large number of Kanab ambersnails were present between the 20,000 and 45,000 cfs flow levels (Dennis Kubly, AGFD, and Larry Stevens, Northern Arizona University, personal communication). If a controlled or uncontrolled flood were to occur under those conditions, a number estimated to exceed 1,000 Kanab ambersnails would have been directly affected. While the total number of individuals is not known, the loss of this many individuals may be serious.

Individuals would not likely be impacted by daily flows during low water years but would be impacted during high water years or during uncontrolled floods or controlled flows above 20,000 cfs. The recent change in the maximum flow of the preferred alternative to 25,000 cfs will inundate more vegetation and push individuals higher in the vegetation or eliminate the inundated habitat. Flood releases might impact individuals through direct mortality or displacement and distribute individuals or egg masses further downstream. The likelihood of impact is greatest if individuals have migrated or have been washed down to the river's edge after a natural disturbance. This method of distribution is not known for this species and would likely result in mortality. No direct impacts on other components of the species habitat are anticipated.

The variability in natural conditions (springflow, floods, and climate) may cause or contribute to large fluctuations in Kanab ambersnail population size and habitat. The time needed to recover after such a disturbance is unknown but may be rather rapid. Operational flows (scheduled releases) that would inundate or remove large portions of the Kanab ambersnail habitat might further deplete the population size.

INDIRECT

The concern that improving conditions for native fish species in Grand Canyon would aid non-native predators and competitors was raised in the 1978 biological opinion on Glen Canyon Dam and more recently by Minckley (1991) and the Draft EIS. Increases in the populations and numbers of species of non-native fishes have been identified as a major problem for native and endangered fishes (Dill 1944; Miller 1961; Holden and Stalnaker 1975; U.S. Fish and Wildlife

Service 1990b). Cold-water fish species such as brown trout, brook trout, and cutthroat trout (*Oncorhynchus clarki*) usually prey on other fishes. Although historically stocked in Glen Canyon and Grand Canyon (U.S. Fish and Wildlife Service 1980), the recovery plan for the humpback chub recommends against stocking predatory or competing non-native fishes into waters occupied by threatened and endangered species, and current practices of management agencies follow this recommendation. Of those three species, only brown trout remain in sizeable numbers in Grand Canyon with concentrations usually found in or near Bright Angel Creek, and only rare catches of brook trout are reported (Valdez et al. 1992a). Investigations are continuing in tributary use and food studies of suspected predators of endangered fishes, however, information is not yet available. Previous food habit studies of rainbow trout conducted in the Grand Canyon have not found the species to be detrimental to the humpback chub (Carothers and Minckley 1981; Maddux et al. 1987). However, because of the large population of rainbow trout downstream of Glen Canyon Dam and the management actions directed for the species, continued investigation into possible adverse impacts on the native fish in Grand Canyon due to rainbow trout are continuing and should identify problems that might develop.

Native fish species persist in the presence of non-native species in tributaries to the mainstem. Of nine tributaries sampled by Angradi et al. (1992) in Marble Canyon and Grand Canyon, seven were found to be dominated by native species, and only two were found to be dominated by non-native species (the cold-water rainbow trout). Maddux et al. (1987) sampled the lower perennial reaches of 11 tributaries in the Grand Canyon and found 79% of the fish caught were native species. By season, they found native fish species comprised 89% of spring use and 96% of summer use while trout comprised 68% of winter use and concluded little overlap occurs between native and non-native fish species in the tributaries. The canyon-bound aspect of the majority of the mainstem and tributaries in the Grand Canyon may assist in decreasing the suitability of those environments to warmwater, non-native fish species.

DISCUSSION OF EFFECTS

Primary adverse effects of operation of Glen Canyon Dam on the humpback chub, razorback sucker, and other native fishes are due to altered temperatures and flow regimes and, possibly, sediment load. These variables are related, for example, fluctuating flows may inundate shallow, warm nearshore areas with colder, mainstem water. Higher flows (greater mass of water) also warm more slowly traveling downstream than lower flows (less mass).

Effects of temperature are discussed in the section on STATUS OF SPECIES. Humpback chubs persistence in the Grand Canyon after Glen Canyon Dam may be because of their continuing movement into the LCR to spawn. Kaeding and Zimmerman (1983) hypothesized that a portion of the humpback chub population spawned in the LCR before the advent of cold releases while the other extirpated (Colorado squawfish and bonytail chub) or rare native fishes (razorback sucker) did not. Because operation of Glen Canyon Dam continues to prohibit, or at least limit, mainstem spawning of humpback chub and most other native fishes, this places an unusually strong dependence for the survival of the Grand Canyon population on the LCR. Also, a related question is, given that tagging studies show limited movements of humpback chub, in how much

of the mainstem will humpback chubs from the LCR be able to use and maintain viable aggregations? Will the range of the humpback chub in the mainstem continue to contract?

The potential for shallow, nearshore areas, particularly backwaters, to warm has been observed by most Grand Canyon researchers. Increases in temperatures at these sites would benefit larvae, young-of-year, and juvenile humpback chubs. The AGFD (1993) found backwaters in May 1991 under fluctuating flows to increase 9 °C during the day and then decrease to just above ambient river temperature at night. Under a steady flow of 15,000 cfs also in May 1991, they found backwater temperatures ranged from 14 to 23 °C while the associated mainstream eddy was 12 to 15 °C. Some decrease in temperatures at night, however, also were observed in backwaters during steady flows. Greater increases would be expected in the summer months than in May, but conclusions are pending further analysis. Angradi et al. (1992) summarized from their 1991 mainstem work that the highest use areas by young native fishes were thermally warmed backwater habitats.

The attraction to more temperate waters also is evident in the collections of adult humpback chub in Grand Canyon. Four of the six concentration sites identified by Valdez et al. (1992b) in the mainstem downstream of the LCR reaches were tributary inflows of warm water or springs in the river. Another spring area where humpback chubs have been captured is near Vasey's Paradise, upstream from the LCR. Potential additional use by humpback chub and other native fishes of these areas might occur with more steady flow regimes that allow warmer water to flow along side the channel margin on a steady basis without the daily tidal influence of cold water fluctuations. Further investigation of adult and juvenile humpback chubs in reaches upstream and downstream of the LCR began this year and may further address habitat use issues.

