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DEPARTMENT OF THE INTERIOR

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ARIZONA ECOLOGICAL SERVICES STATE OFFICE
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June 28, 1994

In Reply Refer To:
AESO/FA

MEMORANDUM

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

FROM: State Supervisor

SUBJECT: Operations of Glen Canyon Dam - Fish and Wildlife Coordination Act Report

Attached is our final Fish and Wildlife Coordination Act Report on the operations of Glen Canyon Dam.

The Fish and Wildlife Service appreciates the opportunity to provide you with this planning information. If you have any questions or if we can be of further assistance, please contact Debra Bills, Don Henry, or Don Metz.

Sam F. Spiller

Sam F. Spiller

Attachment

cc: Regional Director, Fish and Wildlife Service, Albuquerque, NM (AES)
Director, Fish and Wildlife Service, Washington D.C.
Director, Arizona Game and Fish Department, Phoenix, AZ

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

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SUBJECT: Operation of Glen Canyon Dam - Fish and Wildlife Coordination Act Report

This Executive Summary and attached Substantiating Report constitute our Fish and Wildlife Coordination Act (FWCA) report on the operation of Glen Canyon Dam. The Fish and Wildlife Service (Service) recommends that this executive summary be incorporated in its entirety into the Operation of Glen Canyon Dam Environmental Impact Statement (EIS), and the FWCA report be included in its entirety in the Appendices volume of the EIS. This report has been prepared under the authority of and in accordance with the provisions of the FWCA (48 stat. 401, as amended; 16 U.S.C. 661 et seq.) and constitutes the report of the Secretary of the Interior (Secretary) as defined in Sec. 2(b) of that Act. This report was developed in coordination with the Arizona Game and Fish Department (AGFD) and has their concurrence with stipulations as evidenced by the attached letter (Appendix 1, Substantiating Report) dated June 8, 1994. With the exception of incorporating Recommendations 3b and 8 into Recommendation 1, this report has been modified to reflect their comments.

EXECUTIVE SUMMARY

Construction of Glen Canyon Dam on the Colorado River in northern Arizona began in 1959 and was completed in 1963, prior to the enactment of the National Environmental Policy Act (NEPA). Therefore, no EIS was prepared prior to construction of the dam. During the late 1970's, the Bureau of Reclamation (Reclamation) proposed an uprating program for the generators at Glen Canyon Dam. Public concerns were expressed that daily fluctuations and unrestricted ramp rates resulting from the operations of Glen Canyon Dam were degrading the ecosystem and this proposal would increase this degradation. It became evident that environmental impacts of dam operations needed to be thoroughly analyzed. Reclamation responded by initiating the Glen Canyon Environmental Studies (GCES) Program for the purposes of conducting research for evaluation of:

"... how the present flow patterns impact upon the total riverine environment in the Grand Canyon and how various low-flow periods affect rafting and the fisheries resources in the river.... We also anticipate that you will evaluate fluctuating patterns as well as periodic high flow periods to see if there is a point where high flows materially affect beach erosion, recreation, and fisheries" [U.S. Department of the Interior (USDI), Reclamation, memorandum, December 6, 1982].

On July 27, 1989, the Secretary announced that Reclamation would prepare an EIS to reevaluate the operation of Glen Canyon Dam (USDI, Office of the Secretary 1989). The purpose of this reevaluation is to determine specific options that could be implemented to minimize, consistent with law, adverse impacts on the downstream environmental and cultural resources and Native American interests in Glen Canyon and Grand Canyon. The purpose of this reevaluation is further directed by the Grand Canyon Protection Act of 1992 to develop and assess alternatives for Secretarial review:

"...in such a manner as to protect, mitigate adverse impacts to, and improve the values for which the Grand Canyon National Park and Glen Canyon National Recreation Area were established, including, but not limited to natural and cultural resources and visitor use" (Public Law 102-575).

Interim Operating Criteria were tested from August through October 1991 and implemented by the Secretary on November 1, 1991. These criteria were for the purposes of minimizing the rate of adverse impacts on downstream resources resulting from past dam operations and to further study those impacts pending completion of the EIS and subsequent Record of Decision on the operation of Glen Canyon Dam. Preliminary observations and analyses have found Interim Operating Criteria to be beneficial for some fish and wildlife resources, primarily through enhancement of riparian, shoreline emergent marsh, and aquatic vegetation; while other fish and wildlife resource responses are yet unclear (e.g. native fish) (USDI, Reclamation 1992a, 1992b).

This report focuses on the aquatic and riparian communities associated with the Colorado River in northern Arizona from Glen Canyon Dam to Separation Canyon, river mile (RM) 239.5, a total of approximately 255 river miles. The first 15 miles from Glen Canyon Dam (RM -15) to Lees Ferry (RM 0) is within the boundaries of Glen Canyon National Recreation Area. The remainder of the area from Lees Ferry to Separation Canyon is within Grand Canyon National Park and includes the south side of the river downstream from Tuckup Canyon (at RM 164.5) to Separation Canyon. This section of the river, the southern portion just below Tuckup Canyon to Separation Canyon, is also claimed by the Hualapai Tribe as part of their Reservation.

Historic operations of Glen Canyon Dam have negatively impacted some fish and wildlife resources while enhancing others. Major floods and daily fluctuations have eroded sediment and scoured banks and sandbars. A decrease in maximum flows has allowed for the establishment of new riparian vegetation, thus enhancing terrestrial habitat. Releases of cold, clear water have facilitated the establishment of a blue-ribbon trout fishery; however, cold temperatures are detrimental to native fish populations (USDI, Reclamation 1989).

This report utilizes information on fish and wildlife resources obtained from Phase I and Phase II of the GCES Program, analysis conducted for the draft EIS, the Interim Flow Monitoring Program, and other surveys and historic accounts from Glen Canyon National Recreation Area, Grand Canyon National Park, Hualapai Reservation, and Lake Mead National Recreation Area.

There are currently nine alternatives under consideration for the operation of Glen Canyon Dam. These include six fluctuating flow alternatives and three steady flow alternatives. Detailed descriptions of operating criteria and associated impacts for each of the proposed alternatives are contained in the attached substantiating report.

The complexity of the Grand Canyon ecosystem makes it difficult to manage Glen Canyon Dam to optimize all resources present. The presence of the dam has changed the hydrology of the river, decreased the range in water temperatures, and reduced sediment load in the canyon. These changes affect the aquatic and terrestrial systems. Ecosystems are characterized by a variety of physical and biological processes under which native species have evolved. The preservation and promotion of native species wherever possible would ensure the best chances for viability. Acknowledging this, the goal of management of this project area should be to maintain, as closely as possible, pre-dam ecosystem processes under which fish and wildlife resources have evolved. The Service believes the Seasonally Adjusted Steady Flow (SASF) Alternative is the alternative that would most closely resemble pre-dam conditions and would best meet this objective. The Service believes this objective would focus on the natural resources most vulnerable to dam operations at this time, specifically endangered and native fish populations. This alternative would also benefit other fish and wildlife resources and the Lees Ferry trout fishery.

However, dam operations alone may not be sufficient to allow recovery of the endangered humpback chub due to the incompatibility of the cold water temperatures in the mainstem. The Service believes a selective withdrawal structure such as a multilevel intake structure (MLIS), in conjunction with flows which would protect and maintain backwater and nearshore habitats, has the potential for improving or correcting the current situation by facilitating the establishment of one or more additional spawning populations of humpback chub in tributaries or the mainstem. Before a MLIS is constructed, information should be collected and fisheries experts convened to conduct risk assessment evaluations to determine the potential biological responses from competitive and piscivorous exotic fishes and their interactions with native fishes. A list of potential studies is included in our recommendations.

The Service has prepared a draft Biological Opinion for the Modified Low Fluctuating Flow (MLFF) Alternative on species in the project area listed under the Endangered Species Act. The MLFF Alternative was identified as the preferred alternative in the draft EIS. The draft Biological Opinion states that the MLFF Alternative is likely to jeopardize the continued existence of the humpback chub and razorback sucker. The endangered fish research flows recommended as part of the Reasonable and Prudent Alternative (RPA) in the draft Biological Opinion are included as part of the preferred alternative in the draft EIS.

The MLFF Alternative as the preferred alternative has the concurrence of all the cooperating agencies, except the Service. The Service believes that the SASF Alternative would best represent the pattern of the pre-dam natural hydrograph, and that it may more thoroughly enhance and maintain ecosystem components. The October 1993 draft Biological Opinion does not fully represent the Service's selection of SASF as the preferred alternative. The draft Biological Opinion represents the minimal need to remove jeopardy to humpback chub and razorback sucker within the legal requirements of section 7 of the Endangered Species Act.

At this writing, the Service understands that during five low water years, steady flows would occur from April through October. These steady flows would affect the amount of water available for the fluctuating releases from November through March. A question arises as to whether releases as described under the MLFF Alternative would be realized during the period of November through March. Since different flow patterns would occur during two separate times of low water years, a new alternative has in effect been developed. Additional analysis on the preferred alternatives is warranted.

In order to assist in equal consideration for fish and wildlife resources in the process of selecting a plan for operations of Glen Canyon Dam, the Service makes the following recommendations:

RECOMMENDATIONS

1. The historical operations of Glen Canyon Dam have eliminated the features of a natural hydrograph from river operations. To provide conditions more suitable for endangered and other native fish species, a hydrological pattern comparable to the pre-dam hydrologic pattern should be evaluated.

   a. Flows should be as described in the October 1993 Draft Biological Opinion. The preferred alternative would be used as a platform from which to conduct studies of an experimental flow regime that more closely resembles the pattern of the pre-dam hydrograph. Experimental flows should occur from April through October and include high steady flows in the spring and low steady flows in the summer and fall carried out during low water years. High flows should occur during the spring run-off, peaking sometime between April and June. Low flows should follow and continue through October. Flows should include beach/habitat building and habitat maintenance flows to be released during the spring in low water years.

Experimental flows should be conducted for a sufficient period of time to allow biological processes to function and for variability inherent in riverine ecosystems to be expressed.

2. In order to maintain the integrity of the Grand Canyon ecosystem, the sediment resource should be maintained or enhanced. Associated resources that provide habitat such as backwaters, substrate, and vegetation depend upon the availability and placement of sediment.

a. During steady flow periods, daily flows should be steady with the exception of system regulation and adjustments that would allow fluctuations limited to 2,000 cubic feet per second (cfs) per day. Ramp rates for greater flow adjustments should be limited to 2,000 cfs per hour. These restrictions would minimize the rate of sediment erosion.

b. Annual controlled high flows within powerplant capacity and periodic (approximately once in ten years) controlled high flows that exceed powerplant capacity should be conducted to reform the channel and translocate sediment and nutrients. These high flows should coincide with the pre-dam, spring run-off peak. Implementation of these flows should take into consideration sediment storage and availability, channel configuration, and vulnerable species' life cycles. The frequency and magnitude of these flows should be determined after an assessment is made of resource response to trial flows.

c. Juvenile native fish may be susceptible to displacement by high volume flows. Therefore, these fish need to be considered when determining the magnitude and timing of controlled floods.

3. Construction of Glen Canyon Dam has greatly modified the aquatic environment and resulted in degraded conditions for native fish species. Every attempt should be made to ensure native fish life stage requirements are met. These requirements include a reliable food resource and availability of and access to suitable spawning and rearing habitat.

a. Extended periods of flows less than 5,000 cfs should be avoided, and releases below 8,000 cfs for fluctuating flows should be minimized to protect aquatic food resources. Studies indicate that extended periods of exposure to desiccation or freezing limit occupation of the wetted perimeter of the channel by Cladophora and its associated invertebrate community (Angradi et al. 1992, Blinn et al. 1992, AGFD 1993). Cladophora production should continue to be monitored.

b. Flows should be steady on a seasonal basis, particularly during the summer months (some variations may exist from tributary input or forecast changes), to provide warmer, stable backwaters and other low velocity sites suitable as native fish rearing habitat.

c. Information on the life stage requirements, distribution, and abundance of non-native warmwater fishes should be collated and analyzed. Native and non-native fish interactions and responses to changes in dam operations should be evaluated in both the lab and the field. If operations are found to be detrimental or offer no improvement in conditions for native fishes, operations should be reevaluated and modified if necessary.

d. 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 the *Gila* taxonomy study (Reclamation contract 1-CS-40-0970), Reclamation, in consultation with the Service, National Park Service, AGFD, and land management agencies such as the Havasupai Tribe, should 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.

4. Trout health problems in the Lees Ferry reach are significant. Infestation by nematode parasites (Bulbodacnitis ampullastoma), possibly transmitted by a copepod or amphipod intermediate host, continues to be the prime factor.

a. The life cycle of this parasite should be verified.

b. Environmental stressors such as flow regime, food reduction, water temperature, angling pressure, and stocking rate that may exacerbate parasitic infestations should be quantified.

5. A high incidence of the Asian tapeworm (Bothriocephalus acheilognathi) occurred in humpback chub in 1990 to 1992, and in speckled dace in 1991 and 1992 (AGFD 1993). This parasite was not detected before 1990 (Angradi et al. 1992, AGFD 1993). The intermediate hosts for this parasite are cyclopoid copepods.

a. Effects of this exotic parasite on humpback chub and other native fishes should be assessed.

b. Effects related to flow regime, food availability, water temperature, and density-dependent factors should be quantified.

6. Special status species and their habitats should continue to be monitored, taking measures to protect species and promote their recovery as information is developed.

a. The minimum patch-size and vegetation-structure requirements of nesting Southwestern willow flycatchers should be determined. The rates of cowbird parasitism on Southwestern willow flycatchers as a function of patch-size should also be determined. Population numbers and associated habitats should continue to be monitored.

b. Wintering and migrating bald eagle habitat utilization and foraging patterns should continue to be monitored.

c. The northern leopard frog should be considered during the experimental high flows or floods which have the potential to negatively impact the frogs and/or their habitat.

7. Neotropical and other avifauna that may be potentially affected by operations of Glen Canyon Dam should continue to be monitored in association with shoreline emergent marsh and other riparian vegetation they utilize.

8. Reclamation should continue to evaluate alternatives characteristic of the BIO/WEST proposal which include high spring flows, stable summer flows, temperature modification, and sediment augmentation.

9. The Service recommends that Reclamation pursue a risk assessment and other necessary studies to determine the feasibility of a MLIS. We believe Reclamation should seek authorization to complete a feasibility study. The completion of these studies would be necessary in order for the Service and AGFD to make a recommendation for Reclamation to pursue congressional authorization. We offer the following guidelines for inclusion in the risk assessment and feasibility studies.

a. 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 change of the mainstem.

b. Determine from the literature, experimentation, and/or consultation with the scientific community, the 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, young-of-year and juvenile growth and temperature.

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

d. Assess the effects of elevated temperature on water quality, Cladophora and associated diatoms, Gammarus, aquatic insects, and fish parasites and diseases.

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

f. Investigate the effects of reservoir withdrawal level on fine particulate organic matter to understand the relationship between withdrawal level and reservoir and downstream resources, including aquatic invertebrates and fish species.

Reclamation is in the process of evaluating comments on the draft EIS and has not determined the extent of changes that may occur in the final document. The Service reserves the option to update this FWCA report with a supplement and/or a planning aid document to address subsequent changes as necessary and appropriate.

The Service appreciates the opportunity to provide you with this planning information. If you have any questions or we can be of further assistance, please contact Debra Bills, Don Henry, or Don Metz.

Sam F. Spiller

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Attachment

cc: Regional Director, Fish and Wildlife Service, Albuquerque, NM (AES)
Director, Fish and Wildlife Service, Washington D.C.
Secretary, Department of the Interior, Washington D.C.
Director, Arizona Game and Fish Department, Phoenix, AZ
Superintendent, Grand Canyon National Park, Grand Canyon, AZ
Superintendent, Glen Canyon National Recreation Area, Page, AZ
Director, Bureau of Indian Affairs, Phoenix, AZ (Attn: A. Heuslein)
Program Manager, Glen Canyon Environmental Studies, Flagstaff, AZ
NEPA Manager, Bureau of Reclamation, Denver, CO (D-117)
Bureau of Reclamation, Denver, CO (D-5910)
Regional Environmental Officer, Department of the Interior, Environmental Affairs, San Francisco, CA
Director, Hualapai Wildlife Management, Peach Springs, AZ
Hopi Tribal Council, Flagstaff, AZ
Navajo Nation, Historic Preservation Department, Window Rock, AZ (Attn: A. Downer)
Chairman, The Paiute Indian Tribe of Utah, Cedar City, UT
Chairman, Kaibab Paiute Tribe, Pipe Spring, AZ
San Juan Southern Paiute Tribe, Tuba City, AZ (Attn: J. Lehi)
Governor, The Pueblo of Zuni, Zuni, NM
Chairman, Havasupai Indian Tribe, Supai, AZ
Environmental Protection Agency, San Francisco, CA (Attn: J. Geselbracht)
Regional Director, Western Area Power Administration, Salt Lake City, UT

References

Angradi, T.R., R.W. Clarkson, D.A. Kinsolving, D.M. Kubly, and S.A. Morgensen. 1992. Glen Canyon dam and the Colorado River: responses of the aquatic biota to dam operations. Prepared for the Bureau of Reclamation, Upper Colorado Region, Glen Canyon Environmental Studies, Flagstaff, AZ. Cooperative Agreement 9-FC-40-07940. Arizona Game and Fish Department, Phoenix, AZ. 155 pp.

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SUBSTANTIATING REPORT

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INTRODUCTION

This Fish and Wildlife Coordination Act (FWCA) report assesses effects to fish and wildlife resources which would result from alternatives under consideration by the Bureau of Reclamation (Reclamation) for the operation of Glen Canyon Dam. This report utilizes information on fish and wildlife resources obtained from Phase I and Phase II of the Glen Canyon Environmental Studies (GCES) Program, analysis conducted for the draft Environmental Impact Statement (EIS), the Interim Flow Monitoring Program, and other surveys and historic accounts from Glen Canyon National Recreation Area, Grand Canyon National Park, Hualapai Reservation along the Colorado River, and Lake Mead National Recreation Area.

This report has been prepared under authority of and in accordance with Section 2(b) of the FWCA (48 Stat., 401, as amended; 16 U.S.C 661 et seq.) and was developed in coordination with the Arizona Game and Fish Department (AGFD) and has their concurrence with stipulations as evidenced by the attached letter (Appendix 1, Substantiating Report) dated June 8, 1994. With the exception of incorporating Recommendations 3b and 8 into Recommendation 1, this report has been modified to reflect their comments. The FWCA requires that federal agencies which propose, or are authorized to, control or modify waters of any stream or other body of water to provide wildlife conservation equal consideration with other features of such projects throughout the agencies' planning and decision-making processes.