Nearshore areas, particularly backwaters, provide habitats with little or no velocities that are utilized by larval and young-of-year humpback chub (see STATUS OF SPECIES). These habitats are more productive in food resources required of these life stages, and they provide some protection from larger, predatory fishes. However, predation and competition exist now on native fish in Grand Canyon and will continue in the future. The susceptibility of fish as prey often depends on the size of the fish. As previously mentioned, cold mainstem waters limit or slow growth of young-of-year and juvenile native fish, and those smaller fish may be available as prey for a longer period of time than faster growing fish. A critical examination by species of non-native fish is needed to fully understand predator-prey and competition relationships in Grand Canyon. However, a prediction of all possible consequences related to the interactions of native and non-native fishes may be unobtainable. Using operations of the dam as a tool, the Service believes aquatic resources in Grand Canyon can be managed to avoid disastrous outcomes for endangered and other native fish species.

The biological support document for critical habitat designation for the humpback chub in the mainstem identifies that shallow, low velocity areas with silt substrate, preferred by young-of-year and juvenile life stages, are affected by river temperatures and change in flows (U.S. Fish and Wildlife Service 1993a). Also identified are influences of mainstem flow on impounding or fluctuating the lower portion of the LCR. For the razorback sucker critical habitat components specifically discussed as affected by changes in flows are shallow waters,

backwaters, or pool habitats. For both species, cold mainstem temperatures substantially reduces spawning and rearing areas in designated critical habitat.

Flows define and maintain riverine habitat required for the life stages of each fish species. Responses of riverine fishes to flows and habitat requirements by life stage are discussed in STATUS OF SPECIES. Flows that provide optimal quantity and quality of physical habitat for spawning, nursery, juvenile, and adult life stages also need suitable temperature regimes to make those habitats viable. Behavioral responses to flow, such as cues for spawning, may be important to the humpback chub and other native species.

Flows less than powerplant capacity may not affect composition of native versus non-native fish species, but flood flows might favor native fishes in canyon reaches (Minckley and Mefee 1987). Thus, habitat building and other flood flows would be expected to provide benefits to native fish species.

The humpback chub and other native fish species have evolved with large annual sustained spring floods and short-term rainfall events. During spring floods, stage change was often substantial, building as snowmelt from upstream watersheds reached the mainstem then decreasing when runoff subsided. Rainfall on tributary watersheds would variously influence mainstem stage depending on amount and location. However, since operation of the large hydroelectric power dams of CRSP, of which Glen Canyon Dam is the largest, the species has experienced daily oscillations of river stage. In a review of fluctuating flows from hydroelectric plants, Cushman (1985) notes that the pattern of daily fluctuations is relatively recent and "... not one to which most species are adapted." Researchers and others are increasingly recognizing that high fluctuating flows, particularly in the summer when larvae and young-of-year fishes are dependent on backwaters and nearshore habitats, are constraining to native fish populations and uncharacteristic of the natural hydrograph (Wydoski and Hamill 1991; Tyus 1992; U.S. Fish and Wildlife Service 1992; Clarkson et al. 1994). Tyus and Karp (1989) recommended low stable flows in late summer and fall for endangered and other native fish in the Green River. Because summer season operations of Glen Canyon Dam, including research periods, have never been low and steady for more than a few days, there has not been enough time to allow fish in Grand Canyon to respond to those conditions or habitats.

In August 1994, the Service learned that pre-Glen Canyon Dam hydrographs at Lee's Ferry and Grand Canyon gauges were being examined by the U.S. Geological Survey to look at changes in daily stage for the first time, and this information may be available in late 1994. Interest in this information has been high as the data appear to show the increased variability in stage changes over a shorter period of time than was previously reported. Along with the physical data, an analysis of the flows for the period of record and possible impacts to native fishes that evolved with such flows will be necessary. Because the period of record is brief compared to the evolutionary history of the endemic fish species, an appraisal of conditions that existed outside of the record also would be important.

Sediment augmentation in the Grand Canyon has been advocated as an action to assist the restoration of historic conditions for endangered and native fish. Turbidity may be an important component of the fishes habitat. However, whether the numbers of humpback chub found near

the LCR are only there because of the proximity to spawning or rearing habitat in the LCR, or whether the increased productivity of the mainstem in the upper reaches of Grand Canyon also contribute to the increased numbers, is not known. Also, not known is whether humpback chub populations in the lower reaches of Grand Canyon are limited because of unfavorable spawning conditions (i.e., low water temperatures), increased predator numbers, or reduced food production due to increased turbidity. The question of sediment augmentation could be investigated by studying responses of native fishes to various tributary floods or laboratory experiments to test various hypotheses.

The discussion of effects on razorback sucker is limited due to the now rare occurrence of the species in the Grand Canyon. Very infrequent encounters with razorback suckers by researchers in Grand Canyon have made the task of reporting on status as difficult as reporting on responses of the species to operations. Riverine conditions that support recruiting populations of razorback suckers have not been found throughout the species' range. However, the potential for increasing numbers of razorback suckers and to attempt to achieve a spawning population may be possible because of the connection with Lake Mead. The Colorado River in the Grand Canyon because of its length, management direction, and limited number of non-native fish species offers one of the few remaining possibilities for recovery of the razorback sucker. Development of razorback sucker populations in Lake Mead, similar to the work being accomplished in Lake Mohave by the Native Fish Work Group (a multi-agency group), is possible and would provide considerable time (razorback suckers have been aged to 44 years) while the limitations in their riverine ecosystem are identified and modified.

The potential value for the razorback sucker created by the availability of both riverine and lacustrine habitats, Lake Mead and the Colorado River upstream, was also noted in the biological support document for critical habitat for the species (U.S. Fish and Wildlife Service 1993a).

The distance from Glen Canyon Dam to Lake Mead Recreation Area is approximately 470 river km, most of them providing little more than basic survival values for only some life stages of endangered and native fishes. Management and enhancement of native fish populations in Grand Canyon will require an understanding of the habitat needs of species and the ecosystem processes that create and maintain them.

When reviewing locations of reproducing populations of humpback chub (Yampa River, Black Rocks, and LCR), one common element is a river that still maintains much of its natural character. These types of rivers are rare today. Carlson and Muth (1989) chronicle the considerable changes within the Colorado River basin and describe the uniqueness represented by the extremes within the Colorado River basin and the species that evolved in such a system. Nesler et al. (1988) stressed the cyclic patterns of the Yampa River and the adaptation of the Colorado squawfish and other native fish species to such an environment. Tyus (1992) notes the need for more than a minimal approach to recovery of endangered fishes and a philosophy of using experimental design to test community of fish responses to various scenarios.

The monthly pattern of pre-dam discharge at Lee's Ferry (1947-1957) is displayed in Figure 4. The pattern is one of flows building in March and April to high flows in May and June and then decreasing to lower levels in late summer through winter. That pattern was the basis for the Seasonally Adjusted Steady Flow Alternative (SASF), shown in Figure 5. The important features of the SASF for endangered and other native fishes were provisions for a more natural, pre-dam hydrograph: (1) a spring peak that would reinforce spawning aggregations of humpback chub and other species in the mainstem as they begin to form and move towards tributaries; and (2) steady, low flows during summer and early fall to stabilize and warm the backwaters and other nearshore habitats for larval, young-of-year, and juvenile life stages. Mainstem food resources such a zooplankton would increase in stable, warmer conditions and would be more available to endangered and other native fishes.

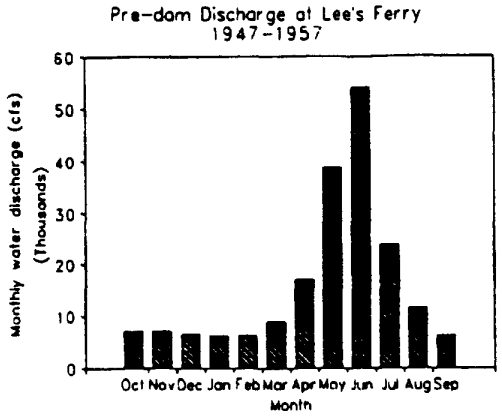

Figure 4. Monthly pre-dam discharge at Lee's Ferry (1947-1957) (Adapted from Andrew, E.D. 1991)

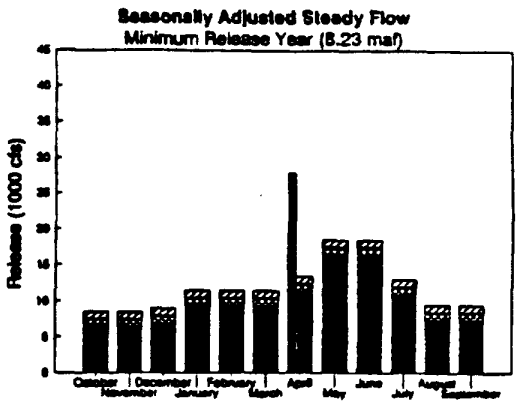

Figure 5. Seasonally Adjusted Steady Flow Alternative with habitat maintenance flow, 8.23 maf water year. (Preliminary DEIS January 8, 1993)

Average pre-dam flows in June were 53,900 cfs compared to the peak of 30,000 cfs with 18,000 cfs for two months under the SASF. The constraints of the SASF were to keep high flows within limits of available sediment and to release sufficient water to meet lower basin requirements. Since the development of the alternatives and, later, interim flows, information on sediment resources have shown that increases in the maximum for daily flows beyond 20,000 cfs would not be as erosive as was first believed. Thus, at the request of Western Area Power Administration, the daily maximum for MLFF has been increased to 25,000 cfs. Conceivably, other alternatives, such as SASF, could also be increased or timing of peak discharge modified as long as the volume of water is available. Information gathered to date indicates a need to more closely mimic the natural hydrograph of the Colorado River. The degree of deviation from historic conditions that can be tolerated by those fish species now endangered remains unresolved. The adaptive management concept provides for modifications to operations as information on the requirements of these endangered fish become further defined.

Reclamation provided an opportunity for any interested party to review and comment on the October 1993 draft biological opinion. A reoccurring concern expressed in this review was that actions in the Reasonable and Prudent Alternative benefiting native fishes would similarly benefit non-native fishes, and the increased non-native fishes would disadvantage native fishes by competition or predation. This concern is not taken lightly by the Service and was one of the basic questions raised in the 1978 jeopardy biological opinion. Assistance in responding to that question was provided by endangered fish researchers at meetings called by Reclamation to review flow recommendations on June 11, 1993, and March 2, 1994. Generally, the researchers supported the Service's flow scenario. The position paper by the GCES endangered fish researchers also was in general support of the Service flow recommendations (Clarkson et al. 1994). To assure that actions recommended by the Service will be beneficial to endangered and native fish species, the Service will review information in the final GCES research reports and from fishery scientists to determine if there is a need to reconsult if that information would reveal that the Service recommended actions would not achieve their purpose.

The Recovery Implementation Program for the Endangered Fish Species of the Upper Colorado River Basin contracted the comprehensive review of instream flows for the four endangered fish species. For that review, a report was recently provided by Stanford (1994) on the past and ongoing technical activities, methods, and knowledge in the upper basin associated with the instream flow needs of endangered and native fish. Stanford identified key issues to be resolved and provided recommendations that couple management actions with additional ecosystem based studies to resolve uncertainties identified with those actions.

His review found that endangered fishes were strongly influenced by the availability of physical habitats, and these habitats were flow dependent. Particularly important was the relationship of peak flows to base flows and the occurrence of low velocity habitats for young life history stages. He found peaking power operations on the Gunnison River and Green River destabilized the varial zone (the shallow shoreline) and prevented establishment of food webs and resting areas for small fishes. Stanford also found that analysis of studies and recovery efforts for endangered and native fishes could be thwarted by presence of nonnative fish species. Stanford recommended that considerably more consideration should be place on the population structure of the entire community of fishes and stated that "Strong inferences about the potential for recovering endangered fishes may be derived from population dynamics of other native species." He recommended using all available ecological information to implement a flow regime for the basin ecosystem and to quantify variables that identify whether the changes are favoring recovery. He also identified the value of peer review and the need to integrate the various studies and recovery efforts within the upper basin.

CUMULATIVE EFFECTS

Cumulative effects are those effects of future non-Federal (State, Tribal, local government, or private) activities on endangered or threatened species or critical habitat that are reasonably certain to occur during the course of the Federal activity subject to consultation. Future Federal actions are subject to the section 7 consultation requirements and, therefore, are not considered cumulative in the proposed action.

Because the Colorado River from above Glen Canyon Dam to below Lake Mead is within the jurisdiction of the National Park Service, little opportunity exists for actions that would affect the habitat of species being considered in this consultation that would not require a Federal action. Tributary origins and upstream reaches may include areas that would not require a Federal action. We are not aware of any proposed non-Federal actions that may affect tributary habitats of species being considered in this consultation. However, we are aware that the potential exists for such actions to occur, and that might, for example, appreciably affect the spawning and rearing areas of the humpback chub in the LCR. Such an action could be an increase in ground water pumping of the aquifer that is connected to the source of perennial water for the humpback chub in the LCR.

Actions by Indian Tribes whose land is adjacent to the Colorado River or its tributaries may or may not require a Federal action. We are unaware of any proposed non-Federal action by these entities that affect habitats of species being considered in this consultation.