An evaluation of direct and indirect effects of Glen Canyon Dam operations is included in this report. The primary focus of this evaluation is to determine effects and provide recommendations which would conserve and protect fish and wildlife resources. While this report considers impacts of dam operation alternatives on threatened and endangered species, it does not fulfill requirements of the Endangered Species Act. A draft Biological Opinion was provided to Reclamation on October 13, 1993 (U.S. Department of the Interior [USDI], Fish and Wildlife Service [Service] 1993a).

DESCRIPTION OF THE STUDY AREA

The greater Grand Canyon area, including Marble Canyon and that portion of Glen Canyon below Glen Canyon Dam, is located in northern Arizona along the Colorado River. Grand Canyon National Park and Glen Canyon National Recreation Area constitute a nationally significant geologic area and ecosystem. These two National Park Service (NPS) units receive high public use, attracting tourists world-wide. The river is utilized by many rafters, kayakers, and other users. In 1992, Glen Canyon National Recreation Area was used by approximately 40,000 individuals on concessionaire trips (John Ritenour, NPS, pers. comm.); while Grand Canyon National Park hosted more than 22,000 recreational boat, raft and kayak users (Sue Cherry, NPS, pers. comm.). The Lees Ferry trout fishery, located in the Glen Canyon National Recreation Area, constitutes a nationally significant sport fishery. In 1992, the AGFD estimated in excess of 14,000 angler use days based on NPS and AGFD data (Charles Benedict, AGFD, pers. comm.). These uses are indicative of the high public fish and wildlife resource and associated ecosystem values in the area.

This report addresses the aquatic and riparian communities associated with the Colorado River in Arizona from Glen Canyon Dam to Separation Canyon, a total of 255 river miles (RM). The 15-mile portion from Glen Canyon Dam (RM -15) to Lees Ferry (RM 0) is within the boundaries of Glen Canyon National Recreation Area. The remainder of the river corridor, from Lees Ferry to Separation Canyon (RM 239.5), is within Grand Canyon National Park and includes the south side of the river just below Tuckup Canyon (RM 164.5) to Separation Canyon. This section of the river, the southern portion just below Tuckup Canyon to Separation Canyon, is also claimed by the Hualapai Tribe as part of their Reservation.

DESCRIPTION OF THE PROJECT

Construction of Glen Canyon Dam on the Colorado River in northern Arizona began in 1959 and was completed in 1963, prior to the enactment of the National Environmental Policy Act (NEPA). Therefore, no EIS was prepared before the construction of the dam. During the late 1970's, Reclamation proposed an uprating program for the generators at Glen Canyon Dam. Public concerns were expressed that daily fluctuations and unrestricted ramp rates resulting from the operations of Glen Canyon Dam were degrading the ecosystem and this proposal would increase this degradation. It became evident that environmental impacts of dam operations needed to be thoroughly analyzed. Reclamation responded by initiating the GCES Program for the purposes of conducting research for evaluation of:

> "... how the present flow patterns impact upon the total riverine environment in the Grand Canyon and how various low-flow periods affect rafting and the fisheries resources in the river.... We also anticipate that you will evaluate fluctuating patterns as well as periodic high flow periods to see if there is a point where high flows materially affect beach erosion, recreation, and fisheries" (USDI, Reclamation, memorandum, December 6, 1982).

Phase I of GCES began in 1983 to investigate the concerns for recreational and environmental resources along with alternatives to protect those resources. Phase II of GCES was subsequently initiated in 1989 to more fully analyze the initial questions and concerns and provide additional information.

On July 27, 1989, the Secretary of the Interior (Secretary) announced that Reclamation would prepare an Environmental Impact Statement (EIS) to reevaluate the operation of Glen Canyon Dam (USDI, Office of the Secretary 1989). The purpose of this reevaluation is to determine specific options that could be implemented to minimize, consistent with law, adverse impacts on the downstream environmental and cultural resources and Native

American interests in Glen Canyon and Grand Canyon. The purpose is further directed by the Grand Canyon Protection Act of 1992 to develop and assess alternatives for Secretarial review:

> "...in such a manner as to protect, mitigate adverse impacts to, and improve the values for which the Grand Canyon National Park and Glen Canyon National Recreation Area were established, including, but not limited to natural and cultural resources and visitor use" (Public Law 102-575).

Interim Operating Criteria were tested July 30, 1991, through October 31, 1991, and implemented by direction of the Secretary on November 1, 1991. These criteria were for the purposes of minimizing the rate of adverse impacts on downstream resources resulting from past dam operations and to further study those impacts pending completion of the EIS and subsequent Record of Decision on the operation of Glen Canyon Dam. The Interim Low Fluctuating Flow Alternative was developed to represent these operating criteria. Preliminary observations and analyses have found Interim Operating Criteria to have reduced earlier detrimental effects of fluctuating flows and to be beneficial for some fish and wildlife resources, primarily through enhancement of riparian, shoreline emergent marsh, and aquatic vegetation. Other fish and wildlife resource responses are unclear (USDI, Reclamation 1992a, 1992b).

The nine alternatives currently under consideration for Glen Canyon Dam operations can be categorized as follows:

-UNRESTRICTED FLUCTUATING FLOW ALTERNATIVES
- No Action
- Maximum Powerplant Capacity (MPC)

-RESTRICTED FLUCTUATING FLOW ALTERNATIVES
- High Fluctuating Flows (HFF)
- Moderate Fluctuating Flows (MFF)
- Modified Low Fluctuating Flows with Research Flows (MLFF)
- Interim Low Fluctuating Flows (ILFF)

-STEADY FLOW ALTERNATIVES
- Existing Monthly Volume (EMV)
- Seasonally Adjusted Steady Flows (SASF)
- Year-Round Steady Flows (YRSF)

For purposes of this analysis, the project is the development of alternative methods of operating Glen Canyon Dam. Therefore, the No Action Alternative refers to historical dam operations (1963 until June 1990 when the research flows began) and is addressed under Resources Without the Project.

The annual volume of water released under each alternative would be influenced by regional hydrology and legal requirements. Release volumes under some alternatives will be further influenced by downstream resource management requirements. In general, the types of water years are classified as: low [8.23 million acre-feet (maf), minimum discharge required to meet allocation mandates, (e.g. 1989)], moderate [wide ranged, often between 13.6 maf (e.g. 1987) and 16.0 maf], and high [19.3 maf, (e.g. 1985)]. Low water years are considered normal and likely to occur about 50 percent (%) of the time. However, recent calculations indicate that low water years may occur only 30% of the time in the next 20 years and 46% of the time in the next 50 years (USDI, Reclamation 1994). Monthly volumes would vary depending on the type of water year and the operational regime. The fluctuating flow and EMV alternatives would have greatest monthly releases during peak energy requirement periods (Table 1). In contrast, the SASF Alternative would release water based on aquatic resource requirements while the YRSF Alternative would maintain constant releases.

Table 1. Potential monthly water release patterns in millions of acre-feet (maf) from Glen Canyon Dam for fluctuating flow alternatives and the EMV Alternative during low, moderate, and high water years, and calculated average daily flow in cubic feet per second (cfs) (Adapted from the 1994 Glen Canyon Dam operations Environmental Impact Statement, Chapter 2, Reclamation files).

Month	Low		Moderate		High	
	Monthly (maf)	Daily (cfs)	Monthly (maf)	Daily (cfs)	Monthly (maf)	Daily (cfs)
October	0.55	8,940	0.60	9,760	0.90	14,640
November	0.55	9,240	0.60	10,080	0.90	15,130
December	0.95	15,450	1.00	16,260	1.00	16,260
January	1.00	16,800	1.30	21,140	1.50	25,200
February	0.80	14,410	1.10	19,820	1.40	25,225
March	0.60	9,760	0.90	14,640	1.20	19,510
April	0.55	9,240	0.80	13,445	1.50	25,210
May	0.55	8,940	0.80	13,000	1.50	24,340
June	0.55	9,240	0.80	14,630	1.50	25,210
July	1.10	17,890	1.20	19,510	1.60	26,010
August	1.10	16,260	1.30	21,140	1.70	27,640
September	0.80	13,445	0.90	15,130	1.30	21,850

Daily and hourly discharge rates are primarily a function of power generation requirements within defined fluctuation and ramp rate restrictions for each alternative. Possible river stage changes which would result from allowable daily changes in discharge rate for the fluctuating flow alternatives are listed in Table 2. Steady flow alternatives are not expected to fluctuate more than 2,000 cubic feet per day which would not be evident by the time the flows reach Lees Ferry (J. Wilson, USGS, pers. comm.). During low release periods, maintaining minimum flows would limit the amount of water that could be released the remainder of the day. If Lake Powell is full or near full, flows must remain high to avoid spills, again limiting flexibility for power releases. All alternatives include provisions for system emergencies and system regulation.

Table 2. Possible river stage changes at Glen Canyon Dam resulting from a change in discharge rate under restricted fluctuating flow alternatives. (Adapted from the 1994 Glen Canyon Dam operations Draft Environmental Impact Statement, Appendix D, page D-14 through D-14, Bureau of Reclamation files).

Fluctuating Flow Alternatives	Daily fluctuations (cubic feet per second)	Difference in stage (feet) Glen Canyon Dam	Lees Ferry
No Action	1,000 to 24,000	9.2	6.5
Maximum Powerplant	1,000 to 24,000	9.2	6.5
High Fluctuating	3,000 to 23,000	7.6	4.9
Moderate Fluctuating	5,000 to 13,200	3.5	2.3
Modified and Interim Low Fluctuating	5,000 to 10,000	2.3	1.5

Unrestricted Fluctuating Flow Alternatives

No Action

The No Action Alternative describes the operation of Glen Canyon Dam from 1963 through June 1990. From 1963 to 1980, the dam was operated under the filling criteria. These criteria ended when the dam spilled for the first time in 1980. Since 1980, the objective of this alternative was 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 fluctuations and ramp rates. Flood frequency for flows greater than 45,000 cfs are estimated to occur 1 in 40 years. Historically, daily fluctuations exceeded 12,000 cfs more than 58% of the time and 20,000 cfs 15% of the time.

Maximum Powerplant Capacity

The objective of this alternative would be to utilize full powerplant capacity. Operations under this alternative would be similar to those under the No Action Alternative with the exception of an increase in the potential maximum allowable flow to 33,200 cfs.

Restricted Fluctuating Flow and Steady Flow Alternatives

The restricted fluctuating flow and steady flow alternatives would have the following elements in common:

- *Flood Protection* limiting floods greater than 45,000 cfs to an estimated 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*) (MLIS) for the purpose of warming downstream waters for native fishes.

- *Beach/Habitat Building Flows* during low water years for the purpose of rebuilding high elevation sandbars, watering vegetation and depositing nutrients, restoring backwater channels, and providing some of the dynamics of a natural system. The required water would be taken equally from the other eleven months and put into March or April for the purposes of the analyses but could be in any month. Parameters of these flows would include:

Magnitude:	At least 10,000 cfs greater than the allowable peak discharge but not greater than 45,000 cfs (Table 3)
Duration:	Approximately 1-2 weeks
Ramp Rates:	Ascending 2,500 cfs/hour Descending 1,500 cfs/hour
Season:	Spring
Water Year:	Low water years (8.23 maf) when Lake Powell is below 19 maf and not expected to fill
Frequency:	When sufficient quantities of sediment are available but not following a strong year class of humpback chub. Maximum frequency would be 1 in 5 years.

Habitat Maintenance Flows

Habitat maintenance flows are included in three alternatives: MFF, MLFF, and the SASF Alternatives. The objectives of a habitat maintenance flow are similar to the beach/habitat building flow. However, the habitat maintenance flow will not build sand bars as high as the beach/habitat building flows. These flows would be near powerplant capacity, 30,000 cfs (Table 3), and occur every year when projected Lake Powell storage on January 1 is less than 19 maf (low reservoir condition). The flows would last for approximately 10 days and are likely to occur in March or April.

Table 3. Possible maximum flows (cfs) during standard operations in low water years for habitat maintenance flows and beach building flows.

Alternative	Standard Operations	Habitat Maintenance	Beach/Habitat Building flows
Unrestricted Fluctuations			
No Action	31,500	n/a	n/a
MPC	33,200	n/a	n/a
Restricted Fluctuations			
HFF	31,500	n/a	41,500
MFF	31,500	30,000	41,500
ILFF	20,000	n/a	30,000
MLFF	20,000	30,000	40,000
Steady Flows			
EM	16,300*	n/a	26,300
SASF	18,000	30,000	40,000
YRSF	11,400	n/a	21,400

* Maximum flows for this alternative will be prorated based on project annual releases and forecast predictions.

Restricted Fluctuating Flows

The restricted fluctuating flow alternatives would offer varying amounts of flexibility for power operations while providing a range of downstream resource protection measures. These alternatives would restrict daily fluctuations and ramp rates as compared to the unrestricted fluctuating flow alternatives.

High Fluctuating Flows

The HFF Alternative would slightly reduce historic daily flow fluctuations for the benefit of downstream resources while allowing flexibility for power operations. This alternative would vary depending on whether the firm load[1] would be less than or

[1]Firm load: electric power which Western Area Power Administration guarantees to be available at all times during the period covered by a commitment, even under adverse conditions.

greater than 500 gigawatt hours (GWh) and whether market conditions were favorable or unfavorable.[2] Descending ramp rates would be restricted to 5,000 cfs/hour under adverse market conditions or 4,000 cfs/hour under favorable market conditions. Ascending ramp rates would not be restricted. Maximum daily fluctuations of 15,000 cfs would accompany monthly water release volumes less than 0.65 maf, 20,000 cfs for monthly releases between 0.65 and 0.85 maf, 21,000 cfs for monthly releases between 0.85 and 1 maf, and 22,000 cfs for monthly release volumes greater than 1 maf. Minimum flows would vary depending on monthly release volumes, market conditions, and firm load demands but would be at least 3,000 cfs (Table 4). Maximum flows would be limited only by the daily fluctuations and the capacity of the dam and could reach 31,500 cfs. The implementation of a beach/habitat building flow with this alternative would result in a maximum flow of 41,500 cfs to 45,000 cfs.

Table 4. Minimum flows (cfs) under the High Fluctuating Flow Alternative based on favorable and unfavorable market conditions (Adapted from the 1993 draft Glen Canyon Dam operations Environmental Impact Statement, Bureau of Reclamation files).

Monthly Releases (maf)	Unfavorable		Favorable	
	Firm Load in Gigawatt hours (GWh)			
	> 500 GWh	< 500 GWh	> 500 GWh	< 500 GWh
<0.65	3,000	3,000	3,000	3,000
0.65-0.85	3,000	3,000	3,000	5,000
0.85-1.0	5,000	5,000	5,000	8,000
>1.0	8,000	8,000	8,000	8,000

Moderate Fluctuating Flows

The MFF Alternative would permit fluctuating flows below No Action levels for the benefit of downstream resources while allowing intermediate flexibility for power operations. Maximum and minimum flows would vary depending on the monthly release volume but would be no greater than 31,500 cfs in moderate and high water years and no less than 5,000 cfs. Maximum flows during a low water year would not exceed 22,300 cfs. Allowable daily fluctuations would be +/- 45% of the mean daily discharge flow, not to exceed 13,200 cfs. Ascending ramp rates would be limited to

[2]"Favorable" or "unfavorable" market conditions generally refer to price, system conditions (availability), where within the system a purchase can be made, and whether transmission capability to deliver the load is available.

4,000 cfs/hour while descending ramp rates would be limited to 2,500 cfs/hour. The implementation of a beach/habitat building flow would result in a maximum flow of 41,500 cfs to 45,000 cfs. This alternative has incorporated a habitat maintenance flow.

Interim Low Fluctuating Flows

The ILFF Alternative was originally developed to meet objectives of the interim operating criteria. This alternative would reduce flow fluctuations to well below No Action levels for the benefit of downstream resources while allowing limited flexibility for power operations. Maximum flow would not exceed 20,000 cfs, while minimum flows would be 8,000 cfs between 7:00 am and 7:00 pm and 5,000 cfs between 7:00 pm and 7:00 am. Allowable daily fluctuations would be 5,000, 6,000, or 8,000 cfs corresponding to low, medium and high monthly release volumes. Ascending ramp rates would be restricted to 2,500 cfs/hour while descending ramp rates would be restricted to 1,500 cfs/hour. The implementation of a beach/habitat building flow would result in a maximum flow of 30,000 cfs. During high water years, flows would remain steady at 20,000 cfs, the designated maximum flow. This alternative is identical to the original interim operating criteria with the exception that it would not include the financial exception criteria allowed under Interim Flows.

Modified Low Fluctuating Flows

This alternative has been selected by Reclamation as the preferred alternative for the draft EIS. This alternative was identical to the ILFF Alternative but has incorporated a habitat maintenance flow. Beach/habitat building flows would result in a maximum flow of 40,000 to 45,000 cfs.

This alternative has been further modified to include endangered fish research flows as a result of the October 1993 draft Biological Opinion issued by the Service (USDI, Fish and Wildlife Service 1993a). During 5 low water years, the dam would be operated in a flow pattern similar to the SASF Alternative to study effects of high, steady flows in the spring (April through July) combined with low, steady flows in the summer and fall (August through October). The dam would be operated as proposed under the MLFF Alternative during the winter months (November through March) and during moderate and high water years. At the end of the research period, Reclamation would implement operational flows determined by the Service to be in compliance with section 7(a)(2) of the Endangered Species Act. A possible result of endangered fish research flows would be a change of operations of the dam without ever enacting the MLFF flows in the spring, summer and autumn months during low water years.

For the purpose of this report the ILFF and the MLFF Alternatives are discussed together, with the differences described as appropriate. In general, the MLFF Alternative is expected to provide more system dynamics than the ILFF Alternative due to inclusion of the habitat maintenance flow.

With inclusion of the endangered fish research flows as an element of the Reasonable and Prudent Alternative (RPA) from the 1993 draft Biological Opinion, additional analysis of the MLFF Alternative would need to be conducted by the EIS technical writing team. The steady flows that would occur from April through October would affect the amount of water available for the fluctuating releases during November through March. A question arises as to whether or not releases as described under the MLFF Alternative would be realized during the period of November through March. Since different flow patterns would occur during two separate times of the year for a number of low water years, a new alternative has in effect been developed.

Steady Flow Alternatives

The objective of each of the 3 steady flow alternatives would be to minimize daily fluctuations and provide relatively constant flows on a monthly, seasonal, or annual basis. Under the steady flow alternatives, the monthly distribution of release volumes would differ according to the month-to-month release pattern specified for each alternative, but the daily and hourly operating criteria would be the same. Minimum and maximum flow rates would be determined by the monthly water volume to be released. Daily fluctuations and ramp rates would not exceed 2,000 cfs/day. Adjustments needed for forecast error would also be limited to 2,000 cfs/day.

Existing Monthly Volume

The EMV Alternative would eliminate the potential negative effects of daily fluctuations while maintaining the operational flexibility necessary to avoid spills and maintain conservation storage. This alternative would provide steady releases at a constant rate within months, with volumes determined from forecasts and current operating objectives. In a low water year, monthly discharge volumes would range from 0.55 maf to 1.0 maf. Daily average discharge would be approximately 9,000 cfs for a 0.55 maf month and 16,300 cfs for a 1.0 maf month. Minimum flows would typically exceed 9,000 cfs although the allowable minimum flow would be 8,000 cfs. Ramps rates would not exceed 2,000 cfs/day between months. However, maximum and minimum flows would likely be plus or minus 1,000 cfs of the mean monthly release. The implementation of a beach/habitat building flow with this alternative would result in a maximum flow of approximately 26,300 cfs.

Seasonally Adjusted Steady Flows

This alternative would enhance the aquatic ecosystem by releasing water at a steady rate within a defined season to more closely resemble the pattern of the natural pre-dam hydrograph. The pre-dam hydrograph was unimodal with a peak flow of 25,300 to 300,000 cfs occurring in June, followed by low flows during the fall and winter (USDI, Reclamation 1989). Sediment input was bimodal, peaking in late spring and again in late summer (USDI, Reclamation 1989).

This alternative would provide steady releases for one to three months, providing seasonal variation throughout the year to meet downstream resource requirements. Minimum flows during low water years would not be below 8,000 cfs and maximum flows would not exceed 18,000 cfs (Table 5). Ramp rates required for changes between seasons would be limited to 2,000 cfs/day. The implementation of a beach/habitat building flow would result in an increase of the maximum flow to 40,000 cfs. This alternative would incorporate a habitat maintenance flow.

Table 5. Potential mean monthly cubic feet per second (cfs) water releases under the Seasonally Adjusted Steady Flow Alternative for a low water years (Reclamation files).

Month	Mean Water Release (cfs)
October	8,000
November	8,000
December	8,500
January	11,000
February	11,000
March	11,000
April	12,500
May	18,000
June	18,000
July	12,500
August	9,000
September	9,000

Year-Round Steady Flows

The YRSF Alternative was developed in response to scoping comments calling for complete elimination of fluctuating flows. Under this alternative, water would be released at a steady rate throughout the year, thus eliminating daily fluctuations and minimizing peak discharges to preserve sediment within the river channel. Targeted releases would be 11,400 cfs for years with an annual release of 8.23 maf. The ability to maintain a constant rate of release for the entire year would depend on the accuracy of streamflow forecasts and level of Lake Powell. If forecast estimates were perfect, the flows would be steady every day, with the exception of modifications needed for system adjustments at a rate of 2,000 cfs per day. Annual releases greater than 8.23 maf would require monthly adjustments of the flows and depend on forecast projections. Daily and monthly adjustments would also be made at a rate of 2,000 cfs per day, except during emergencies. The implementation of a beach/habitat building flow would result in an increase of the maximum flow to approximately 24,400 cfs.

FISH, WILDLIFE, AND ASSOCIATED RESOURCES

SEDIMENT

Sediment is crucial for the continued maintenance of the Grand Canyon ecosystem. It is needed to sustain rooted aquatic, shoreline and backwater emergent marsh plant species, and associated aquatic and terrestrial food chain components. It also provides substrate for riparian vegetation which provides habitats for insects, amphibians, reptiles, birds, and mammals. Variability in discharge from operations of Glen Canyon Dam influences sediment aggradation and degradation processes and resultant sediment placement (Schmidt and Graf 1988).

Sediment placement in the river delineates backwaters important to aquatic invertebrates and native fishes. For the Grand Canyon, backwaters have been defined as a body of water that exhibits none to extremely low velocity and is surrounded on three sides by land. Two types of backwaters have been identified (L. Riley, AGFD, 1992 written comm.; D. Wegner, Reclamation, 1992 written comm.).

> Type I - backwaters associated with eddy return current channels and reattachment bars;
> Type II - shoreline cavities or pocket waters associated with bank irregularities or channel roughness.

Type I backwaters are identified as backwaters of prime concern in Grand Canyon because they have the potential to warm above the ambient temperature of the mainstem Colorado River. More backwaters appear at flows of 5,000 cfs than at flows of 15,000 or 28,000 cfs (Weiss 1993). Additional studies indicate that more backwaters exist at 5,000 cfs versus 8,000 cfs (McGuinn-Robbins 1994).

Since closure of Glen Canyon Dam, sediment loads from tributary input have averaged 11 million tons annually at Grand Canyon, RM 87.5, or about 13% of the 85 million tons measured under pre-dam conditions (1941-1957) (Andrews 1991). Above the gaged tributaries at Lees Ferry, pre-dam annual suspended loads were estimated at 65.4 million tons and post-dam loads between 1982 and 1986 were estimated at 0.4 million tons, a decrease of about 99.4% (USDI, Reclamation 1989).

Since completion of the Dam in 1963, sediment supplied to the Grand Canyon corridor has been dependent on tributaries, principally the Paria River (RM 1), the Little Colorado River (LCR) (RM 61), and Kanab Creek (RM 143). Due to the significant reduction in sediment input above the Paria River, the Lees Ferry reach (RM -15 to RM 0) has become the most highly vulnerable to the erosive influences of daily operations and flow regime.

Sediment transport within the Colorado River is mainly a function of flow regime but also dependent on particle size. The most abundant sediment size class is sand [0.05 to 2.0 millimeters (mm), U.S. Department of Agriculture (USDA) standard in Brady 1974], the basic building material of beaches and backwaters. Most channel storage is limited to this grain size because silt and clay particles (0.002 to 0.05 mm, and less than 0.002 mm, respectively, USDA standard in Brady 1974) are more readily transported downstream to Lake Mead. Silt and clay provide important nutrients. Silt provides suitable habitat for many benthic invertebrates. Clay also provides cohesion for sediment deposits.

More sediment would be transported during periods of flood flows and high fluctuations than during a constant flow period with the same discharge volume. This is due to the capacity of water to carry exponentially more sediment at higher velocities than at lower velocities. Sandbar deposition is a function of upstream sediment supply, river stage, and eddy velocity. Sandbar erosion is linked to eddy velocity, down ramp rates, local wind patterns, precipitation, and recreation use. Stevens and Ayers (1993) found that the existing riparian vegetation does not significantly contribute to stabilizing sand bar deposits. This lack of stabilizing effect may be attributable to the relative lack of ground cover or the small size of the riparian plants, which may likely be the result of fluctuating flows that result from operation of Glen Canyon Dam.

Sediment without the Project

No Action

High flow releases would likely transport more sediment from mainstem reaches above the LCR than is supplied by the Paria River, resulting in a decline in upstream riverbed sand over the short and long-term. The range for historic maximum flows greater than 20,000 cfs for this alternative was approximately 32% of the days in the fall, and 99% of the days in the spring from 1965-1985.

Daily fluctuations would continue to erode sediment resources in the Lees Ferry reach, while the sediment balance downstream from the LCR would be expected to remain in a state of dynamic equilibrium over the long-term. The probability of a net gain in riverbed sand between Lees Ferry and the LCR is 50% in 20 years and 41% in 50 years.

Peak river stages associated with daily flow fluctuations under this alternative would have the potential to maintain high elevation sandbars. However, with the expected decline in riverbed sand upstream from the LCR, many sandbars would experience net erosion.

High daily fluctuations would result in relatively large active widths of unvegetated sandbars. In a low water year, river stage fluctuations would range from about 10 to 15 feet (ft) and active sandbar widths from about 44 to 74 ft, depending on the width and contour of the channel. Seepage-based erosion would be prevalent throughout the canyon due to large daily changes in river stage and rapid decreases in stage upstream from the LCR. Seepage-based erosion would increase during prolonged low discharge releases, such as on Sundays and holidays.

Sediment with the Project

Maximum Powerplant Capacity

Impacts to sediment resources under this alternative would be essentially the same as those under the No Action Alternative but may be exacerbated depending on the frequency at which maximum flows reach 33,200 cfs. The probability of a net gain in riverbed sand between Lees Ferry and the LCR under this alternative is 49% in 20 years and 36% in 50 years.

High Fluctuating Flows

Impacts to sediment resources under this alternative would likely be similar to those described under the No Action Alternative. However, there would be differences primarily due to restrictions in the range of daily fluctuations.

Flows under this alternative are expected to be greater than 20,000 cfs 65% of the days. This relatively high frequency would likely transport more sediment from the reaches above the LCR than that supplied by the Paria River, resulting in little if any gain in riverbed sand over the long-term. Daily fluctuations would continue to erode sediment resources in the area from Glen Canyon Dam (RM -15) to the LCR (RM 61.5), while the sediment balance downstream from the LCR would be expected to remain in a state of dynamic equilibrium over the long-term. The probability of a net gain in riverbed sand would be 53% in 20 years and 45% in 50 years in the Lees Ferry to LCR reach.

Peak discharges would support high elevation sandbars. Daily fluctuations of 15,000 to 22,000 cfs would result in relatively large active widths of unvegetated sandbars. In a low water year, river stage fluctuations would range from about 10 to 15 ft, and active sandbar widths from about 44 to 70 ft, depending on the width and contour of the channel. Seepage-based erosion would occur, especially during weekends and holidays when minimum flows would be lower.

Beach/habitat building flows would be scheduled an average of 1 in 5 years under low reservoir conditions in Lake Powell. Discharges of 41,500 cfs would be designed to aggrade sandbars in major eddies to elevations 3 to 4 ft higher than the normal peak river stage.

Moderate Fluctuating Flows

Additional riverbed sand would be stored and sandbars would become more stable under this alternative than under the preceding alternatives. This would be due to significant reductions in daily fluctuations and ramp rates.

Flows under this alternative are expected to be greater than 20,000 cfs approximately 23% of the days. This relatively low frequency coupled with daily fluctuation and ramp rate reductions would likely result in a net gain in riverbed sand between Lees Ferry and the LCR in the short and long-term. Daily fluctuations would continue to erode sediment resources in the Lees Ferry reach, while net aggradation would occur downstream from the LCR. The probability of a net gain in riverbed sand would be 61% in 20 years and 70% in 50 years in the reach between Lees Ferry and the LCR.

With maximum flows reaching 22,300 cfs during a low water year, sandbar height and active sandbar width would be reduced. River stage fluctuations would range from about 6 to 10 ft throughout the year, while active sandbar widths would range from 28 to 47 ft, depending on the width and contour of the channel.

Seepage-based erosion would decline in comparison to preceding alternatives, due to a reduction in daily fluctuations and ramp rates, and because minimum flow criteria would be constant within each month. Weekend minimum flows would not be less than allowable weekday minimum flows.

Habitat maintenance flows of 30,000 cfs would provide approximately 8.3 ft of stage difference at Glen Canyon Dam versus 3.5 ft under normal operations of this alternative. Beach/habitat building flows would be scheduled an average of 1 in 5 years under low reservoir conditions for Lake Powell. Discharges between 40,000 and 45,000 cfs would be expected to aggrade sandbars in major eddies throughout the river to elevations 3 to 4 ft higher than the normal peak river stage.

Modified and Interim Low Fluctuating Flows

Additional riverbed sand would be stored and sandbars would become more stable under these alternatives than under preceding alternatives. This would be due to significant reductions in maximum flow, daily fluctuations, and ramp rates.

Excluding the period of habitat maintenance flow under the MLFF Alternative, both low fluctuating flow alternatives are expected to be greater than 20,000 cfs 19% of the time. This relatively low frequency combined with fluctuation and ramp rate reductions would likely result in a net gain in riverbed sand between Lees Ferry and the LCR in the short and long-term. Daily fluctuations would continue to erode sediment resources in the Lees Ferry reach, while net aggradation would occur downstream from the LCR. The probability of a net gain in riverbed sand between Lees Ferry and the LCR under the MLFF Alternative would be 64% in 20 years and 73% in 50 years. Under the ILFF Alternative, the probability of net gain in riverbed sand would be 69% in 20 years and 76% in 50 years.

With a maximum flow of 20,000 cfs during all water years, without the habitat maintenance flow, sandbar height and active sandbar width would be reduced. River stage fluctuations would range from about 6 to 9 ft throughout a low water year, while active sandbar widths would range from 24 to 41 ft, depending on the width and contour of the channel. Seepage-based erosion would decline due to a reduction in daily fluctuations and ramp rates. However, seepage-based erosion would still occur during weekends and holidays due to lower minimum flows.

Habitat maintenance flows with discharges of 30,000 cfs would be designed to reform sandbars in major eddies to elevations 3 to 5 ft higher than the normal peak river stage for the MLFF Alternative. Beach/habitat building flows would be expected to aggrade sandbars 0 to 1.0 ft higher under the ILFF Alternative and 3 to 4 ft higher under the MLFF Alternative.

Existing Monthly Volume

Additional riverbed sand would be stored and sandbars would become more stable under this alternative than under the fluctuating flow alternatives. This would be due to significant reductions in maximum flow, daily fluctuations, and ramp rates.

The channel would aggrade at a higher rate downstream from Lees Ferry than under the fluctuating flow alternatives. The Lees Ferry reach would still be subject to erosion but of less magnitude than the preceding alternatives. The probability of a net gain in riverbed sand in the Lees Ferry to LCR reach would be 71% in 20 years and 82% in 50 years.

With a maximum flow of 16,300 cfs during low water years, sandbar height and active sandbar width would be reduced. River stage fluctuations would occur between months and range from about 3 to 5 ft throughout the year, while active sandbar widths would range from 10 to 19 ft, depending on the width and contour of the channel. Seepage-based erosion would be virtually eliminated as a result of steady flows, occurring only during monthly transitions in flow.

Sediment dynamics under a steady flow regime would be significantly different than under a fluctuating flow regime. Sediment resources would not be subject to daily fluctuations and would be more stable but at a lower stage elevation during low water years. During high water years or beach/habitat building flows, releases would have the potential to provide some system dynamics by rebuilding high elevation sandbars and backwater return current channels and redistributing nutrients. Discharges of 26,300 cfs under the beach/habitat building flows would be designed to aggrade sandbars in major eddies to elevations 3 to 5 ft higher than the normal peak river stage.

Seasonally Adjusted Steady Flows

Additional riverbed sand would be stored and sandbars would become more persistent under this alternative than under the fluctuating flow alternatives. This stability would be due to reductions in maximum flow, daily fluctuations, and ramp rates, and the frequency at which the flow levels change.

The channel would aggrade at a higher rate between Lees Ferry and the LCR than under the fluctuating flow alternatives and the EMV Alternative. The Lees Ferry reach would still be subject to erosion but of less magnitude than the fluctuating flow alternatives. The probability of a net gain in riverbed sand in the Lees Ferry to LCR reach would increase to 71% in 20 years and 82% in 50 years. Seepage-based erosion would be virtually eliminated as a result of steady flows, occurring only during seasonal transitions in flow.

With a maximum flow of 18,000 cfs during a low water year, sandbar height and active sandbar width would be reduced. Sediment dynamics under a steady flow regime would be significantly less than those under a fluctuating flow regime. Sediment resources would not be subject to daily fluctuations characteristic of the fluctuating flow alternatives. Throughout the year, river stage fluctuations would occur between seasons and range from about 4 to 7 ft. Active sandbar widths would range from 16 to 29 ft, depending on the width and contour of the channel.

Habitat maintenance flows with discharges of 30,000 cfs would be designed to reform sandbars in major eddies to elevations higher than the normal peak river stage. The habitat maintenance flows are also designed to rebuild eroded sandbars during low water years 4 to 6 ft higher than the regular annual vertical change of 4 to 7 ft. Beach/habitat building flows of approximately 40,000 to 45,000 cfs would have the potential to provide some system dynamics by rebuilding high elevation sandbars and backwater return current channels and redistributing nutrients. Beach/habitat building flows would be designed to aggrade sandbars in major eddies to elevations 8 to 12 ft higher than would the normal maximum flow of 18,000 cfs.

Year-Round Steady Flows

Additional riverbed sand would be stored and sandbars would become more reliable under this alternative than under any of the other alternatives. This would be due to significant reductions in maximum flow, daily fluctuations and ramp rates, and the elimination of monthly or seasonal changes in flow.

The channel would aggrade at a higher rate between Lees Ferry and the LCR than under all other alternatives. The Lees Ferry reach would still be subject to erosion, but the impact would be less than under any other alternative. The probability of a net gain in riverbed sand in the Lees Ferry to LCR reach would increase to 74% in 20 years and 100% in 50 years.

With a year-round steady flow of 11,400 cfs during a low water year, sandbar height and active sandbar width would be limited by effects of wave action. Seepage-based erosion would be virtually eliminated as a result of year-round steady flows.

Impacts to sediment resources under this steady flow regime would be more stable than under any other alternative. Variation would occur between years and with fluctuations in tributary input. However, sediment resources would not be subject to daily fluctuations characteristic of the fluctuating flow alternatives.

Beach/habitat building flows would be essential to provide system dynamics by rebuilding high elevation sandbars and backwater return current channels and redistributing nutrients. Discharges of 21,400 cfs under the beach/habitat building flows would be designed to aggrade sandbars in major eddies to elevations 3 to 5 ft higher than the normal peak river stage.

WATER TEMPERATURE

Before Glen Canyon Dam was constructed, water temperatures in the mainstem Colorado River ranged from approximately near freezing in the winter to 30°C in the summer (Minckley 1991). Native aquatic fauna evolved to survive and reproduce in this seasonally varied but primarily warm aquatic environment. Many inhabitants of the Colorado River require certain temperatures for completion of their life cycles (see Appendix 3 for temperature requirements of certain fish species).