ANALYSIS OF JEOPARDY AND ADVERSE MODIFICATION

The Service's biological opinion on operation of Glen Canyon Dam is based the current status of the species, environmental baseline, effects of the proposed action, and cumulative effects on listed species. To jeopardize the continued existence of a species, as defined in regulations implementing section 7 of the Act, is to engage in an action that would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by further reducing the reproduction, numbers, or distribution of that species. Survival is defined as the ability of a species to persist into the future with sufficient resilience to recover from endangerment. Conditions of survival are found in the LCR for the humpback chub: sufficiently large population, represented by all age classes, genetic heterogeneity, and a number of sexually mature individuals producing viable offspring, that exists in an environment providing all requirements for completion of the species' entire life cycle. The concern with the LCR is that all humpback chub use is in the lower 14.5 km of the LCR; thus, the species and its habitat are extremely vulnerable to chronic or catastrophic threats. The 470 km reach of the mainstem Colorado River downstream of Glen Canyon Dam (to upstream boundary of Lake Mead National Recreation Area) apparently does not provide for survival all age classes nor an environment for successful spawning and recruitment of young to adult humpback chub. For the razorback sucker, only minimal support for the adult life stage has been identified in the mainstem reach downstream of Glen Canyon Dam.

Jeopardy also relates to recovery. Recovery is the process by which the quality and quantity of ecosystems are restored so they can support self-sustaining and self-regulating populations of listed species as persistent members of native biotic communities. The proposed action is anticipated to improve conditions over NA for the humpback chub, but the likelihood of recovery in the mainstem Colorado River is still appreciably reduced. While limited evidence of mainstem spawning has occurred during interim flows, survival and recruitment of those larvae is not known. Studies by GCES during NA and interim flow (similar to MLFF) conditions report occurrence of humpback chub in the mainstem is primarily limited to the reach centered on the LCR.

The final analysis of whether an action is likely to jeopardize a species is to consider the aggregate effects of everything that has led to the species' current status, all future non-Federal activities, and the proposed action. Determination if an action is likely to destroy or adversely modify critical habitat is an assessment of whether all the aggregate effects on the critical habitat and its constituent elements will appreciably diminish the value of critical habitat in sustaining its role in the survival and recovery of the species. Thus, while other actions may be responsible for the humpback chub and razorback sucker being in decline before Glen Canyon Dam, or that cold water releases and reduction in sediment further impacted the native fishery, the Department of the Interior, with the Bureau of Reclamation as lead, is still responsible for the impacts of the proposed action of operation of Glen Canyon Dam as MLFF.

REASONABLE AND PRUDENT ALTERNATIVE

Regulations implementing section 7 define reasonable and prudent alternatives as alternative actions, identified during formal consultation, that (1) can be implemented in a manner consistent with the intended purpose of the action, (2) can be implemented consistent with the scope of the Federal agency's legal authority and jurisdiction, (3) are economically and technologically feasible, and (4) would, the Service believes, avoid the likelihood of jeopardizing the continued existence of listed species or resulting in the destruction or adverse modification of critical habitat.

The Service believes that elements of the reasonable and prudent alternative developed for this consultation meet the above four tests due to the following:

(1) There is an unique opportunity to conserve and protect endangered and other native fish fauna in an ecosystem designated as National Park Service lands for the preservation of these and other natural resource protection values from Glen Canyon Dam to Lake Mead. The Grand Canyon Protection Act of 1992 requires the Secretary of the Interior to "... protect, mitigate adverse impacts to, and improve values for which Grand Canyon National Park and Glen Canyon National Recreation Area were established ..."

(2) Providing water storage and annual water releases of at least 8.23 maf to the lower basin States is a primary function of Glen Canyon Dam. The reasonable and prudent alternative will not conflict with this annual delivery of water. All flows requested in the reasonable and prudent alternative that are not part of the proposed action are within powerplant capacity. Lower basin deliveries of water are met from releases from Hoover Dam and, to a lesser extent, from Lake Mead and do not depend on daily or monthly releases from Glen Canyon Dam. Elements previously defined as conservation measures by Reclamation and the Service are presently being conducted within Reclamation's authority. A structure similar to the selective withdrawal structure identified here has been built and is being operated by Reclamation on Flaming Gorge Dam on the Green River.

(3) Elements of the reasonable and prudent alternative that address operations have been reviewed and included in the draft EIS as viable alternatives. Additional NEPA compliance would be necessary for a selective withdrawal structural element.

(4) The Service believes, that to prevent jeopardy to the endangered fish of Grand Canyon, restoration of the aquatic ecosystem by reducing, to the extent possible, known limiting factors and conducting appropriate research to identify and reduce suspected limiting factors will be necessary and can be accomplished with cooperation, innovative approaches, and elements of the following reasonable and prudent alternative.

ELEMENTS OF THE REASONABLE AND PRUDENT ALTERNATIVE

The following reasonable and prudent alternative contains elements that will focus on the community of endangered and native fish present in the Grand Canyon. The Service believes that actions for one native species should be supportive of other native species in the ecosystem. As the trend of more species becoming endangered or threatened continues in the Colorado River, the difficulties of recovering an ecosystem that is losing functional parts may become insurmountable. Therefore, the health of the entire native fish community will be crucial to the removal of jeopardy for the humpback chub and razorback sucker. We realize that not all of the elements can be implemented at once, and an implementation schedule has been noted for some elements. Those elements that can be accomplished without further verification or NEPA compliance should be implemented without delay. For some elements, such as the selective withdrawal structure, a schedule will be determined. Reclamation and the Service will meet at least annually to coordinate reasonable and prudent alternative activities. Such meetings will provide the Service an opportunity to determine whether sufficient progress is being made in accomplishing those actions set forth to remove jeopardy to federally-listed species impacted by operation of Glen Canyon Glen Canyon Dam.

Refinement of specific flows is dependent on continued studies, including a period of experimental flows, that identify mainstem habitats affected by flows and responses by endangered fishes to those habitats. Successful completion of the reasonable and prudent alternative is necessary to remove jeopardy to the humpback chub and razorback sucker from the proposed action. The reasonable and prudent alternative will be accomplished when all elements of the selected alternative have been effected and studies confirm compatibility between these species requirements and the operation of Glen Canyon Dam.

The draft EIS has seven elements common to all but the unrestricted fluctuating flow alternatives. Six of those EIS common elements that would influence native and endangered fish are adaptive management, flood frequency reduction measures, habitat and beach building flows, establishing a new population of humpback chub, further study of selective withdrawal, and emergency operations exception criteria. Three of the EIS common elements that were identified by Reclamation and the Service as conservation measures (see BACKGROUND) are research or long-term monitoring (adaptive management), flood frequency reduction, and the second spawning population of humpback chub. Development of a management plan for the LCR was another conservation measure being conducted by Reclamation through GCES.