<u>Water Temperature Without the Project</u>

No Action

The formation of Lake Powell behind Glen Canyon Dam changed the temperature regime of the Colorado River throughout Glen Canyon and Grand Canyon. Lake Powell stratifies in the summer into layers of different temperature that may mix together during the winter months (Stanford and Ward 1991). This layering effect results in warm surface water, the epilimnion, while deep water, the hypolimnion, may be quite cold. Water discharged through the turbines at Glen Canyon Dam is drawn from depths as great as 230 ft below the surface of Lake Powell at full pool and is consistently cold (Maddux et al. 1987). The boundary layer or metalimnion, between the seasonally warm epilimnion and the cold hypolimnion, usually begins at 30 to 50 ft below the surface and may be as much as 50 ft thick. As a result, warmer surface waters of the lake are generally isolated from turbine intakes, except when Lake Powell is very low.

Since completion of the dam, the temperature of water from the dam has been significantly colder than pre-dam water conditions. Water discharged from the dam averages 8°C year round (Angradi et al. 1992b) and warms as it travels downstream. Mainstem water temperatures at certain locations downstream of RM 165 have been recorded as high as 16°C during No Action flows of 1991 and during the summer of 1993 under Interim Flows (AGFD files).

Tributaries to the Colorado River in the Grand Canyon reflect seasonal temperature characteristics of natural streams. Water temperatures of tributaries differ considerably from the mainstem; however, tributary inflow has only minimal influence upon the mainstem temperature (Maddux et al. 1987).

Backwaters may warm above the temperature of the mainstem during warm months of the year. However, high daily fluctuations under this alternative tend to inundate backwaters and cool the water to the same level as the mainstem. Angradi et al. (1992b) found the temperatures of backwaters at RM 60.66 and RM 60.85 on May 9, 1991, under high daily fluctuations of 3,000 cfs to 26,000 cfs to range from 9.5-11°C. A backwater at RM 201.6 on May 23, 1991, under 15,000 cfs research steady flows, ranged from 14-23°C; while the associated mainstem eddy ranged from 12-15°C. The temperature of small, stable backwaters will drop down at night to near mainstem temperature (Angradi et al. 1992b). Larger backwaters will retain some heat overnight during warm summer months. In general, backwaters are colder than the mainstem during winter months (AGFD files).

The cold temperature of the mainstem Colorado River below Glen Canyon Dam has affected downstream resources in a number of ways, including: a) native fish reproduction and recruitment has been adversely affected (Minckley 1991) (see Native Fishes section); and b) a blue ribbon trout fishery has developed in the tailwater of the dam (see Trout section).

Water Temperature With the Project

All Action Alternatives

Mainstem temperature parameters under these alternatives would not differ significantly from those described under the No Action Alternative. Mainstem temperature would remain rather constant; however, reduced volume of flow may cause some solar warming as water moves downstream. Backwater areas that become partially isolated, and other low velocity nearshore areas, may show noticeable changes in temperature within a day, particularly during summer months (Maddux et al. 1987). Temperatures in backwater areas are expected to be warmer with lower flows and reduced daily fluctuations. Availability of backwaters and differential warming for the various alternatives are addressed in the Native Fishes section.

NUTRIENTS

Nutrients Without the Project

Productivity of the Glen Canyon tailwater is largely dependent upon Lake Powell. Lake Powell traps nutrients, particularly phosphorus, one of the keys to biological productivity (Stanford and Ward 1991). The concentration and proportion of this nutrient in relationship to other nutrients is influenced by the depth of water released from Lake Powell.

Nutrients With the Project

Nutrient concentration below the dam would not change since all alternatives would continue to withdraw water from the existing penstocks. Although variations in lake levels may affect concentrations of nutrients or constituents, such as lead or salinity, the changes are likely to be similar to No Action conditions. One potential difference may occur under the YRSF and SASF Alternatives which would change the level of Lake Powell. Under the aforementioned alternatives during consecutive years of low reservoir storage and low reservoir inflow, large portions of the lake delta may be exposed. It is unknown whether these changes would result in positive changes to the aquatic system by introducing organic matter, or negative changes by resuspending metals or reducing dissolved oxygen.

Repeated daily fluctuating flows would be expected to gradually deplete detrital-associated nutrient accumulations in backwaters as compared to steady flow affects. This would be expected to reduce those aquatic food chain components dependent on natural, seasonally delivered detrital resources.

VEGETATION

Vegetation is essential to fish and wildlife resources as forage, cover and substrate, and as a source of organic matter for the aquatic ecosystem. Riparian zones in the Grand Canyon corridor are dynamic, adjusting to a range of physical and biological conditions within the constraints of the initial placement and subsequent operation of Glen Canyon Dam. Aquatic vegetation, emergent marsh species, and woody riparian plants occupy discrete bands or zones in response to changes in sediment dynamics, nutrient levels, water sources, and amount of fluctuations. Thus, changes in dam operations that would result in changes in substrate characteristics, nutrient transport, and water availability would affect vegetation composition and distribution, depending on individual species' reproductive strategies and tolerance to disturbance.

AQUATIC VEGETATION

Cladophora glomerata, a filamentous green alga, is important as a substrate medium for diatoms and a refuge for invertebrates such as chironomid larvae and the non-native amphipod, Gammarus lacustris. This community comprises the basis of the aquatic food chain. Drift, that originates from the production of Cladophora in the Lees Ferry reach as coarse particulate organic matter and supports lower reaches of the river is transported downstream as fine particulate organic matter (Angradi et al. 1992b, Blinn et al. 1992). With an increase in range of discharges, there is an associated increase in drift of Gammarus (Leibfried and Blinn 1987) and coarse particulate organic matter, mainly Cladophora (Anagradi et al. 1992b).

Exposure to drying, freezing, and/or ultraviolet light can cause decreases in Cladophora biomass (Usher et al. 1988, Usher and Blinn 1990). Cladophora is susceptible to influences from dam operations, especially fluctuating flows in combination with prolonged exposure periods. Prolonged exposure of 6 to 8 hours along littoral areas limits the potential of this aquatic zone to support Cladophora (AGFD 1993); others have concluded that loss occurs after 8 to 12 hours (Blinn et al. 1992). Abundance is presumed to decrease with increasing stage of fluctuating discharge because of the higher probability of exposure for more than eight hours. Complete recolonization of periphyton biomass requires between 100 and 300 days (Angradi et al. 1992a).

Aquatic Vegetation Without the Project

No Action

The clear water released from Glen Canyon Dam allows light penetration deep into the water column and results in proliferation of Cladophora (Pinney 1991). This alga capitalizes upon available nutrients released through the dam. Cladophora is the dominant alga in the Lees Ferry reach where it is widely distributed (Angradi et al. 1992b).

Downstream from the confluence of the Paria and Colorado rivers, Cladophora prominence declines and becomes restricted to patches in riffle and boulder habitats, while the presence of the blue-green alga, Oscillatoria, increases (Blinn et al. 1992). Of the 94 species of diatoms identified in association with Cladophora, four are co-dominant in the Lees Ferry Reach and represent 79% to 95% of the diatom biomass (Pinney 1991). These four species decline downstream where they represent less than 35% of the diatom community (Usher et al. 1988).

Aquatic Vegetation With the Project

All Action Alternatives

Alternatives that would provide an increased reliable minimum flow would produce an increased reliable wetted perimeter, resulting in a corresponding, though not proportional, increase in aquatic vegetation (Table 6). Steady flow alternatives may provide the greatest potential for an increase in Cladophora but may result in a decrease in drift of food items (See Fishes section for further discussions on drift).

Table 6. Reliable minimum flow, river stage change, and corresponding wetted perimeter for each alternative under consideration. (The No Action Alternative is used as the baseline with all other alternatives expressed as a change from No Action.) (Adapted from the 1994 draft Glen Canyon Dam operations Environmental Impact Statement, Reclamation files).

Alternative[a]	Reliable minimum flow (cfs)	Near Glen Canyon Dam		Shallow, narrow riffle in Glen Canyon		Near Lees Ferry	
		[<----------(change from No Action)----------->]					
		River Stage (ft)	Wetted Perimeter (ft)	River Stage (ft)	Wetted Perimeter (ft)	River Stage (ft)	Wetted Perimeter (ft)
No Action	1,000	3128.9	580.3	3123.9	141.4	3110.9	380.4
		[<---------------baseline data----------------->]					
MPC	1,000	[<-----------no change from No Action--------->]					
HFF	3,000	+2.0	+8.2	+2.7	+99	+1.5	+8.7
MFF	5,000	+3.5	+14.1	+4.2	+153.4	+2.4	+14.1
LFF[b]	5,000	+3.5	+14.1	+4.2	+153.4	+2.4	+14.1
	8,000	+5.3	+20.5	+5.9	+193.5	+3.4	+20.2
EMV	9,000	+5.8	+22.2	+6.5	+203.6	+3.7	+21.8
SASF	8,000	+5.3	+20.5	+5.9	+193.5	+3.4	+20.2
YRSF	11,400	+6.9	+25.9	+7.6	+287.2	+4.3	+25.4

[a] MPC = Maximum Powerplant Capacity Alternative; HFF = High Fluctuating Flow Alternative; MFF = Moderate Fluctuating Flow Alternative; LFF = Interim Low Fluctuating and Modified Low Fluctuating Flow Alternatives; EMV = Existing Monthly Volume Alternative; SASF = Seasonal Adjusted Steady Flow Alternative; YRSF = Year-Round Steady Flow Alternative

[b] The LFF minimum reliable flow is 5,000 cfs from 7:00 pm until 7:00 am and 8,000 cfs from 7:00 am until 7:00 pm for both the Modified and the Interim Low Fluctuating Flow Alternatives. Although Cladophora would not realize the full benefit of a permanent 8,000 cfs minimum flow, the twelve hour period of 8,000 cfs minimum flow would allow for some proliferation of Cladophora above the 5,000 cfs stage.

EMERGENT MARSH VEGETATION

Emergent marsh in the Grand Canyon corridor provides forage and habitat for some wildlife species and recycles nutrients. Few areas of emergent marsh existed within the river corridor prior to closure of Glen Canyon Dam. However, reduced flood frequency since completion of the dam has allowed fluvial marshes to develop along low velocity channel margins (Stevens et al. 1993). The majority of the following analysis assumes low water years, which are expected to occur approximately 50% of the time. High water years or prolonged flooding are likely to result in the loss of marsh vegetation and associated habitats.

The type of emergent marsh vegetation present is dependent on the frequency and duration of inundation and substrate. Beaches and shoreline deposits containing clay/silt sediments are necessary for development of emergent marsh vegetation. Low velocity sites, such as return-current channels protected by high bar platforms in recirculation zones, permit clay/silt particles to settle from suspension. These deposits provide high quality substrate for seed germination as new marsh sites develop. These fine sediments have a greater ability to retain nutrients and hold water than coarser sediments. Wet marsh vegetation (e.g. cattails) requires deposits with clay:silt:sand ratios of approximately 1:4:4 while dry marsh plants (e.g. reed/horsetail) tolerate drier, sandier sites (Stevens and Ayers 1993).

During the post-dam period, two types of emergent marsh vegetation have developed: dry and wet marsh. Dry marsh species include emergent horsetail (Equisetum sp.), giant reed (Phragmites australis), and various grass and herbaceous species. Wet marsh species include sedges (Carex spp.), bulrushes (Scirpus spp.), rushes (Juncus spp.), cattails (Typha spp.), and emergent herbaceous vegetation. Coyote willow (Salix exigua), arrowweed (Tessaria sericea), seep-willow (Baccharis sp.), and tamarisk (Tamarix chinensis) are often associated with both types of marsh habitat (Stevens and Ayers 1991).

Emergent Marsh Vegetation Without the Project

No Action

Emergent marsh vegetation colonization is limited to further expansion because daily flow fluctuations limit the opportunity for extended duration of low velocity sites. Emergent marsh vegetation occurs along wide, shallow reaches, at riverside seeps and tributary mouths, in backwater areas, and in isolated sites within the fluctuating zone located between 10,000 and 31,500 cfs. In general, marsh vegetation occurs below the 23,000 cfs level. The existing marshes would also be low in productivity because of the removal of organic debris by high fluctuations (Stevens and Ayers 1993).

Woody vegetation would continue to expand into clay/silt sites occupied by emergent marsh vegetation. As woody plants mature, shading from their canopies would eliminate the understory of emergent marsh plants. Thus, under the No Action Alternative and until a major uncontrolled flood event occurs, marsh vegetation could decline as a result of woody vegetation expansion. Further marsh vegetation establishment along the immediate river edge would not occur due to daily fluctuating flows.

Emergent Marsh Vegetation Without the Project

Maximum Powerplant Capacity

Due to similar operating criteria, emergent marsh under this alternative would be similar to emergent marsh under the No Action Alternative. The maximum flow to 33,200 cfs would limit the invasion of woody plants and could allow for the expansion of marsh vegetation. An overall change is not likely to be noticed because the vegetation on unstable sites is likely to be lost.

Remaining Action Alternatives

The remaining alternatives would contain provisions for flood protection and beach/habitat building flows. Controlled high flows designed to provide system dynamics would maintain emergent marsh vegetation in the backwater marshes by disrupting woody plant succession, reforming backwater channels, and watering plants. Differences are discussed according to the individual action alternative.

High Fluctuating Flows

Periodic inundation in patterns similar to the No Action Alternative would permit continued maintenance of emergent marsh vegetation at currently occupied backwater sites. Because of the restricted daily fluctuations and decrease in flood frequency, some improvement over the No Action Alternative may be expected. However, the erosive action resulting from daily fluctuating flows associated with this alternative would continue to restrict marsh vegetation establishment along the immediate river edge.

Moderate Fluctuating Flows

Although the maximum allowable flow under this alternative would be 31,500 cfs, 50% of the years would be low water years and the maximum flow would not be expected to exceed 22,300 cfs. Depending on the magnitude and duration of high water years, marsh vegetation could be moderately impacted or result in significant losses. Analysis of changes in the emergent marsh vegetation under this alternative is based on the reduced maximum flow of 22,300 cfs.

A maximum flow of 22,300 cfs would allow for a shift of emergent marsh into suitable backwater sites as a result of this lower maximum stage. A decrease in daily fluctuations and ramp rates would create a less hostile environment for marsh establishment than the preceding alternatives. However, daily fluctuations would continue to limit productivity by removing organic debris and restrict river border marsh vegetation establishment. Emergent dry marsh plants would expand in response to dryer conditions.

Beach/habitat building flows and periodic high water years may water historic marsh sites above the 22,300 cfs stage. However, depending on the magnitude and duration of the beach/habitat building flows, emergent marsh plants below the 22,300 cfs stage may be buried or scoured.

Modified and Interim Low Fluctuating Flows

The decrease in maximum flow to 20,000 cfs during low water years has allowed for the expansion of dry emergent marsh into additional suitable sites created by this lower maximum stage. A substantial decrease in daily fluctuations and ramp rates and the associated stabilization of sediment deposits has encouraged the establishment of new wet emergent marsh vegetation along the river edge. The habitat maintenance flow under the MLFF Alternative and the beach/habitat building flows under both low fluctuating flow alternatives may maintain historic marsh sites above the 20,000 cfs stage and return-current channels below 20,000 cfs stage important for marsh plants. In the low water years without a habitat maintenance flow or beach building flow, there would possibly be a loss in marsh vegetation because of encroachment of woody vegetation.

Existing Monthly Volume

In low water years, emergent wet marsh vegetation would decline above the 16,300 cfs stage due to desiccation. Patches below this level would experience extended periods of inundation. Minimal fluctuations of 2,000 cfs/day and the associated stabilization of sediment may encourage the establishment of new emergent marsh vegetation along the river's edge. Dry marsh vegetation would expand into suitable upper sites that no longer support wet marsh plants. Beach/habitat building flows may provide temporary increases in growth to the few marsh sites up to the 26,300 cfs stage that were not invaded by woody vegetation. Marsh sites below the 26,300 cfs mark that are not eliminated by flood flows will likely be maintained.

Seasonally Adjusted Steady Flows

Emergent marsh vegetation under this alternative may be limited by extended inundation or desiccation. Inundation would occur for plants below 18,000 cfs in May and June, the critical growth period, while drying would occur in August through December for those plants above 9,000 cfs. Steady flows would likely concentrate marshes at low-lying stages. During high water years, this vegetation may be more susceptible to scour. However, the large changes in river stage of approximately 5,500 cfs that would occur between April/May and June/July, could uproot or desiccate young plants along the river edge. Emergent dry marsh vegetation would expand into suitable sites that no longer support wet marsh plants. Emergent wet marsh vegetation along the river edge would be expected to become better established due to erosional reduction associated with fluctuating flows.

Habitat maintenance flows are designed to remove woody vegetation from marsh areas and redistribute sediment and nutrients. Marsh sites below 18,000 cfs flows that are not eliminated by flood flows would likely be maintained and revitalized if the flows are early enough in the growing season. Beach/habitat building flows of 40,000 cfs may provide temporary increases in growth to the few marsh sites above the 18,000 cfs stage. Depending on the timing and duration of the flood, marsh vegetation may be maintained or lost through inundation and erosion as during high water years.

Year-Round Steady Flows

Existing emergent wet marsh vegetation under this alternative would either be inundated below the 11,400 cfs stage or desiccated above the 11,400 cfs stage. Fluctuations due to tributary input may result in increases in flows. However, steady flows with minimal or no daily erosive fluctuations would encourage establishment of wet marsh vegetation near the water's edge where fine sediment is available. Moderate and high water years could result in de-stabilization of this zone. Emergent dry marsh vegetation would recolonize into suitable sites that no longer support wet marsh plants. Beach/habitat building flows would provide temporary increases in growth to the few marsh sites above the 11,400 cfs stage during low water years. Marsh sites below the 11,400 cfs mark that are not eliminated by flood flows would likely be revitalized.

RIPARIAN VEGETATION

The riparian zone exists at the interface between the aquatic and upland communities of the river. Biological and structural diversities make riparian zones the most important wildlife habitat in the region. Riparian vegetation provides forage and cover for migrant and resident terrestrial fauna. Maintenance of aquatic and terrestrial insects, a critical food chain component, is an especially important ecosystem function of riparian habitats.

RIPARIAN VEGETATION - OLD HIGH WATER ZONE (OHWZ)

Prior to construction of Glen Canyon Dam, spring flooding annually scoured and removed most vegetation below the 120,000 to 125,000 cfs level. Vegetation found within the OHWZ was historically influenced by the high water line at the pre-dam 120,000 cfs flood stage (Brian 1987) and prevailing climatic conditions.

<u>OHWZ Without the Project</u>

No Action

Current dam operations affect plants in the OHWZ by reducing the frequency and magnitude of flood events. Without periodic inundation, plant germination in the OHWZ is limited and growth of established plants is inhibited (Anderson and Ruffner 1987). The

OHWZ is dominated by netleaf hackberry (Celtis reticulata), Apache plume (Fallugia paradoxa) and redbud (Cercis occidentalis), in the upper reaches of Glen and Marble Canyons. Honey mesquite (Prosopis glandulosa) and catclaw acacia (Acacia greggii) are most common in the lower reaches of the Grand Canyon. Mesquite appears to be less drought resistant than acacia, and acacia may become the dominant tree in the OHWZ (Anderson and Ruffner 1987). In time, xeric upland plants will move into sites that can no longer support traditional OHWZ vegetation. Although a major uncontrolled flood is only expected to occur once in 40 years, traditional OHWZ vegetation may experience periodic growth but not recruitment, and is expected to decline in the long-term.

OHWZ With the Project

Maximum Powerplant Capacity

Due to the lack of additional flood control measures, OHWZ vegetation under this alternative would be similar to that under the No Action Alternative.

Other Action Alternatives

All of the remaining alternatives would contain provisions for flood protection which would reduce the frequency of major uncontrolled floods to 1 in 100 years. Major flood events that historically maintained the OHWZ before completion of Glen Canyon Dam are expected to continue to be so rare in the future that the OHWZ would cease to exist as a discrete, separate zone of vegetation under these alternatives. Xeric upland plants would continue to move into the OHWZ as traditional plant species decline. Overall results are expected to be the same as under the No Action Alternative.

RIPARIAN VEGETATION - NEW HIGH WATER ZONE (NHWZ)

NHWZ Without the Project

No Action

The NHWZ exists in the pre-dam scour zone (Turner and Karpiscak 1980) between the discharge stages of approximately 25,000 and 40,000 cfs (Stevens and Ayers 1991). Following completion of Glen Canyon Dam, riparian vegetation at selected sites increased at the rate of 1/2 acre per river mile per year between 1965 and 1973. Between 1973 and 1980, the rate of increase slowed to 1/4 acre per mile per year (Pucherelli 1986).

Some common woody plants in the NHWZ include both native and non-native species: seep-willow, desert broom (Baccharis sarathroides), arrowweed, coyote willow, and tamarisk (Turner and Karpiscak 1980, Carothers and Brown 1991, Pucherelli 1986). Tamarisk, a common exotic phreatophyte, has become the dominant woody plant in the NHWZ. Its phenomenal productivity and ability to tolerate prolonged inundation and desiccation characteristic of erratic discharge patterns makes tamarisk well adapted to dam operations under the No Action Alternative. Also, in recent years, two additional exotics have invaded the riparian zone of Grand Canyon: a large Eurasian bunchgrass, Ravenna grass (Saccarum ravennae), and a clonal perennial herb (Lepidium latifolium) (Stevens and Ayers 1993). Both species are rapidly colonizing the NHWZ and may require control attention.

Plant succession in the NHWZ is influenced by the maximum and minimum flows and unrestricted daily fluctuations. Some invasion of honey mesquite and catclaw acacia into the new high water zone (NHWZ) from the OHWZ is occurring (Carothers and Brown 1991). Fluctuating discharges wet a large surface area that encourages seed germination. However, recurring changes in river stage uproot seedlings before they become established, particularly on sandy substrates. Most colonization of sandy substrates has occurred from coyote willow and arrowweed rhizomes from adjacent stands.

Because no additional flood control measures are anticipated, at least one major uncontrolled flood event is expected to occur in 40 years. This flood event could occur at any time, resulting in impacts to vegetation similar to those reported by Stevens and Waring (1986) following the flood flows of 1983 which resulted in significant losses of vegetation. Future vegetation response to a major uncontrolled flood would depend on the timing, intensity, and duration of the flood and the existing vegetation and substrate condition. Recovery of riparian vegetation lost during the 1983 flood is currently estimated at 75% of 1982 levels (Stevens and Waring 1986, Stevens and Ayers 1993).

NHWZ With the Project

Analyses of change in area coverage of woody plants in the NHWZ resulting from alternative operations utilize analyses of unstable sandbars or active width of sandbars. The active sandbar width is in the hydrologically active zone. The active sandbar width is subject to regular wetting, drying, deposition and erosion and is, therefore, not conducive to woody plant colonization due to instability. For modeling purposes, vegetation change under No Action is assumed to be zero and the change under the other alternatives is calculated as a percentage change away from the No Action Alternative conditions based on active sandbar width during low water years. Percent changes are useful for relative comparisons among alternatives. Not all areas available may be suitable for plant growth.

Maximum Powerplant Capacity

Higher maximum flows under this alternative compared to the No Action Alternative would result in a potential decline of 0-9% in the area coverage for NHWZ vegetation. A major uncontrolled flood is expected to occur once in 40 years with impacts similar to the No Action Alternative.

Remaining Action Alternatives

Because of flood control measures, plant species composition in the NHWZ would be somewhat different than under the No Action Alternative. Tamarisk would be concentrated near the maximum discharge stage, with honey mesquite and other native species occupying the higher NHWZ elevations. Coyote willow and arrowweed would occupy sandy sites and expand to lower elevation sites as the river stage decreases.

In the absence of beach/habitat building flows, only the HFF and MFF Alternatives would water the historic NHWZ vegetation during low water years. High flows under the other alternatives would not reach current NHWZ vegetation levels of 25,000 to 40,000 cfs. Under these conditions, more xeric species would replace NHWZ vegetation at higher stage levels while the NHWZ would move toward the edge of the river in response to lower maximum flows. Beach/habitat building flows would water vegetation in the upper areas. With beach/habitat building flows to 45,000 cfs, sufficient moisture and nutrients should be supplied to maintain riparian vegetation in the NHWZ and support its expansion into suitable sites made available by reduced flows. The addition of beach habitat/building flows may also affect species composition.

High Fluctuating Flows

NHWZ vegetation under this alternative would be similar to the No Action Alternative because of their identical 31,500 cfs maximum discharge and high daily fluctuations. Analysis of unstable sandbars suggests no change in the area available for woody vegetation expansion.

Moderate Fluctuating Flows

A decrease in maximum flow to 22,300 cfs during low water years would allow for an increase in the area available for NHWZ vegetation expansion. Decreased daily fluctuations and ramp rates would benefit plants trying to establish and thrive in this zone. Analysis of unstable sandbars predicts a potential 23-40% increase in area available for NHWZ vegetation expansion. The habitat maintenance flows are designed to provide an additional level of disturbance to areas that are filling in with sediment or woody vegetation, and may provide an added opportunity for tamarisk invasion in the lower, wetter zones unless the timing of flow is carefully planned.

Modified and Interim Low Fluctuating Flows

A decrease in maximum flow to 20,000 cfs would allow for an increase in the area available for NHWZ vegetation expansion. Decreased daily fluctuations and ramp rates would benefit plants trying to establish and thrive in this zone. Analysis of unstable sandbar predicts a potential 30-47% increase in area available for NHWZ vegetation expansion. The habitat maintenance flows are designed to provide an additional level of disturbance to areas that are filling in with sediment or woody vegetation, and may provide an added opportunity for tamarisk invasion in the lower, wetter zones unless the timing of flow is carefully planned.

Steady Flow Alternatives

During low water years, vegetation would be concentrated around the river's edge. Decreased daily fluctuations and ramp rates would further benefit plants trying to establish and thrive in this zone due to the further reduction in fluctuating flows. During moderate and high water years, the discharge patterns identified for steady flow alternatives could not be maintained and the low-lying vegetation would likely be scoured.

Existing Monthly Volume

A decrease in maximum flow to 16,300 cfs would allow for an increase in the area available for NHWZ vegetation expansion. Analysis of unstable sandbar predicts a potential 45-65% increase in area available for NHWZ vegetation expansion. Steady flows would encourage plant establishment in this zone.

Seasonally Adjusted Steady Flows

A decrease in maximum flow to 18,000 cfs would allow for an increase in the area available for NHWZ vegetation expansion. Analysis of unstable sandbar predicts a potential 38-58% increase in area available for NHWZ vegetation expansion. Steady flows would encourage plant establishment in this zone. The habitat maintenance flows are designed to provide an additional level of disturbance to areas that are filling in with sediment or woody vegetation, and may provide an added opportunity for tamarisk invasion in the lower, wetter zones unless the timing of flow is carefully planned.

Year-Round Steady Flows

A decrease in maximum flow to 11,400 cfs would allow for an increase in the area available for NHWZ vegetation expansion. Analysis of unstable sandbar predicts a potential 63-94% increase in area available for NHWZ vegetation expansion. Steady flows would encourage plant establishment in this zone.

INVERTEBRATES

This section focuses on invertebrate species directly and/or indirectly affected by the operations of Glen Canyon Dam. Included are those species dependent on riparian or marsh vegetation and species which constitute part of the aquatic food resource.

Production and maintenance of a diverse invertebrate community is a necessary component of fish and wildlife resources. Several thousand species of insects, representing 260 families, have been identified within the river corridor (Stevens and Waring 1986). Various species of invertebrates including snails, oligochaetes (earthworms), and insects contribute to the biological diversity of the ecosystem. Some terrestrial invertebrates and/or their aquatic larvae serve as major food sources for aquatic and terrestrial wildlife. Invertebrates also serve as plant decomposers and pollinators.

While aquatic species diversity is depauperate in the mainstem compared to the Grand Canyon tributaries, individuals of species present in the mainstem have increased since construction of Glen Canyon Dam (Blinn et al. 1992). This increase can be attributed to invertebrate habitat expansion and diversification resulting from an increase in riverside vegetation, along with increased aquatic vegetation, providing new food resources. There also appears to be a difference in invertebrate productivity between native and non-native plant species, with native vegetation supporting greater species diversity than non-native plants.

In general, Lees Ferry lacks the assemblage of mayflies, stoneflies, etc. common in cold, clear reaches (Blinn et al. 1992). Some possible reasons may be fluctuating flows from Glen Canyon Dam and the lack of seasonal variation in water temperature and coarse particulate organic material required for case-building caddisfly populations. The invertebrate community is still colonizing the new riparian habitats and additional species of insects are certain to become established.

Species composition, abundance, and distribution can be influenced by flow regime. Changes in the post-dam shoreline created by fluctuating flows has had a direct effect on the terrestrial invertebrate community. This analysis will focus on general groupings identified by substrate.

Aquatic/Aerial Forms

The mainstem river supports a relatively low diversity of aquatic invertebrates, but these few species are numerous and produce a high biomass. In contrast, tributaries and springs support high species diversity with each supporting a different assemblage of species. An initial survey for the phylum Annelida (earthworms, leeches, etc.) was recently conducted in Grand Canyon. Twelve species in five families were identified (Blinn et al. 1992). In general, aquatic oligochaetes feed on filamentous algae, diatoms, or miscellaneous plant and animal detritus (Pennak 1978). Midges (Chironomidae), buffalo gnats (Simuliidae), and amphipods (Gammarus) dominate the mainstem river (Leibfried and Blinn 1987, Blinn et al. 1992, Carothers and Brown 1991), with the greatest biomass occurring around Lees Ferry (Blinn et al. 1992).

Species that develop in the river and emerge as adults are often important in terrestrial food chains. For example, buffalo gnats are associated with cobble and boulders in fast flowing water and are important food resources for trout and native fishes (Blinn et al. 1992). These emerging flies are also an important food source for foraging species, especially harvester ants, in the fluctuating zone (Carothers and Brown 1991).

Adult midges comprise a significant proportion of food resources available to predacious insects, amphibians, reptiles, and birds (Stevens and Waring 1986). Following emergence, midges typically alight on Salix spp. and appear to use Tamarix less frequently. Adult chironomid populations were lowest during years of high flood discharges and high fluctuations. Leibfried and Blinn (1987) noted dramatic reductions in benthic macroinvertebrates in the fluctuating zone along river margins.

Ground-Dwelling Forms

Another group of insects important in terrestrial food chains are species that live just below, or on, the surface of the ground. The most familiar of these species is the harvester ant (Pogonomyrmex californicus). Before construction of Glen Canyon Dam, annual flooding removed colonizing harvester ants from the scour zone. Populations rose to 2.4 nests/100 square yards (yds^2) after closure of Glen Canyon Dam but were reduced to pre-dam levels by the floods of 1983-1984. Current population levels have stabilized at about 0.35 nests/100 yds^2 (Carothers and Brown 1991). Harvester ants feed on vegetation, other insects, human food debris, and black flies. They are in turn fed upon by predacious insects, herpetofauna, and birds.

Invertebrates Without the Project

No Action

Most terrestrial insects use vegetation and several forms exhibit important relationships with particular riparian species. While tamarisk is the most abundant woody plant along the Colorado River in the Grand Canyon, it supports a low diversity of insects. These include leafhoppers, armored scales, lady bugs, and Apache cicadas (Carothers and Brown 1991). In contrast, coyote willow which is second only to tamarisk in abundance, supports a greater diversity of insect species. Even with the apparent differences in species diversity, tamarisk produces a much greater amount of insect biomass due primarily to large outbreaks of leafhoppers (Carothers and Brown 1991). Leafhopper outbreaks provide abundant food for native predaceous insects, amphibians, reptiles, birds, and mammals (L. Stevens, NPS, pers. comm.). Tributaries also serve as important sources of colonizing insects and are influenced by changes in vegetation and discharge regime.

Diversity in the aquatic macroinvertebrate community at Lees Ferry is quite limited. Individuals readily abandon dewatered Cladophora and move into pools (Blinn et al. 1992). Experiments conducted at Lees Ferry showed losses of macroinvertebrate biomass in Cladophora after a 12-hour period of exposure and significant reductions after a 5 day period of repeated exposure of 12 hours (Blinn et al. 1992).

Invertebrates With the Project

All Action Alternatives

Invertebrate populations would be indirectly affected by impacts of flows on riparian, emergent marsh, and aquatic habitats. Due to the complexity of species or species groups within invertebrates, various impacts may result from the different alternatives. Daily flow fluctuations are expected to continue to reduce the production of aquatic insects by disrupting their feeding behavior, reproduction, and life stage development.

Species or species groups requiring stable backwaters would be expected to be adversely affected by any fluctuating flow alternative. This would result from dewatering and the influx of cold water. Under steady flows, species living in small backwaters would experience a high water temperature during the day, higher than mainstem temperature, and a low water temperature at night, nearer ambient temperature. Larger backwaters may retain some heat at night. Within the array of fluctuating alternatives, the low fluctuating flow alternatives would be the least damaging and the MPC Alternative most damaging.

Steady flow alternatives are likely to result in an accumulation of detritus and detritivores, and may benefit the production of semi-aquatic biting flies. Also, steady flow alternatives should allow increased production of insects whose larval or immature stages depend on emergent marsh vegetation bordering the river. This would result from reduced fluctuating flows that would innundate this vegetation. Seasonal warming of water temperatures may provide cues for larval development and reproduction.

High steady flows may provide conditions favorable for proliferation of insects such as mosquitos dependent on calm pools, or blackflies feeding on drift that require continuously wetted hard surfaces to complete their life cycle. Long-term maintenance of habitats may require periodic flooding to replenish sediment and encourage vegetation recruitment and growth. Beach/habitat building and habitat maintenance flows would likely clear cobbles of Cladophora and improve buffalo gnat habitat.

FISHES

Since 1958, 31 species of fish (8 natives and 23 non-natives) have been reported within the Colorado River between Glen Canyon Dam and Diamond Creek (RM 226) (Stone and Rathbun 1968, Holden and Stalnaker 1975, Suttkus et al. 1976, Maddux et al. 1987, Haden 1992, Valdez et al. 1992) (Table 7).

The ability of fish populations to persist and thrive depends on how well their life requirements are met at each life stage. Important life requirements include availability of appropriate food and physical characteristics of the aquatic environment such as temperature, water velocity and volume, cover, and substrate. Other factors that influence

Table 7. Names and status of native and non-native fishes recorded since 1958 and found within the Colorado River between Glen Canyon Dam (RM -15) and Diamond Creek (RM 226) (Adapted from Haden 1992, Glen Canyon Environmental Studies).

NATIVE SPECIES	SCIENTIFIC NAME	CURRENT STATUS
Colorado squawfish	Ptychocheilus lucius	extirpated
razorback sucker	Xyrauchen texanus	rare
bluehead sucker	Pantosteus discobolus	common
flannelmouth sucker	Catostomus latipinnis	common
humpback chub	Gila cypha	locally common
speckled dace	Rhinichthys osculus	abundant
bonytail chub	Gila elegans	extirpated
roundtail chub	Gila robusta	extirpated
NON-NATIVE SPECIES		
cutthroat trout	Oncorhynchus clarki	rare
rainbow trout	Oncorhynchus mykiss	abundant
brown trout	Salmo trutta	locally common
brook trout	Salvelinus fontinalis	rare
coho salmon	Oncorhynchus kisutch	introduced, never established
Virgin River spinedace	Lepidomeda mollispinis	unknown
carp	Cyprinus carpio	abundant
Utah chub	Gila atraria	rare
fathead minnow	Pimephales promelas	locally common
red shiner	Cyprinella lutrensis	unknown
redside shiner	Richardsonius balteatus	unknown
golden shiner	Notemigonus crysoleucas	unknown
channel catfish	Ictalurus punctatus	locally common
black bullhead	Ameiurus melas	unknown
yellow bullhead	Ameiurus natalis	rare
striped bass	Morone saxatilis	rare
plains killifish	Fundulus kansae	locally common
walleye	Stizostedion vitreum	rare
woundfin	Plagopterus argentissimus	unknown
largemouth bass	Micropterus salmoides	rare
green sunfish	Chaenobryttus cyanellus	rare
bluegill	Lepomis macrochirus	rare
threadfin shad	Dorosoma petenense	unknown

survival are the absence or degree of predators or competitors, and diseases and parasites. Appendix 3 lists life stage habitat requirements for selected native and non-native fish species found in Glen and Grand Canyons. The construction of Glen Canyon Dam has significantly altered the ability of the aquatic ecosystem to meet the requirements of several native fish species. However, some non-native fishes, such as the rainbow trout, have found the changes favorable.