Because of the importance of the EIS common elements and conservation measures to the continued existence of the humpback chub, razorback sucker, and other Colorado River native fish, many of the elements and measures are included below as elements of the reasonable and

prudent alternative to assist in identification of actions necessary to be included in any future modification of the preferred alternative.

1. Attainment of riverine conditions that support all life stages of endangered and native fish species is essential to the Colorado River ecosystem. Therefore, Reclamation shall develop an adaptive management program that will include implementation of studies required to determine impact of flows on listed and native fish fauna, recommend actions to further their conservation, and implement those recommendations as necessary to increase the likelihood of both survival and recovery of the listed species.

The Adaptive Management Program, an EIS common element, was still being formulated as we prepared this biological opinion. The Service supports adaptive management as an iterative approach to resource management. We recognize that the aquatic and terrestrial ecosystems below Glen Canyon Dam are still adjusting to impacts from dam operations that will continue into the future. Thus, the need for adaptive management. Actions taken through this approach must be based on an integrated resource approach, and, as discussed by Hilborn (1992), an active rather than a passive learning system that includes deliberate experimental design.

A. A program of experimental flows will be carried out to include high steady flows in the spring and low steady flows in summer and fall during low water years (releases of approximately 8.23 maf) to verify an effective flow regime and to quantify, to the extent possible, effects on endangered and native fish. Studies of high steady flows in the spring may include studies of habitat building and habitat maintenance flows. Research design and hypotheses to be tested will be based on a flow pattern that resembles the natural hydrograph, as described for those seasons in the SASF.

Information from final GCES endangered fish reports, researchers who conducted those studies, and other knowledgeable individuals will be used to assist in determining an experimental flow regime of high spring flow and low summer and fall flow for endangered fishes and to develop hypotheses and studies to accompany those flows with final review and approval by the Service. Reclamation will provide technical assistance and funding.

Design of the experimental flows and associated studies will begin as soon as possible and be targeted for completion by October 1996. Unless the Service determines information provided seriously questions the validity of experimental designs developed or contribution of the resulting data to remove jeopardy to the federally-listed aquatic fauna of the Grand Canyon, experimental flows will be initiated in April 1997. If sufficient progress and good faith effort is occurring towards initiating experimental flows, implementation of experimental flows may occur later in 1997. If the Service believes there is not sufficient progress, Glen Canyon Dam would be operated as SASF flows during spring through fall (April to October) beginning in 1998. If the Service determines a study design can not be developed that is expected to provided information to support removal of jeopardy to the razorback sucker and humpback chub populations in the Grand Canyon and associated tributaries, such will be considered new information and may be grounds for reinitating formal consultation.

This element is based on low release years (8.23 maf) occurring approximately 50% of the time. Further improvement of the means for determining a low water year that would initiate the implementation of research flows in a given year will be developed by Reclamation with concurrence by the Service. This may include, for example, methods based on content of water in Lake Powell at a given date. When implemented, experimental flows will be conducted for a sufficient period of time to allow for experimental design, biological processes to function, and for variability inherent in riverine ecosystems to be expressed. The number of years to conduct the experimental flows is, therefore, indeterminate.

During moderate and high release years, Reclamation shall operate Glen Canyon Dam according to requirements of the MLFF. Operations during moderate and high water years would assist in achieving some of the variability that was always present in the historic Colorado River and under which the endangered and other native fish evolved.

Following analysis of the data, appropriate operational flows will be determined by the Service and implemented by Reclamation in compliance with section 7(a)(2), Endangered Species Act.

B. Reclamation shall implement a selective withdrawal program for Lake Powell waters and determine feasibility using the following guidelines.

i. Review historic information and employ existing modeling with possible updates using alternative reservoir and operating conditions to prepare a set of possible scenarios of temperature changes in the mainstem.

ii. Determine from the literature, experimentation, and consultation with the AGFD, Native American Tribes, National Park Service, Service, and other native fish species experts the anticipated effects on native fish populations which may result from implementation of temperature changes from a selective withdrawal structure. Determine the range of temperatures for successful larval fish development and recruitment and the relationship between larval/juvenile growth and temperature.

iii. Assess the temperature induced interactions between native and non-native fish competitors and predators.

iv. Assess the effects of temperature, including seasonality and degree, on *Cladophora* and associated diatoms, *Gammarus*, aquatic insects, and fish parasites and disease.

v. Evaluate effects of withdrawing water on the heat budget of Lake Powell, effects of potentially warmer inflow into Lake Mead, and the concomitant effects on the biota within both reservoirs. Evaluate the temperature profiles along with heat budget for both reservoirs.

vi. Evaluate effects of reservoir withdrawal level on fine particulate organic matter and important plant nutrients to understand the relationship between withdrawal level and reservoir and downstream resources.

Installation of a selective withdrawal structure at Glen Canyon Dam may be essential in order to increase water temperatures downstream. Warmer mainstem temperatures are needed to ensure successful spawning and recruitment of endangered and native fishes in the mainstem. Research identified for this element should be integrated or combined with the research program specified in Element C. A selective withdrawal structure would provide considerable flexibility in managing the aquatic ecosystem downstream of Glen Canyon Dam. Management options, such as when to release warmer temperature water, seasonal pattern of releases to avoid establishment of permanent backwater areas, and use of floods, would all be available to limit expansion or invasion of non-native fish species.

The Service cautions the selective withdrawal structure should not be considered the only action needed to provide successful mainstem spawning and recruitment and ultimate recruitment for the humpback chub and razorback sucker. Aspects of the natural hydrograph, including low, steady releases in the summer, are considered necessary based on our present knowledge of the temperature capabilities of a selective withdrawal structure and habitat requirements of the species. Future studies might identify opportunities to operate Glen Canyon Dam in a manner that would alleviate conditions that jeopardize the continued existence of listed fish in the Grand Canyon and minimize impacts on water utilization for power production and other purposes. This program also is one of the EIS common elements.

C. Determine responses of native fishes in Grand Canyon to various temperature regimes and river flows of the experimental flows and other operations of Glen Canyon Dam. Studies will emphasize collection of information necessary to remove jeopardy to federally-listed species and identify actions necessary to enhance their recovery. Reclamation will provide technical assistance and funding for research to accomplish the following studies.

i. Determine the effects of water temperature on reproductive success, growth, and survivorship of Grand Canyon fishes.

ii. Determine relationships among tributary hydrology, reproductive success of fishes, and the abundance of fishes in mainstem rearing habitats.

iii. Determine the effects of mainstem hydrology on the number of nearshore rearing habitats, environmental conditions in these habitats, and their successful utilization by fishes.

iv. Assess biotic interactions between native and non-native fishes, particularly those that occur in nearshore rearing habitats affected by dam operations.

v. Determine humpback chub life history schedule for populations downstream of Glen Canyon Dam.

vi. Determine origins of fish food resources, energy pathways, and nutrient sources important to their production, and the effects of Glen Canyon Dam operations on these resources.

vii. Determine the effects of dam operations, including modifications to regulate water temperatures, on the parasites and disease organisms of endangered and native fishes in Grand Canyon.