Aquatic Food Base

Cladophora and associated organisms form the basis of the food chain in the tailwater below Glen Canyon Dam. Cladophora is the dominant algal species of the periphyton assemblage. Cladophora, either dead from desiccation or scoured loose by water flow; attached diatoms; and suspended invertebrates make up much of the drift that feed fish and other aquatic organisms. Diatoms may be an important source of energy for fishes due to their high lipid content (Pinney 1991). Drift also settles to the river bottom in eddies and backwaters where it is used by organisms that feed on detritus.

Drift also contains zooplankton dominated by forms that originally came from Lake Powell (Haury 1988). Kubly (1990) found higher zooplankton productivity in backwaters than in the mainstem. These microscopic animals are important food sources for fish, particularly recently hatched larval fish (Blinn and Cole 1991, AGFD 1994). However, Clarkson (1992) found chironomids were the dominant food source for native fishes in the LCR.

Macroinvertebrates are also important members of the aquatic and terrestrial communities. An amphipod (Gammarus lacustris) and a snail (Physa sp.) were introduced below Glen Canyon Dam by the AGFD during 1967 and 1968 as a food source for the developing trout fishery (AGFD 1968). Gammarus was previously introduced into Bright Angel Creek in the 1930s by the National Park Service (Carothers and Minckley 1981). Gammarus is susceptible to drift, particularly during fluctuating flows (Leibfried and Blinn 1987). Other important species already present included aquatic worms (Oligochaetes), chironomid midges, and buffalo gnats (Carothers and Minckley 1981). Production of aquatic invertebrates is greatest in riffle areas and cobble bars. Aquatic invertebrates utilize eddies and backwaters, areas of slower currents, to feed on the accumulated detritus. Consequently, eddies and backwaters are important areas for fishes feeding on aquatic invertebrates and detritus.

Degradation of Cladophora beds from prolonged exposure results in decreased biomass and productivity (Angradi et al. 1992a, 1992b); adversely affects food resources for fishes; and leads to reduced growth, unsuccessful reproduction, and diminished health (Valdez 1992). However, disruption of Cladophora beds resulting from fluctuating flows would add to the volume of drift (Leibfried and Blinn 1987).

NATIVE FISHES

The native fishes of the Colorado River system comprise one of the world's most unusual assemblages of fishes. These warmwater fishes have adapted to the challenge of living in a highly variable environment subject to seasonal extremes of flow and water temperature and highly turbid conditions.

The construction of major dams has negatively impacted many native fish species by modifying river flows, altering water temperatures, reducing sediment loads, and blocking natural movement corridors. Since construction of Glen Canyon Dam, there has been a trend toward decreasing numbers of native fish species which are dependent on a diversity of habitat types (Minckley 1991).

Native fishes of the Colorado River through Glen and Grand Canyons addressed in this section are the speckled dace, flannelmouth sucker, and bluehead sucker. The humpback chub and razorback sucker are discussed in the Special Status Species section. The Colorado squawfish, bonytail chub, and roundtail chub are not addressed in this document because they are extirpated from the system.

Water temperature is a major factor affecting the life requirements of native warmwater fishes. The cold temperature of water released from Glen Canyon Dam varies little throughout or between years. This condition limits the ability of warmwater fishes to successfully reproduce in the mainstem (Hamman 1982, Marsh 1985, Maddux et al. 1987, Angradi et al. 1992b) and limits the likelihood for young native fishes to grow to reproductive size (Valdez 1992). With implementation of a selective withdrawal structure (such as a MLIS), temperature conditions in the mainstem would likely be improved for native fishes.

Due to the cold water temperature of the mainstem Colorado River, native fishes rely heavily on tributaries of the Grand Canyon for successful reproduction (Angradi et al. 1992b, AGFD 1994). Flows below 5,000 cfs have the potential to impede fish access to tributaries (Valdez 1992).

Backwaters and shallow nearshore areas in the mainstem and tributary mouths that have the potential to warm, particularly during the summer rearing months, are important rearing sites for native fishes (Angradi et al. 1992b, AGFD 1994). Warm backwaters become more suitable for young fish as their capacity for production of food increases and conditions for fish growth improve. Weiss (1993) determined that greater numbers of backwaters appear at flows of 5,000 cfs than at flows of 15,000 cfs and 28,000 cfs. Other work (McGuinn-Robbins 1994) showed that more backwaters appear at flows of 5,000 cfs than at 8,000 cfs. Also, an increase in the numbers of backwaters in the Grand Canyon occurs during flooding events due to importation of sediment into the system (McGuinn-Robbins 1994). Numbers of backwaters alone are not enough to determine suitability for native fish rearing habitat.

Information on the quality of backwaters is needed. There is no information available on quality of backwaters for native fish rearing but research is being conducted.

All Alternatives

Because none of the alternatives provide suitable mainstem temperatures for native fish requirements, access to tributaries and availability of backwaters are critical for native fish reproduction and recruitment. Differences in tributary access and backwater stability and warming occur among the alternatives.

Native Fishes Without the Project

No Action

Bluehead sucker, flannelmouth sucker, and speckled dace are most common in the lower reaches of the Grand Canyon (Maddux et al. 1987, Angradi et al. 1992b, AGFD 1994). Flannelmouth suckers use the lower reaches as nursery/rearing areas (backwaters, tributary mouths, and nearshore, low velocity areas), and as they grow they distribute themselves into the upper reaches of the mainstem (Maddux et al. 1987). Young-of-year flannelmouth suckers, bluehead suckers, and speckled dace use backwaters extensively (Maddux et al. 1987, AGFD 1994). Adult native fishes are also found in backwaters (Maddux et al. 1987).

All life stages of native fishes are found in tributaries (Carothers and Minckley 1981, Maddux et al. 1987, Angradi et al. 1992b). Access to tributaries is a key factor in determining the success of native fish populations. Major warm water tributaries [primarily the Paria River, LCR, and Kanab Creek, but also Shinumo (RM 109) and Diamond Creeks, and the more coolwater Bright Angel (RM 88) and Tapeats (RM 134) Creeks], meet the requirements of native fishes for spawning and recruitment (Maddux et al. 1987, Angradi et al. 1992b). Low flows of 1,000 cfs (Labor Day until Easter) or 3,000 cfs (Easter until Labor Day) under this alternative preclude access to tributaries, except perhaps the LCR, Paria River, and Bright Angel and Tapeats Creeks, especially if low river stage occurs at night when spawning fish would likely be moving.

High daily fluctuations would continue to destabilize backwaters and nearshore areas through periodic drying and flooding (Angradi et al. 1992b, Valdez 1992). Forcing larval native fishes into the mainstem may result in direct fish mortality from cold water shock, high energy expenditures from movements in high velocity currents, and exposure to predators (Maddux et al. 1987, Angradi et al. 1992b). The overall consequence of rearing in the mainstem may be a decrease in growth, less survival to sexual maturity (Angradi et al. 1992b), and lower population viability (Shaffer 1987). Speckled dace are short-lived fishes and more susceptible to the effect of lower population viability than long-lived species (Carothers and Minckley 1981, Maddux et al. 1987). However, the longer-lived fishes may also be adversely affected if unsuitable temperature conditions persist. Successive losses of year-classes may be irreversible.

The minimum flow of 1,000 cfs under this alternative limits further production of Cladophora and associated food resources as described in the AQUATIC VEGETATION section.

Native Fishes With the Project

Maximum Powerplant Capacity

Impacts are likely to be similar to those under No Action, but may be exacerbated due to the 33,200 cfs potential maximum flow.

Remaining Action Alternatives

All remaining alternatives would have the provision of beach/habitat building flows. Three alternatives, MFF, MLFF, and SASF, would include the provision of habitat maintenance flows. Consistent low water years with high sediment inflow may result in the filling of some backwaters. Greater stability in backwaters may result in establishment of vegetation in the long-term, ultimately eliminating existing backwater areas. This should be offset by periodic moderate or high water years, beach/habitat building flows, habitat maintenance flows, and to some extent fluctuating flows; which would scour and reform backwater areas.

High Fluctuating Flows

Many of the effects, as those under the No Action Alternative, would continue to occur under this alternative. Low flows below 5,000 cfs may preclude access to tributaries by flannelmouth sucker and bluehead sucker, except perhaps into the LCR, Paria River, Bright Angel Creek and Tapeats Creek.

High daily fluctuations would continue to occur. Larval and young-of-year nursery areas would be limited by this alternative, particularly during the high volume months of July, August, and September when young fish require warm, sheltered areas. Food resources would likely increase with the increase in reliable minimum flow to 3,000 cfs. This alternative is expected to result in overall effects similar to the No Action Alternative, but with slight improvement.

Moderate Fluctuating Flows

Many of the effects of this alternative would be similar but with slight improvement to those under the previous alternatives. Low flows of 5000 cfs; likely during the lower volume spring months of March, April, and May; should not preclude access to tributaries.

Nursery areas would be affected to a lesser degree due to the more constrained daily range of fluctuations, and some warming may occur. However, fluctuations would be sufficient to continue to destabilize backwaters and may force fish from preferred sites, thus affecting energy expenditures and potentially reducing growth, survival, and reproduction (Angradi et al. 1992b, Valdez 1992).

Food resources are expected to increase under this alternative due to a higher minimum flow of 5,000 cfs. Conditions for fish under this alternative are not expected to differ much from the No Action Alternative.

Modified Low and Interim Low Fluctuating Flows

Many of the effects of the MLFF and ILFF Alternatives would be similar, but of lesser magnitude to those under previous alternatives. Low flows of 5,000 cfs (7:00 pm to 7:00 am), likely during the lower volume spring months of March, April, and May, should not preclude access to tributaries.

Nursery areas would be affected to a lesser degree than under the previous alternatives due to the more constrained daily range of fluctuations and ramp rates. Some warming of these areas would occur. However, fluctuations would be sufficient to continue destabilizing smaller backwaters and force movements of fish from preferred sites (G. Doster, AGFD, pers. comm.), affecting energy expenditures and potentially reducing survival and reproduction (Angradi et al. 1992b, Valdez 1992).

Food resources would increase under these alternatives due to higher minimum flow of 5,000 cfs at night and 8,000 cfs during the day. Although the aquatic food resource would not realize the full benefit of a permanent 8,000 cfs minimum flow, the 12-hour period of 8,000 cfs minimum flow would allow for some proliferation of the food resource above the 5,000 cfs stage. The overall effect of these alternatives may be a minor increase in the native fish population from current levels.

Existing Monthly Volume

Effects of this alternative would be similar to the LFF and the YRSF Alternatives (discussed below) although mechanisms by which the effects would occur would differ. Daily fluctuations would be replaced with monthly fluctuations with constrained ramp rates. Tributary access would likely not be impeded due to the reliable minimum flows of 8,000 cfs.

Backwaters and nearshore areas would have a greater potential to warm due to stable monthly flows, particularly in the summer months, and would provide rearing habitat for juvenile native fish. The daily drying and flushing of backwaters would be eliminated. However, monthly adjustments may force movement of juvenile fish from sheltered areas and result in an increase in energy expenditures and potential exposure to predation, particularly during water years when forecast is uncertain. Valdez (1992) speculated that nursery backwaters may not appear under the higher projected June, July, August, and September flows. Flows during these months would be greater than 12,000 cfs. However, Weiss (1993) showed that backwaters did appear at flow levels of 15,000 and 28,000 cfs between 1985 and 1991, but there were very few.

Food resources would be expected to increase under this alternative due to the increased reliable minimum flows. However, under steady flows, the amount of drift may be reduced. The overall effect of this alternative may be a minor increase in native fish populations.

Seasonally Adjusted Steady Flows

Several effects of this alternative would be different than those of other alternatives. There would likely be no impediment in access to tributaries. Also, higher constant flows during April, May, and June may enhance access and spawning aggregations at tributary mouths.

Nursery areas would likely be enhanced due to elimination of daily fluctuations. Lower constant flows would stabilize backwaters during August through October and may provide the warmest, most dependable rearing areas of all alternatives during low water years, thus resulting in increased growth for young-of-year fish. Shallow, protected habitats, important for larval and juvenile life stages, and associated tributary inflows, cobble shorelines, and cobble riffles may also be enhanced (Valdez 1992).

Food resources would be expected to increase due to higher dependable minimum flows of 8,000 cfs. However, under steady flows, the amount of drift may be reduced.

This alternative, compared to the other alternatives under consideration, would more closely resemble the pattern of the natural hydrograph under which native fishes evolved. Overall effects of this alternative may provide the greatest potential for a major increase in native fish populations.

Year-Round Steady Flows

Effects of this alternative would be similar to the EMV Alternative but without monthly flow adjustments. Constrained ramp rates would be utilized only for adjustments due to changing weather patterns. This alternative would provide year-round access to tributaries.

Stable backwaters would likely warm under this alternative, particularly during the summer months. However, most backwaters currently appear at levels below the 11,400 cfs reliable minimum flow of this alternative (Weiss 1993, McGuinn-Robbins 1994). Backwaters that would appear would likely provide rearing areas for fishes.

This alternative would have the highest increase in reliable minimum flow of all alternatives, and therefore, the greatest corresponding increase in food resources. However, Cladophora and associated organisms may not be readily swept into the drift and transported downstream in the absence of fluctuations (Angradi et al. 1992b). It is uncertain if this would limit overall food production in downstream reaches. The overall effect of this alternative may be a minor increase in native fish populations.

TROUT

Various trout species occur throughout the Colorado River in Glen and Grand Canyons with rainbow trout being the most abundant species. Trout are not native to the project area and were introduced for sport purposes. Trout were first introduced into the lower Colorado River basin by the NPS and Forest Service in the 1920's (Carothers and Minckley 1981). The AGFD began stocking rainbow trout at Lees Ferry in 1964 after closure of the dam (Reger et al. 1989), a management practice that continues today. Stocking practices has changed, shifting from stocking catchable sized trout (1964-1976) to stocking fingerlings (1976-1993). The shift was prompted by the establishment of Gammarus, a reliable food source (Reger et al. 1989).

Optimum habitat for rainbow trout is characterized by clear, cold water (Raleigh et al. 1984) and silt-free, gravelly substrate (Raleigh et al. 1984, Angradi et al. 1992b). The assumed optimal temperature ranges for rainbow trout life stages are as follows: (1) embryo incubation: 7-12°C, (2) fry: 13-19°C, (3) juveniles: 11-21°C, and (4) adults: 12-18°C with lower and upper lethal limits of 0°C and 25°C, respectively (Raleigh et al. 1984).

Trout spawn in the mainstem and tributaries (Maddux et al 1987, Angradi et al. 1992b). Trout access to tributaries is a function of the mainstem and tributary flow. Mainstem flows less than 5,000 cfs may limit trout accessibility to tributaries. High mainstem flows during winter months provide access into tributaries for winter spawning trout.

Several researchers (Montgomery et al. 1986, Maddux et al. 1987, Leibfried 1988, Usher et al. 1988) have noted the importance of Cladophora as the base of the food chain for trout. Angradi et al. (1992a) tied the maintenance (growth and condition) of trout closely with conditions for Cladophora and its associated diatoms and invertebrates. Effects upon growth and condition of trout are indirect and related to the productive band of shoreline that may be occupied by Cladophora. The reliable wetted perimeter provides for the establishment of algae (see AQUATIC VEGETATION section). A net increase in the aquatic food base would likely result in a positive response in the fishery.

Trout Without the Project

No Action

Rainbow trout occur throughout the study area and make up the major part of the sport fishery in the 15-mile Lees Ferry reach below Glen Canyon Dam. Brook trout, brown trout, and cutthroat trout are also present. Brown trout appear to increase in abundance below Bright Angel Creek. Brook trout are found in the upper reaches below Glen Canyon Dam (Carothers and Minckley 1981, Maddux et al. 1987).

Natural reproduction has been noted since the late 1970's (Persons et al. 1985) and is well documented in the Lees Ferry reach (Maddux et al. 1987, Angradi et al. 1992b). Mainstem reproduction of rainbow trout is most likely to occur in the reach above the confluence with the Paria River (Angradi et al. 1992b). This area also represents the segment of the river corridor most prone to effects from fluctuating flows. Reproduction of rainbow trout and brown trout below the confluence with the Paria River occurs primarily in tributaries (Angradi et al. 1992b).

Daily fluctuations cause mortality of spawning adult fish that are stranded near their nesting sites. Spawning trout display a strong affinity and fidelity to a spawning site and may not abandon it even as the water recedes (Angradi et al. 1992b). Under the No Action Alternative, the causes of death for stranded adults include dewatering, high water temperature in stranding pools, low dissolved oxygen in stranding pools, and/or exposure to predation by birds and terrestrial animals.

While mainstem temperature and nesting gravel may be acceptable for rainbow trout spawning, daily fluctuations may limit the survival of eggs and fry. Angradi et al. (1992a) reported that fewer than 10% of the mapped redd sites from the Lees Ferry reach were unaffected by minimum flows of 3,000 cfs. At least 90% of the measured utilized spawning habitat was within the zone of potential daily fluctuation under the No Action Alternative. Actual minimum flows during peak trout spawning seasons may be as low as 1,000 cfs. Natural reproduction would be minimized under this alternative.

The contribution of naturally reproduced rainbow trout to the Lees Ferry reach during high, steady flow conditions during the mid-1980s floods was estimated to be approximately 27%. However, the contribution of naturally reproduced fish to the Lees Ferry fishery under No Action under low water years is probably less (Maddux et al. 1987). Direct mortality of eggs (Maddux et al. 1987), larval fish, and fry (Persons et al. 1985) was caused by exposure of redds, stranding of young fish, and/or forcing young fish into less acceptable rearing habitats. This mortality prevents successfully spawned young from surviving to a size large enough to be less vulnerable to changing flow conditions. Population size is maintained only through stocking and regulation.

Trout are opportunistic feeders and often display distinct trophic shifts in foods consumed based on their size. In Glen and Grand Canyons, trout fry appear to be dependent upon zooplankton in the mainstem (Haury 1986, Maddux et al. 1987). Adults primarily utilize chironomids, Cladophora, Gammarus, and snails (Angradi et al. 1992b). Leibfried (1993) found the dominant food items in adult rainbow trout to be Cladophora, Gammarus, simuliids, and chironomids. These food items were also dominant in drift samples. Angradi et al. (1992b) found that adult rainbow trout primarily utilize chironomids, Cladophora, Gammarus, and snails. In one study, fish remains appeared in approximately 1% of stomach samples (Maddux et al. 1987). Leibfried (1993) found that 6 out of 23 brown trout had fish remains in their stomachs. No fish were found in rainbow trout stomachs. However, following exceptional production of humpback chub in the LCR in spring 1993, an examination of rainbow trout stomachs collected near the LCR's confluence with the mainstem found very small bones of humpback chub (Paul Marsh, Arizona State University, pers. comm.).

Montgomery et al. (1986) and Leibfried (1988) proposed that because of the high lipid content of diatoms encrusting Cladophora, consumption of the algae provided a ready energy source for trout and may be partially responsible for the growth of trout in the tailwater area. The availability and contribution of Cladophora in the diet of adult rainbow trout generally declines downstream (Maddux et al. 1987).

Trout With the Project

Because the temperature of releases would be essentially the same for all alternatives, and in an acceptable range for rainbow trout spawning, no temperature limitation for trout spawning is assumed for any alternative. With further study of a MLIS and possible implementation of such a structure, temperature conditions may be improved for trout.

A pattern of spawning locations of trout occurs in the study area. In general, above the LCR, trout spawn in the mainstem and tributaries. Below the LCR, trout rely on tributaries for spawning. This pattern of reproduction in the mainstem and tributaries is expected to occur under all alternatives.

Maximum Fluctuating Flows

Impacts for this alternative would likely to be similar to those under the No Action Alternative but may be exacerbated by the potential increase in maximum flows to 33,200 cfs.

High Fluctuating Flows

Many of the effects of the No Action Alternative would apply to this alternative. Higher minimum flows of 3,000, 5,000, or 8,000 cfs under this alternative may reduce the degree of stranding. All of the stranding pools evaluated by Angradi et al. (1992a) would still be affected at the most commonly encountered minimum flow of 3,000 cfs under this alternative. Monthly minimums of 5,000 cfs would isolate 80% of the pools evaluated by Angradi et al. (1992a). An 8,000 cfs minimum flow would further reduce the stranding effect.

Higher minimum flows under this alternative may reduce the effects of redd exposure over short periods. At each successive minimum flow described by this alternative, a smaller proportion of the redd sites evaluated by Angradi et al. (1992a) are exposed daily (Table 8).

Table 8. Percent (%) of exposed rainbow trout redds under various minimum flows (Adapted from Angradi et al. 1992b).

MINIMUM FLOW (cfs)	% OF REDDS EXPOSED DAILY
3,000	90
5,000	83
8,000	59

Trout larvae and fry would continue to be affected by daily flow fluctuations, thus reduci ng their likelihood for survival. The effects may potentially be offset through stocking an d regulation.

Access to tributaries by trout may be precluded with flows below 5,000 cfs. With the increased reliable minimum flow to 3,000 cfs, Cladophora and associated organisms woul d be expected to increase, as would the growth potential for trout.

Moderate Fluctuating Flows

Under this alternative the daily fluctuation range would be decreased and the minimum flow would be increased compared to the No Action Alternative. Both of these parameters would benefit trout. Higher minimum flows may reduce the risk of stranding as experienced under No Action. Monthly minimum flows of 5,000 cfs would isolate only 80% of the pools evaluated by Angradi et al. (1992a). Additionally, because the daily range limits the mean daily release, the absolute minimum may only be reached during low volume months, and fewer pools may become isolated.

Higher minimum flows under this alternative may reduce the effects of redd exposure ov er short periods. A minimum flow of 5,000 cfs would expose approximately 83% of the redd sites evaluated by Angradi et al. (1992b) (Table 8). Because the daily range would be constrained by this alternative, the actual minimum may be higher than allowed, except during low water months in low water years. The daily range constraint may also limit the actual maximum flow and force trout to select redd sites lower on gravel bars. These sites may be proportionately less susceptible to exposure.

Trout would likely have adequate access to tributaries for spawning. Due to the long-ter m, reliable minimum flow, Cladophora and associated organisms would be expected to increase, as would the growth potential for trout.

Modified and Interim Low Fluctuating Flows

Under both the MLFF and ILFF Alternatives, the daily range of fluctuations would be decreased to 5,000, 6,000 or 8,000 cfs per day. The minimum flow would be increased to

5,000 cfs at night and 8,000 cfs during the day. Both of these parameters would likely benefit trout. Higher minimum flows may reduce the degree of stranding experienced un der No Action. Monthly minimum flows of 5,000 cfs would isolate only 80% of the pools evaluated by Angradi et al. (1992a). Additionally, because the daily range would be limit ed by the mean daily release, the absolute minimum may only be reached during low wat er months in low water years. Fewer pools would become isolated, especially during high volume months. The requirement under this alternative to increase minimum flows to 8,000 cfs by 7:00 am may also limit the period of isolation of some stranding pools.

Higher minimum flows may also reduce the effects of redd exposure over short periods. A minimum flow of 5,000 cfs would expose approximately 83% of the redd sites evaluated by Angradi et al. (1992a) (Table 8). The daily range constraint may also limit the actual maximum flow and force trout to select redd sites lower on gravel bars. These sites may be proportionately less susceptible to exposure.

Redd exposure and stranding are still expected to occur, and thus, this would not be a fully desirable situation. However, it would be an improvement over the previous alternatives. In fact, since the implementation of interim flows in August 1991, a reduction in trout stranding and an improvement in trout weight has occurred (AGFD 1993). Also, the Lees Ferry trout population is reported to be comprised of 78% naturally reproduced trout ba sed on August 1992 electrofishing data (AGFD 1993).

Access to tributaries would not be impeded. The long-term, dependable minimum flow would increase, and therefore, food resources would be expected to increase, as would the growth potential for trout. Although the aquatic food resource would not realize the full benefit of a permanent 8,000 cfs minimum flow, the 12-hour period of 8,000 cfs minimum flow would allow for some proliferation of the food resource above the 5,000 cfs stage.

Existing Monthly Volume

Under the EMV Alternative, daily fluctuations would be eliminated and replaced with monthly adjustments limited to 2,000 cfs change per day. The reliable minimum flow wo uld be increased to 8,000 cfs. Both of these parameters would likely benefit trout.

Steady monthly flows would likely reduce the degree of stranding as experienced under the No Action Alternative. Monthly steady flows greater than 8,000 cfs would isolate only 45% of the pools evaluated by Angradi et al. (1992b). The events that strand fish would likely decrease and be limited to monthly adjustments. Once a pool becomes isolated, it would probably not be recaptured by the river and stranded fish would not be liberated. Those fish stranded during monthly adjustments are unlikely to survive.

Hatching time for rainbow trout eggs is usually between 28 and 40 days (Raleigh et al. 1984) and may be facilitated by relatively constant flows within a month under this alternative. Higher steady flows may reduce redd exposure within months. Redds are not likely to be exposed in the absence of daily fluctuations. Downward adjustments in monthly flows are likely to expose redds. Because flows would be steady and dependable within months, successful emergence of larval fish from redds would be likely. In the absence of daily fluctuations, larval trout and fry would not be forced to move among rearing habitats, thus resulting in a higher likelihood of survival. Enhanced redd success and increased recruitment would be direct effects of monthly steady flows.

Access to tributaries would not likely be impeded by this alternative. With the increase i n minimum flow, Cladophora and associated organisms would be expected to increase, as would the growth potential for trout. The absence of velocity changes typical of fluctuating flows may reduce the amount of Cladophora and invertebrate drift. This may possibly reduce the availability of forage for trout and the efficiency of organic matter transport t o downstream reaches. It is not known if the decrease in the amount of drift may be offset by the anticipated increase in Cladophora biomass.

Seasonally Adjusted Steady Flows

Under this alternative, daily fluctuations would be eliminated and replaced with seasonal adjustments with constrained ramp rates. The reliable minimum flow would increase to 8,000 cfs. Both of these factors should benefit trout.

Steady seasonal flows under this alternative would likely reduce stranding. During low volumes of 8,000 cfs, only 45% of the pools evaluated by Angradi et al. (1992b) would be isolated. Additionally, because the flow would be steady, the occurrences that likely strand fish would be limited to downward adjustments and would not likely occur during the wi nter spawning months during a low volume year. In the event a pool became isolated, it would probably not be recaptured by the river and stranded fish would not be liberated. Any fish stranded during monthly adjustments are unlikely to survive.

Enhanced redd success and increased recruitment would be direct effects of steady flows. Higher steady flows and the absence of daily fluctuations under this alternative would likely reduce the potential for redd exposure. Because flows would be steady and dependable over seasonal periods, successful emergence of larval fish from redds would be likely. The absence of daily fluctuations would benefit trout by not forcing larval trout and fry to move among rearing habitats.

Access to tributaries would not likely be limited under this alternative. An increase of the food resource would occur up to the dependable minimum flow. The growth potential fo r trout is expected to also increase. The absence of velocity changes typical of fluctuating flows may reduce the amount of Cladophora and invertebrate drift on a daily basis. This may reduce the availability of forage for trout downstream and the efficiency of organic matter transport to downstream reaches. The decrease in drift may be offset by the anticipated increase in Cladophora biomass and a potential increase in drift during seaso nal flow adjustments.

Year-Round Steady Flows

Under this alternative, fluctuations would be eliminated and minimum flows increased to approximately 11,400 cfs. Both of these parameters should benefit trout. Monthly adjustments may be necessary due to forecast error and during moderate and high water years.

Steady flows of 11,400 cfs or greater would not have isolated any of the pools evaluated by Angradi et al. (1992a). Because the flow would be steady, the occurrences that would likely strand fish would be limited to downward monthly adjustments that are more likely in years when inflow forecast changes. As a result, significantly fewer pools would become isolated. Similar to the other steady flow alternatives, it would be highly unlikely for the river to recapture an isolated pool and liberate stranded fish, resulting in the loss of such fish.

High steady flows and the absence of daily fluctuations under this alternative would likely reduce the potential for redd exposure throughout the spawning season. Because flows would be generally steady and dependable over annual periods, successful emergence of larval fish from redds would be likely. In the absence of daily fluctuations, larval trout a nd fry would not be forced to move among rearing habitats which might result in higher likelihood of survival.

Access to tributaries would not likely be limited under this alternative and probably be enhanced. The elimination of daily fluctuations would encourage development of Cladophora up to the dependable minimum flow. The growth potential for trout would also be expected to increase. As with all steady flows, the absence of fluctuations may reduce the amount of Cladophora and invertebrate drift. This may possibly reduce the availability of forage for trout downstream and the efficiency of organic matter transport to downstream reaches. It is not known if the decrease in drift would be offset by the anticipated increase in Cladophora biomass.

OTHER NON-NATIVE FISHES

Before the construction of Glen Canyon Dam, attention was given to the development of sport fishery resources in the Colorado River. Non-natives were introduced to the lower Colorado River to meet the desires of sport anglers (USDI, Service 1980).

The presence of non-native fishes and their relationship to native fishes has emerged as an issue of considerable controversy, intensified by the possible construction of an MLIS designed to warm the water for native fishes. Competition and predation by non-native fishes, before and after Glen Canyon Dam was built, along with habitat modification, have been implicated as a cause of the decline of native fishes in the Colorado River system (Minckley 1991, Minckley and Deacon 1991). Conditions that protect or enhance native fishes may also enhance non-native fishes. The end result may be a greater probability of conflict between the two groups.

The concern over native and non-native fish interactions is accentuated by the Service's 1978 jeopardy Biological Opinion on the operation of Glen Canyon Dam (USDI, Service 1978) (see HUMPBACK CHUB section). Many of the same conditions and questions persist today as reiterated in the draft Biological Opinion issued October 1993 (USDI, Service 1993a).

Other Non-Native Fishes Without the Project

No Action

Although trout species make up the majority of non-native fishes, other species have also been introduced (Table 7). In the years immediately following closure of Glen Canyon Dam, resident warmwater native fishes, warmwater non-native fishes, and non-native coldwater fishes co-existed. Many of these fishes persist today, although conditions resulting from dam construction and operations are not conducive to optimal growth or reproduction. As interest in reservoir sport fisheries increased, other warmwater and coolwater fishes were introduced. These included striped bass in Lake Powell and Lake Mead and walleye and smallmouth bass in Lake Powell.

Striped bass would be expected to negatively impact native fish populations due to their presence in Lake Powell and Lake Mead and reputation as a predator of smaller fish. Striped bass are generally found in the lower reaches of the Grand Canyon below Lava Falls (RM 179). However, in recent years isolated individuals have been captured near the mouth of the LCR, an important habitat for the endangered humpback chub (Valdez et al. 1992). Striped bass display an ascend and retreat spawning behavior in the project area. Recent research suggests that the seasonal occurrences of striped bass in the Grand Canyon coincide with the spawning season of the species from April through July (Valdez et al. 1992).

The fathead minnow has the highest potential for competition with young native fishes. The fathead minnow is the most abundant non-native fish species encountered in mainstem backwaters below the LCR (AGFD 1993, 1994). Fathead minnows utilize backwaters for all life stages in their reproductive cycle (see Appendix 3). Native fishes are also more abundant below the LCR and the larval and young-of-year life stages are found primarily in backwaters (AGFD 1994).

The omnivorous channel catfish, established in and around the LCR, may prey on native fishes and compete for food. Channel catfish numbers appear to increase with distance from Glen Canyon Dam, reaching peak abundance below Lava Falls at the western end of Grand Canyon (Haden 1992). Largemouth bass and green sunfish, currently restricted to the lower reaches of the river, also share the potential for predatory interactions with native fishes. Brown trout, concentrated between Clear Creek and Kanab Creek, are often piscivorous as adults. Rainbow trout, generally not piscivorous, also have been indicated as a possible predator on young native fish and eggs (Maddux et al. 1987, Angradi et al. 1992b, Valdez 1992). Carp are also known to consume eggs of other fish species.

Non-native fishes also compete with native fishes for rearing habitats and food resources. Non-native species residing in the study area are found in the mainstem, backwaters, and/or tributaries (AGFD 1993). Responses of non-native fishes to changes in the food resource would likely be similar to native fishes. (See NATIVE FISHES section).

Overall, factors that limit native fishes also limit warmwater non-native fishes (see NATIVE FISHES section). Cold water releases, daily fluctuations, and flood events will continue to affect non-native fishes. Reproduction in the mainstem will continue to be marginal under the No Action Alternative. Channel catfish and carp will continue to rely on tributaries for spawning, and fathead minnows will continue to utilize backwaters for spawning to maintain their populations. Growth and recruitment of these fishes will depend on the availability of tributaries, backwaters, and shallow nearshore areas capable of warming separate from the mainstem.

Other Non-Native Fishes With the Project

Maximum Powerplant Capacity

The effects of this alternative on non-native fishes would be very similar to those under the No Action Alternative.

Remaining Action Alternatives

All remaining alternatives have the provision of beach/habitat building flows. Three alternatives, MFF, MLFF, and SASF, include the provision of habitat maintenance flows. Consistent low water years with high sediment inflow may result in the filling of some backwaters. Greater stability in backwaters may result in establishment of vegetation in the long-term, ultimately eliminating existing backwater areas. This should be offset by periodic moderate or high water years, beach/habitat building flows, habitat maintenance flows, and to some extent fluctuating flows, which would scour and reform backwater areas.

Non-native fishes are not adapted to flooding conditions, but the native fishes are. Although floods may displace non-native fish competitors and predators, and thus serve as a mechanism to enhance native fish populations, the effects may be short-term. Beach/habitat building and habitat maintenance flows, that enhance beaches and backwaters (see SEDIMENT and NATIVE FISHES sections), may also aid in displacing non-native fishes.

High Fluctuating Flows

The effects of this alternative on non-native fishes would be similar to those under the No Action Alternative. The high daily fluctuations, beach/habitat building flows, and other controlled floods may discourage non-native fishes from migrating up the mainstem. However, the more persistent non-native fishes may benefit by flood protection of the magnitude of one major flood anticipated per 100 years. Any de-stabilization of non-native species would likely be temporary and reversible.

Moderate Fluctuating Flows

The effects of this alternative on non-native fishes would be similar to, but of lesser magnitude than, those under the previous alternatives. Spawning, rearing, and growth of non-natives would continue to be limited under this alternative. However, as backwater stability increases, habitat suitability would also increase. This, combined with higher minimum flows and decreased fluctuations, may directly increase the recruitment of some non-native fishes. Fathead minnow, in particular, may dominate stable backwaters (Maddux et al. 1987). The high daily fluctuations, beach/habitat building flows, habitat maintenance flows, and other controlled floods may discourage non-native fishes from migrating up the mainstem. However, the more persistent non-native fishes may benefit by flood protection of the magnitude of one major flood anticipated per 100 years. Any de-stabilization of non-native species would likely be temporary and reversible.

Modified and Interim Low Fluctuating Flows

Conditions for non-native fishes under the MLFF and ILFF Alternatives would be improved over conditions under the previous alternatives due primarily to more stable backwaters. Higher minimum flows, improved tributary access, and a narrower range of daily fluctuations may increase the recruitment of some non-native fishes. Daily fluctuations, beach/habitat building flows, and habitat maintenance flows under the MLFF Alternative, may discourage non-native fishes from migrating up the mainstem. However, the more persistent non-native fishes may benefit by flood protection of a frequency of one major flood anticipated per 100 years. Any de-stabilization of non-native species would likely be temporary and reversible. These improved conditions for non-native fishes may result in a greater probability of conflict between native and non-native fish species.

Existing Monthly Volume

The effects of this alternative on non-native fishes would differ from those under the fluctuating flow alternatives. Although spawning, rearing, and growth would not be optimized in the mainstem due to cold water releases, backwater stability would increase during low water years that do not require major forecast adjustments. This increase would improve conditions in isolated areas which may provide the competitive edge for recruitment of some non-native fishes, particularly fathead minnow. The absence of daily fluctuations, improved tributary access, and implementation of flood control measures may eliminate displacement of non-native fishes. Temporary de-stabilization of non-native fishes would not likely be significant during monthly adjustments but may occur during beach/habitat building flows and high water years.

Seasonally Adjusted Steady Flows

The effects of this alternative on non-native fishes would be somewhat similar to those under the EMV Alternative during low water years. Spawning, rearing, and growth of warmwater non-native fishes would continue to be limited due to cold water releases from the dam. This impact may be offset by the availability of warm, stable backwater and nearshore habitats. These improved habitat conditions may provide the competitive edge for some non-native fishes, such as the fathead minnow and carp. The factors that would protect or limit the native fishes may also protect or limit non-native fishes and result in a greater probability of increased conflict between the two groups. However, the seasonal pattern of the hydrograph under this alternative may prove disadvantageous for non-native fishes.