Emphasis to be placed on experimental approaches using various flow and temperature scenarios to determine cause and effect relationships between dam operations and responses of the community of endangered and native fishes endemic to the Grand Canyon. Efforts should be hypothesis driven and specific in objectives. Explanation of the above research efforts is provided in Appendix 1 along with suggested hypotheses. The success of these research efforts will require sufficient flexibility in operations to design and carry out the experiments. Wherever feasible, off-site experiments should be considered as a means of generating or supporting the testing of hypotheses to reduce on-site study time and complexity. Long-term measurements should more appropriately be incorporated into the monitoring program, but there must be an active synergism between the two efforts.

The long-term monitoring plan should define objectives and methods for tracking the status of native fishes in Grand Canyon. Relevant indices should be developed and measured in support of the long-term monitoring plan. A major advantage of the current intensive marking studies using passive integrated transponder tags is the ability to measure future movements, growth rates, and population sizes of these fishes. This legacy, and others made available by this period of intensive research effort, should be effectively incorporated into the long-term monitoring program for fishes. Adaptive management, an EIS common element, would likely include a number of the above research objectives.

2. Protect humpback chub spawning population and habitat in the LCR by being instrumental in developing a management plan for this river.

This element remains very important to the survival of the humpback chub in Grand Canyon. Reclamation has, through contracts with the Navajo Nation, developed an extensive database for use in developing the plan. Reclamation will work with the Service, Navajo Nation, Hopi Tribe, National Park Service, Bureau of Indian Affairs, AGFD, and others to develop a management plan that includes actions to avoid possible adverse impacts to humpback chubs and their spawning and rearing habitats in the LCR. The principle objective of this plan shall be the protection of humpback chub habitat in the Colorado River and LCR. A draft plan will be prepared within 2 years from the date of this biological opinion and transmitted to agencies, parties, and others having authority to implement the plan.

3. Develop actions that will help ensure the continued existence of the razorback sucker by first sponsoring a workshop within 1 year following the biological opinion to enlist the advise of species experts, endangered fish researchers in Grand Canyon, Native Fish Work Group biologists, and others, such as Colorado River Recovery Team members, to develop a management plan for the species in the Grand Canyon. Following review of the workshop results, the Service will recommend a course of action and develop a Memorandum of Understanding with Reclamation and other entities who may wish to participate. The memorandum will provide detail on development of the management plan and implementation of actions identified in the plan.

Activities establishing razorback suckers in the Grand Canyon might include development of spawning and rearing areas that would function like flooded river bottom lands. Opportunities for such actions could be at (1) Lee's Ferry in a former gravel storage area along the mainstem and Paria River or (2) near the inflow area of the Colorado River into Lake Mead (Lake Mead National Recreation Area and Hualapai Indian Reservation). Cooperation of land managing agencies, such as the National Park Service and Hualapai Indian Tribe would be necessary.

4. Establish a second spawning aggregation of humpback chub downstream of Glen Canyon Dam.

Baseline information on possible tributary use or suitability for use by spawning humpback chub is being collected. Using that information, information from other Grand Canyon endangered fish research, and information from studies of *Gila* taxonomy, Reclamation, in consultation with the Service, National Park Service, AGFD, and land management agencies such as the Havasupai Tribe, will make every reasonable effort through funding, facilitating, and provide technical assistance to establish a program for additional spawning aggregations (or populations depending on genetic status) in the mainstem or tributaries. This effort has been identified as one of the EIS common elements.

INCIDENTAL TAKE

Section 9 of the Act, as amended, prohibits any taking (harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or attempt to engage in any such conduct) of listed species of fish and wildlife without a special exemption. Harm is further defined to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing behavioral patterns such as breeding, feeding, or sheltering. Under the terms of Section 7(b)(4) and Section 7(o)(2), taking that is incidental to, and not intended as part of, the agency action is not considered a prohibited taking provided that such taking is in compliance with the incidental take statement. The measures described below are nondiscretionary, and must be undertaken by the agency or made a binding condition of any grant or permit issued to the applicant, as appropriate.

The Service anticipates that the proposed operation of Glen Canyon Dam according to operating and other criteria of the MLFF, as described in the Draft EIS, and as changed by the reasonable and prudent alternative will result in incidental take of the humpback chub and Kanab ambersnail as follows: Some young humpback chub will be transported downstream from the reach of the mainstem below the LCR into unfavorable habitats due to habitat maintenance or habitat building flows. Some Kanab ambersnail individuals and associated habitat of the known population, or other populations as they may be discovered, may be lost due to flood releases from Glen Canyon Dam.

The Service anticipates that the incidental take level of the humpback chub will be difficult to detect due to the inaccessibility of the vast mainstem river with white-water reaches where the small fish may be transported. Habitat maintenance and habitat building flows, operations when these losses may occur, are to be tested as a part of the proposed action. Biological criteria, such as not conducting habitat building flows following a year in which a large population of

young humpback chub have been produced, have been recommended in the Draft EIS. During testing, studies to determine impacts of flows on young humpback chubs and methods of detecting changes in numbers will assist in establishing levels of incidental take. The development of biological criteria will assure that levels of incidental take are not exceeded.

The Service anticipates that the incidental take level for the Kanab ambersnail will be difficult to estimate and detect because the species is small and is found in thick vegetation and near the shear wall of the inner Grand Canyon. The population also has wide seasonal and annual fluctuations. This is the only known population of the Kanab ambersnail in a wilderness setting and the survival of this population is critical to the species (U.S. Fish and Wildlife Service 1994b). Because the lower areas of Kanab ambersnail habitat can be quantified, incidental take will assume to be exceeded if more than 10% of the occupied habitat in Grand Canyon will be inundated by high flows or a controlled flood.

Implementation of the reasonable and prudent alternative which includes habitat maintenance and building flows is expected to minimize take of the humpback chub and is not likely to result in jeopardy to the species. Channel bottom sediment will be redistributed to channel margins to establish and maintain habitats for use of young life stages of humpback chubs in the mainstem.

Flood frequency reduction measures will assist in balancing the budget of sediment necessary for humpback chub habitats.

Implementation of the reasonable and prudent alternative is expected to minimize take of the Kanab ambersnail by reducing flood frequency, duration, and magnitude to a level determined to be in the best interests of conserving ecosystem processes and the continued survival of the endangered fish. Monitoring following flood events will assist in defining the species' response to those events and in refining a take level.

The Service does not anticipate that the proposed operation of Glen Canyon Dam according to operating and other criteria of the MLFF, as described in the Preliminary Draft EIS, would result in any incidental take of the bald eagle, peregrine falcon, or razorback sucker. Accordingly, no incidental take is authorized. Should any take occur for these species, Reclamation must reinitiate formal consultation with the Service and provide a description of the circumstances surrounding the take.

If, during the course of an action, the amount or extent of the incidental take limit is reached, Reclamation must reinitiate consultation with the Service immediately to avoid violation of Section 9. Operations must be stopped in the interim period between the initiation and completion of the new consultation if it is determined that the impact of the additional taking will cause an irreversible and adverse impact on the species, as required by 50 CFR 402.14(i). Reclamation should provide an explanation of the causes of the taking.

REASONABLE AND PRUDENT MEASURES

The Service believes the following reasonable and prudent measures are necessary and appropriate to minimize incidental take of the humpback chub or Kanab ambersnail authorized by this biological opinion.

During the testing of habitat maintenance and building flows, studies to determine impacts on young-of-year and juvenile year classes of humpback chub will be used to assist in establishing levels of incidental take. Biological criteria governing the implementation of those flows will be developed that will assure that the level of incidental take is not exceeded.

The Kanab ambersnail population and habitat should be surveyed before scheduled flows greater than 25,000 cfs or a controlled flood to document levels of incidental take.

TERMS AND CONDITIONS FOR IMPLEMENTATION

In order to be exempt from the prohibitions of Section 9 of the Act, Reclamation is responsible for compliance with the following terms and conditions, which implement the reasonable and prudent measures described above.

1. Information on size of young-of-year and juvenile year classes of humpback chubs will be collected prior to and following tests of habitat maintenance and building flows, in areas where they are suspected to occur before and after such flows. To the extent possible, these studies should be integrated with ongoing mainstem humpback chub studies. Results of the studies will be provided to the Service and other interested parties within 60 days following completion of the field research.

2. A method will be developed to determine the number of humpback chubs suspected to be lost and the relationship of this loss to the Grand Canyon population. A strategy will be developed to sustain notable year classes of humpback chubs that are susceptible to being transported downstream into unfavorable habitats. This will incorporate an understanding of the frequency of such year classes in the system and impact of flows on that year class. The need to maintain nearshore habitats dependent on sediment will be a prime consideration in this strategy. Criteria will be developed by the involved research entities and agencies, with final review by the Service, that will provide for the implementation of this strategy.

3. The Kanab ambersnail population and habitats will be quantified and analyzed by qualified personnel to determine specific habitat characteristics required by the species. Gage height and flow levels will also be quantified for the known habitat. Research protocol should be mutually agreed upon by the Service, Reclamation, AGFD, National Park Service, other land management agencies as appropriate (e.g. Navajo Nation, Hualapai Tribe, and Havasupai Tribe) and will be conducted in such a manner as to minimize disturbance to the population and habitat. Research summary will be submitted to the Service within 60 days from completion of field research.

4. Kanab ambersnail habitat will be surveyed before and after any flow greater than 25,000 cfs. Individuals found in the zone to be inundated may need to be relocated to higher levels. Recommendations of the Kanab ambersnail Recovery Team will guide this decision. When flows exceed 25,000 cfs, the Kanab ambersnail population and its habitat will be surveyed within 30 days after flows return to normal and again six months later to determine Kanab ambersnail response to disturbance and ability to recover. If an uncontrolled flow exceeds 25,000 cfs, the Kanab ambersnail population and habitat will be surveyed within 30 days after flows return to normal and again 6 months later to determine the species response to disturbance and ability to recover. Initial research summaries of surveys will be submitted to Service within 30 days and subsequent summaries within 60 days following survey completion.

The incidental take statement provided in this opinion satisfies the requirements of the Endangered Species Act, as amended. This statement does not constitute an authorization for take of listed migratory birds under the Migratory Bird Treaty Act, the Eagle Protection Act (bald or golden eagles) or any other Federal statute.

CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the Act directs Federal agencies to utilize their authorities to further the purposes of the Act by carrying out conservation programs for the benefit of endangered and threatened species. The term conservation recommendations has been defined as Service suggestions regarding discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or critical habitat or regarding the development of information. The recommendations provided here related only to the proposed action and do not necessarily represent complete fulfillment of the agency's 7(a)(1) responsibility for these species.

1. Operate Glen Canyon Dam according to operating and other criteria of the SASF alternative. Draft EIS Elements common to all alternatives, habitat and maintenance flows, and elements two through seven of the Reasonable and Prudent Alternative would be part of this recommendation. The SASF has been analyzed as completely as any other alternative in the Draft EIS and would not require any additional analysis.

2. Monitor peregrine falcon breeding sites in Glen Canyon and Grand Canyon in cooperation with the AGFD, National Park Service, and AGFD, and Tribes.

3. Peregrine falcon habitat utilization will continue to be monitored to more fully understand population dynamics and determine their relationship to the changing riparian ecosystem for meeting life stage requirements.

4. Use of the Colorado River corridor and its tributaries by wintering bald eagles has increased significantly in recent years suggesting either highly favorable habitat or a decline in suitable habitat elsewhere. Monitoring of eagle habitat utilization and foraging patterns and their relationship to dam operations will continue in cooperation with AGFD, National Park Service, Navajo Nation, and Service paying particular attention to age-class representation and behavior. Additionally, any observed use of the river

corridor by breeding bald eagles will be reported to the Service and should become the focus of additional eagle monitoring where deemed feasible by the Service and AGFD.

5. Because little is known about the ecology of the Grand Canyon population of the Kanab ambersnail, a thorough investigation into their life cycle processes and requirements is necessary to determine their relationship to the riparian ecosystem and their susceptibility and response to disturbance. A census of the population will be taken and their habitat characterized. Once habitat requirements are determined, other potential habitat sites within the Grand Canyon corridor will be surveyed to determine species presence and recovery potential.

In order for the Service to be kept informed of actions that either minimize or avoid adverse effects or that benefit listed species or their habitats, the Service requests notification of the implementation of any conservation recommendations.

CONCLUSION

This concludes formal consultation on the proposed operation of Glen Canyon Dam according to operating and other criteria of the as described in the Preliminary Draft EIS. As required by 50 CFR 402.16, reinitiation of formal consultation is required if: (1) the amount or extent of incidental take is reached; (2) new information reveals effects of the agency action that may impact listed species or critical habitat in a manner or to an extent not considered in this opinion; (3) the agency action is subsequently modified in a manner that causes an effect to the listed species or critical habitat that was not considered in this opinion; or (4) a new species is listed or critical habitat designated that may be affected by the action.

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APPENDIX 1. Investigations

1. Determine effects of water temperature on reproductive success, growth, and survivorship of Grand Canyon fishes.

> Hypothesis: Experimental flows will alter the water temperatures in the Grand Canyon which will in turn significantly improve reproductive success, growth, and survivorship of Grand Canyon endangered and native fishes.

There is general agreement among fisheries biologists conducting studies in Grand Canyon that the ecological and environmental bottleneck for the endangered fishes occurs in the early stages of life. The Service found in the 1978 biological opinion on Glen Canyon Dam that successful reproduction and recruitment of humpback chub were limited by the perennially cold waters of the Colorado River. Ensuing studies have confirmed that finding, and there remains a present need to investigate the impacts of water temperature on reproduction, growth, and survivorship of early life stages, not only of the endangered fishes, but also of their potential predators and competitors. Some of these investigations have been completed previously or are being currently examined. Specific needs for additional research should be identified in the review of products following submission of the 1994 Conservation Measures reports.

2. Determine relationships among tributary hydrology, reproductive success of fishes, and the abundance of fishes in mainstem rearing habitats.

> Hypothesis: Under experimental flows, the relationship between tributary hydrology and the mainstem will significantly improve reproductive success of endangered and native fishes, as well as the abundance of those fishes in mainstem rearing habitats.

The endangered fishes of Grand Canyon utilize nearshore habitats, e.g. backwaters and their associated eddies, as rearing habitats during the spring-autumn period. Utilization of these habitats in the mainstem by larval and juvenile fishes is well documented, although it is unclear what proportion of young fishes rear in mainstem habitats as opposed to tributaries. Research continues to indicate that limited successful mainstem reproduction occurs; thus, early life stages in mainstem rearing habitats must have originated largely in tributary habitats. Findings of Conservation Measures research have shown that numbers of young fishes in mainstem backwaters, particularly those below the LCR, often change following hydrological events (floods) in tributaries. Timing, magnitude and duration of these tributary events are very important determinants of reproductive success, and thus of the numbers of young native fishes available to be transported to mainstem rearing habitats.

Although these relationships are recognized, they have not been sufficiently quantified or modeled so that this information could be used effectively to adjust dam operations according to protect mainstem rearing habitats in any given year. Conservation Measures research products and those of earlier studies should provide the basis for a more definitive relationship between tributary hydrology, reproductive success, and the relative numbers of young fishes in downstream Colorado River backwaters. If this relationship could be modeled successfully, it would provide an important tool for determination of acceptable dam operations.

3. Determine effects of mainstem hydrology on the number of nearshore rearing habitats, the environmental conditions in these habitats, and their successful utilization by fishes.

> Hypothesis: Experimental flows will significantly reduce the negative effects of mainstem hydrology on the number of nearshore rearing habitats, the environmental conditions of those habitats, and their successful utilization by endangered and native fishes.

Mainstem hydrology affects nearshore rearing habitats in several related ways. Short-term fluctuations in discharge cause concomitant changes in river stage that inundate and dewater nearshore habitats forcing fishes from their preferred environs. Although it is well recognized that dewatering effectively removes these habitats, it is less well understood that they also can be compromised by rising water levels. Daily exchanges of cold mainstem waters with warmer backwaters also reduce the availability of desirable thermal regimes for these fishes, whether they are displaced or remain in these habitats. On a different time scale, mainstem hydrology affects the location, geometry, and elevation of nearshore habitats through sediment deposition and erosion processes. Conservation Measures research should provide a good understanding of the proximal relationship between hydrology and environmental conditions in nearshore habitats. There is little indication at present, however, that these studies will lead to a determination of behavioral or physiological responses by fishes to these changes in their rearing habitats. Furthermore, there is a decided need for further investigations by physical scientists to determine the relationship between hydrology and the formation and maintenance of these habitats.

4. Assess biotic interactions between native and non-native fishes, particularly those that occur in nearshore rearing habitats affected by dam operations.

> Hypothesis: Experimental flows will benefit endangered and native fishes of the Grand Canyon through significantly reducing their interactions with non-native fishes, particularly those that occur in nearshore rearing habitats affected by operations.

Much of the resistance to temperature modification of the Colorado River in Grand Canyon is predicated on fears for the undesirable enhancement of conditions for non-native fishes and subsequent negative impacts on native fishes. Some of these concerns are about the effects of large predators, like striped bass (*Monroe saxatilis*), that could affect even adult native fishes, but the major concern seems directed at effects on preadult life stages in rearing habitats. No amount of research will answer all questions or allay all fears associated with temperature modification. Yet, carefully directed studies conducted in semi-controlled field settings or laboratories could provide much needed information on these interactions.

5. **Determine the humpback chub life history schedule for the population downstream of Glen Canyon Dam.**

> Hypothesis: Experimental flows will significantly alter the life histories of the populations of humpback chub and other long-lived native fishes of the Grand Canyon.

Knowledge of the population structure is essential to determine sustainable, viable populations of native fishes in the Grand Canyon. Long-lasting tags placed in all native fish over 150 mm total length will assist future population estimates.

(6) **Determine the origins of fish food resources and energy pathways and nutrient sources important to their production, and the effects of Glen Canyon Dam operations on these resources.**

> Hypothesis: Experimental flows will significantly alter the energy pathways of food resources and nutrient sources to significantly improve the production of endangered and native fishes of the Grand Canyon.

A basic question throughout most GCES research has been how Glen Canyon Dam impacts downstream food resources. The contribution of Lee's Ferry reach in organic mater, nutrients, and biota such as zooplankton and benthic invertebrates to fishes and other aquatic life downstream is not well quantified and considerable questions remain. As an example, the Lee's Ferry trout fishery declined somewhat during or shortly after the experimental flow period, and declines in relative condition of humpback chub also were observed but later in time. Whether the change in relative condition of humpback chubs is related to the same factors that affected the trout fishery is one of the questions that should be addressed.

(7) **Determine the effects of dam operations, including modifications to regulate water temperatures, on the parasites and disease organisms of endangered and native fishes in Grand Canyon.**

> Hypothesis: Experimental flows, including modifications to regulate water temperatures, will cause significant changes on the parasites and disease organisms of endangered and native fishes of the Grand Canyon.

Bacteria, protozoans, and a fungus have been identified from humpback chub in Grand Canyon. A new organism, Asian tapeworm (*Bothriocephalus acheilognathi*) has recently been observed in humpback chubs in the Grand Canyon (first record in United States is 1975). Changes in one operating regime to another may increase or decrease infestations of these disease organisms in endangered and native fishes and should be investigated.