Year-Round Steady Flows

The effects of this alternative on non-native fishes would differ considerably from those under the fluctuating flow alternatives, and somewhat from those under the other steady flow alternatives. The main differences would include the effects of year-round steady flows of 11,400 cfs during low water years and the creation of low velocity habitats.

The number of backwater habitats may be reduced since most currently appear at lower flows (Weiss 1993, McGuinn-Robbins 1994). Backwaters that are available would provide excellent spawning and rearing habitat for warmwater non-native fishes in the short-term. The absence of daily, monthly, or seasonal fluctuations during low water years would provide the most stable conditions for non-native fishes relative to the other alternatives, potentially allowing them to outcompete native fishes. This competition resulting from increased stability may be temporarily offset during moderate or high water years and/or with implementation of beach/habitat building flows, which would likely de-stabilize conditions for all fishes.

AMPHIBIANS AND REPTILES

Twenty-seven species of amphibians and reptiles (herpetofauna) inhabit the Colorado River corridor (Miller et al. 1982, Carothers and Brown 1991). Three species; the leopard frog (Rana pipiens pipiens) the desert banded gecko (Coleonyx variegatus), and the Woodhouse's toad (Bufo woodhousei); are restricted to the riparian zone throughout their lives. In general, frogs and toads lay their eggs in water. Many frogs are dependent on water throughout their life (Dickerson 1969, Heymann 1975).

Woodhouse's and red-spotted toads (Bufo punctatus) are common. The desert banded gecko is considered rare (Carothers and Brown 1991, Drost and Sogge 1993) and little is known about this nocturnal lizard in Grand Canyon (Miller et al. 1982). Woodhouse's toad is the most common amphibian along the river in the Glen Canyon reach (Drost and Sogge

1993). Most of the remaining species in Glen and Grand Canyons use both upland desert and riparian sites, with 10 species considered common to abundant in Grand Canyon (Table 9) (Miller et al. 1982, Carothers and Brown 1991).

Table 9. Common amphibians and reptiles of the Colorado River in Grand Canyon (Adapted from Miller et al. 1982, Carothers and Brown 1991).

COMMON NAME	SCIENTIFIC NAME
Woodhouse's toad	Bufo woodhousei
red-spotted toad	Bufo punctatus
canyon treefrog	Hyla arenicolor
chuckwalla	Sauromalus obesus
yellow-backed desert spiny lizard	Sceloporus magister
side-blotched lizard	Uta stansburiana
tree lizard	Urosaurus ornatus
Northern whiptail	Cnemidophorous tigris
California kingsnake	Lampropeltus getulus
Grand Canyon rattlesnake	Crotalus viridis abyssus

Although surveys are limited, the leopard frog is considered very rare in the Grand Canyon with recent sightings limited to Cardenas Marsh (Miller et al. 1982) and Glen Canyon above Lees Ferry (C. Pinnock, Glen Canyon National Recreation Area, pers. comm.; Drost and Sogge 1993). The primary marsh area that leopard frogs inhabit in Glen Canyon is a spring-fed stream and not directly dependent on flows from Glen Canyon Dam. However, experimental high flows or floods have the potential to negatively impact the frogs and/or their habitat.

Amphibians and reptiles utilize the riparian zone for foraging on insects and worms (Dickerson 1969, Miller et al. 1982, Carothers and Brown 1991). The importance of insects to herpetofauna is illustrated by the abundance of both groups in the riparian zone. Four common species of lizards in the riparian zone are the side-blotched lizard (Uta stansburiana), the Northern whiptail (Cnemidophorous tigris), the desert spiny lizard (Sceloporus magister), and the tree lizard (Urosaurus ornatus). Individuals of these species are most abundant within 16 ft of the water's edge, intermediate in numbers in the NHWZ and OHWZ, and least abundant in adjacent upland sites (Warren and Schwalbe 1987).

Some herpetofauna appear to be substrate specific within the Colorado River riparian corridor. For example, side-blotched lizards are most commonly observed in open areas on rocks or bare soil, Northern whiptails on bare soil or litter, desert spiny lizards on large boulders or large tree trunks, and tree lizards on vertical cliff faces along eddies and quiet shorelines just above the splash zone (Warren and Schwalbe 1987). In other studies along the Hassayampa River near Wickenburg, Arizona, desert spiny and tree lizards were randomly distributed (Jones and Glinski 1985).

Amphibians and Reptiles Without the Project

No Action

Under this alternative, the fluctuating zone has been an important source of food. The Northern whiptail lizard commonly feeds in the fluctuating zone on harvester ants stranded Gammarus, and blackflies (Carothers and Brown 1991). Warren and Schwalbe (1987) observed 8 Northern whiptails and 5 desert spiny lizards simultaneously feeding along the same section of shoreline at Cardenas Marsh. Specific microhabitats within the riparian corridor, including the shoreline in the fluctuating zone and open tamarisk sites in the NHWZ, support lizard densities equal to or higher than any other sites reported in the Southwest (Warren and Schwalbe 1987). Other species, such as amphibians which are directly dependent on shallow waters or the river's edge may not have managed as well.

Amphibians and Reptiles With the Project

All Action Alternatives

Fluctuating flows may disturb and displace herpetofauna in the fluctuating zone. Higher daily fluctuations may be most detrimental. Adverse effects would include displacement and excess energy expenditure. However, fluctuating flows strand insects and Gammarus, food sources for herpetofauna (Carothers and Brown 1991). Amphibians and their eggs may also be susceptible to changes in flow levels or fluctuations.

Steady flows would offer more stable conditions for herpetofauna, thus reducing displacement and excess energy expenditure. However, stabilizing the NHWZ could result in an increased density of vegetation which could limit lizard use or displace individuals to different areas. In general, the numbers of lizards observed in the NHWZ were lowest in dense tamarisk sites (Warren and Schwalbe 1987). Along the Gila River, only desert spiny and tree lizards were captured in dense tamarisk (Jakle and Gatz 1985). Jakle and Gatz (1985) speculated that dense tamarisk stands lack structural diversity and reduce light penetration and basking sites.

Beach/habitat building flows are designed to keep woody vegetation from becoming dense and encroaching into backwater areas and down to the river edge. Although lizards and other reptiles are quite resilient and capable of re-establishing populations, it would be beneficial to population maintenance if flood and other detrimental water fluctuations were minimized during reproductive months (Warren and Schwalbe 1987; USDI, Reclamation 1989). Amphibians likewise would probably experience a disruption on nesting and feeding sites.

The leopard frog is one of the first frogs to come out of hibernation. Eggs are commonly laid in March (Dickerson 1969). This and other early breeding species may be impacted by habitat maintenance flows or a beach/habitat building flow in March, or any other high flow which would destabilize nearshore, shallow areas used by amphibians. It is unknown whether the leopard frog or other amphibian species may be able to compensate for adverse impacts to the population.

WATERFOWL

Pre-dam observations indicated little breeding activity and winter concentration of migrant waterfowl in the Colorado River corridor. Post-dam observers since 1975 have commonly reported abundant waterfowl primarily in Glen Canyon, presumably in response to food resource availability and greater nesting habitat (Stevens and Kline 1991). Dam construction resulted in a clearer, colder discharge and increased abundance of Cladophora and associated aquatic macroinvertebrates. Marsh habitat has increased significantly throughout the river corridor, especially in recent years, as a result of a decline in daily fluctuations and ramp rates and control of scouring floods (Stevens and Ayers 1991). Increasing waterfowl numbers are probably a response to this increased aquatic and marsh productivity. The river system also serves as a migratory corridor for many waterfowl species providing food resources and resting habitat.

A draft report by Stevens and Kline (1991) indicated waterfowl abundance to be strongly negatively correlated with turbidity and speculated that the considerably more turbid pre-dam river would have attracted fewer waterfowl. Dam induced habitat changes in the Colorado River corridor have positively influenced waterfowl abundance, distribution, and species composition (Stevens and Kline 1991). Other factors affecting waterfowl distribution and utilization include water velocity and depth, vegetation, and human disturbance.

Areas supporting emergent marsh vegetation are centers for many biological processes along the river corridor and provide important habitat requirements for many waterfowl species using the canyon. Emergent marsh is maintained through periodic inundation from the river or perennial tributaries. Certain operations of Glen Canyon Dam may prevent or limit the creation and/or maintenance of emergent marsh (see Emergent Marsh section).

Waterfowl Without the Project

No Action

Glen and Grand Canyon waterfowl abundance data collected by Stevens and Kline (1991) indicate a bell-shaped trend of increasing numbers in late November, peak numbers in late December and early January, and decreasing numbers in February, March and April. Maximum winter waterfowl concentrations recorded during the 1990-1991 survey were 53 ducks per mile between Lees Ferry and Soap Creek (RM 11) and consisted of 19 species of Anseriformes. Average winter waterfowl abundance for the entire upper Grand Canyon (RM 0 - 76) was 6.82 ducks per mile with greater abundance in wide reaches. Significant numbers of waterfowl concentrate in the upstream reaches during the winter months. Summer duck abundance is greatest downstream in the wide reaches of Marble Canyon and upper Grand Canyon (RM 23 - 76).

Mallard (Anas platyrhynchos), blue-winged teal (Anas discors), and common merganser (Mergus merganser) are some of the waterfowl species observed to breed in the Colorado River corridor (Stevens and Kline 1991, C. Pinnock NPS, pers. comm.). Mallard pairs were observed in virtually every large eddy in the Marble Canyon and upper Grand Canyon reaches in summer 1991 (Stevens and Kline 1991). Mallard nests have been found in the fluctuating zone (L. Stevens NPS, pers. comm.) as well as high in the NHWZ (C. Pinnock NPS, pers. comm.).

Strongly fluctuating daily flows and the rising limb of flow fluctuations were observed to force wintering waterfowl off foraging areas (Stevens and Kline 1991). Daily fluctuations under this alternative may adversely affect nesting waterfowl by inundating near-shore nests or preventing the birds from locating suitable nesting habitat.

The numbers of waterfowl have increased from pre-dam conditions under this alternative. Feeding waterfowl may take advantage of low flows during the morning. However, individuals may be adversely affected as a result of living in a highly variable, unpredictable system. Scouring resulting from fluctuations would limit the establishment of shoreline marsh vegetation patches and create unstable sandbars. This would minimize suitable waterfowl habitat, available organic matter, and associated insect populations. The absolute minimum flow of 1,000 cfs under this alternative would limit the production of Cladophora and associated food resources as described in the AQUATIC VEGETATION section.

Under this alternative, a major uncontrolled flood would be expected to occur once in 40 years. A flood of this magnitude would impact riparian resources similarly to the flood of 1983 as described in the VEGETATION section.

Waterfowl With the Project

Maximum Powerplant Capacity

Impacts under this alternative would be similar to those under the No Action Alternative.

High Fluctuating Flows

Higher minimum flows of 3,000 cfs would allow for slightly greater production of Cladophora and associated food resources. Impacts resulting from daily fluctuations under this alternative would be similar to those under the No Action Alternative.

Beach/habitat building flows may or may not affect waterfowl depending on the timing and duration of flows. Flows that would result in the enhancement of emergent marsh and aquatic vegetation may enhance waterfowl habitat while flows that would occur during the nesting season may adversely affect waterfowl populations by limiting availability of suitable nest sites or direct nest inundation.

Moderate Fluctuating Flows

Higher minimum flows of 5,000 cfs would allow for production of Cladophora and associated food resources at higher stage levels than under the preceding alternatives. The restrictions on allowable daily flow change and ramp rates would be more favorable for waterfowl than the preceding alternatives. Sandbar stability and marsh establishment would increase the quantity of suitable nesting habitat. Fluctuations commonly reaching 6 to 8 ft may continue to inundate nearshore nests and negatively impact the birds. The general effects of beach/habitat building flows and habitat maintenance flows would be the same as described under the HFF Alternative.

Modified and Interim Low Fluctuating Flows

Higher minimum flows of 8,000 cfs from 7:00 am until 7:00 pm, and 5,000 cfs from 7:00 pm until 7:00 am would allow for production of Cladophora and associated food resources greater than the preceding alternatives. A decrease in the maximum allowable flow to 20,000 cfs would increase the area of stable sandbar available for nearshore emergent marsh and riparian vegetation development. The restrictions on allowable daily flow change and ramp rates would provide a more stable environment for waterfowl than the preceding alternatives. Greater fluctuations which would occur during periods of high energy demand (July-August) would still have the potential to inundate near shore nests. The general effects of beach/habitat building and habitat maintenance flows would be the same as described under the HFF Alternative.

Existing Monthly Volume

Steady monthly flows are not expected to fall below 8,000 cfs and could be as high as 16,300 cfs in a low water year. These high minimum flows would allow increased production of Cladophora and associated food resources at higher stage levels than the preceding alternatives. Steady flows would also provide a significantly more stable environment within months as well as between some months where stage adjustments are minimal. Significant stage adjustments that would occur between November and December, and June and July in response to power demand would have the potential to scour and/or inundate nearshore habitat and inundate nests of late breeding waterfowl. These stage changes, however, although considerable, would still be less than those that would occur on a daily basis under all the fluctuating flow alternatives. This would be due to the 2,000 cfs daily change limit under the this alternative. The general effects of beach/habitat building flows would be the same as described under the HFF Alternative.

Seasonally Adjusted Steady Flows

Steady seasonal flows are not expected to fall below 8,000 cfs and could be as high as 18,000 cfs in a low water year. These high minimum flows would allow increased production of Cladophora and associated food resources at higher stage levels similar to Existing Monthly Volume. Steady flows would also provide a significantly more stable environment within seasons as well as between some seasons where stage adjustments are minimal. The significant stage adjustment that would occur between April and May as an attempt to resemble the natural pre-dam hydrograph pattern would have the potential to scour and/or inundate nearshore habitat and inundate nests. However this stage change, although considerable, would still be less than those which would occur on a daily basis under all the fluctuating flow alternatives. This is due to the 2,000 cfs daily change limit under this alternative. The general effects of beach/habitat building flows and habitat maintenance flows would be the same as described under the HFF Alternative.

Year-Round Steady Flows

Under this alternative, flows would be maintained at 11,400 cfs in a low water year. This would provide a stable and predictable yearly flow regime that would maximize production of Cladophora and associated food resources compared to other alternatives. These flows would also promote nearshore emergent marsh development in the short-term. However, over the long-term, lack of overbank flooding would adversely affect vegetation and aquatic resources by preventing translocation and recycling of nutrients and lead to rapid rates of succession during low water years. This would ultimately result in the conversion of backwaters and marsh areas to invading terrestrial vegetation. High water years have the potential to reverse these conditions. The general effects of beach/habitat building flows would be the same as described under the HFF Alternative.

RIPARIAN BIRDS

Some 303 species of birds have been recorded within the Grand Canyon region. Of these, 250 or 83% were within the Colorado river corridor (Johnson 1991). Of these, 30 are known to be permanent residents (Linder 1992) (Table 10).

Riparian vegetation supplies cover, nesting substrate, and forage for birds. Many birds use the corridor as a migration route and are not directly affected by dam operations. However, birds that nest and feed along the river's edge, including neotropical migratory birds, may be impacted by flow regime. Flows which enhance vegetation recruitment and maintenance and prevent habitat fragmentation are most suitable for riparian birds.

Table 10. Grand Canyon bird species list of all known permanent residents (Linder 1992).

COMMON NAME	SCIENTIFIC NAME
great blue heron	Ardea herodias
mallard	Anas playrhynchos
common merganser	Mergus merganser
red-tailed hawk	Buteo swainsoni
golden eagle	Aquila chrysaetos
American kestrel	Falco sparverius
prairie falcon	Falco mexicanus
Gambel's quail	Callipepla gambelii
American coot	Fulica americana
greater roadrunner	Geococcyx californianus
western screech-owl	Otus kennicottii
great horned owl	Bubo virginianus
ladder-backed woodpecker	Picoides scalaris
black phoebe	Sayornis nigricans
Say's Phoebe	Sayornis saya
common raven	Corvus corvax
verdin	Auriparus flaviceps
cactus wren	Campylorhychus brunneicapillus
rock wren	Salpinctes obsoletus
canyon wren	Catherpes mexicanus
Bewick's wren	Thryomanes bewickii
American dipper	Cinclus mexicanus
black-tailed gnatcatcher	Polioptila melanura
European starling	Sturnus vulgaris
rufous-crowned sparrow	Aimophila ruficeps
black-throated sparrow	Amphispiza belli
song sparrow	Melospiza melodia
red-winged blackbird	Agelaius phoeniceus
house finch	Carpodacus mexicanus
house sparrow	Passer domesticus

Riparian Birds Without the Project

No Action

The importance of riparian vegetation as wildlife habitat, particularly the NHWZ, is exemplified by bird use. Forty-eight species of birds nest along the river (Linder 1992). Fifteen species nest in both the OHWZ and NHWZ, with an additional 14 species restricted to nesting in the NHWZ. One species, phainopepla (Phainopepla nitens), has been primarily documented as nesting in the OHWZ (Carothers and Brown 1991), although NPS data indicate that one phainopepla nest was found at Granite Park in 1993 (USDI, NPS, written communication, 1993). Nesting at some sample sites exceeded 8 pairs per acre, among the highest recorded in North America (Brown and Johnson 1987). Bell's vireo (Vireo bellii), summer tanager (Piranga rubra), hooded oriole (Icterus cucullatus), and great-tailed grackle (Quiscalus mexicanus) have expanded their nesting ranges into the Grand Canyon in response to riparian vegetation development (Carothers and Brown 1991). Of the 30 species that nest exclusively in the riparian corridor, 13 are insectivorous and at least 10 species depend on insects to feed their young. Species such as phoebes, swifts, and swallows do not nest in riparian vegetation but feed on flying insects associated with this zone.

Vegetation within the riparian corridor occurs in discontinuous blocks or patches. Factors, such as erosion, that would affect the patch size or fragment existing patches indirectly affect the use of habitat by birds. For example, black-chinned hummingbirds nest in vegetation patches in the NHWZ that are at least 0.5 hectare with 69% vegetative cover and mean canopy height of 1.4 meters (m) (Brown 1992).

Brown and Johnson (1987) determined that discharges within the range of current dam operations had little direct effect on bird nests along the river, inundating only one nest. The release of surplus water in excess of 31,000 cfs during the breeding season in 1983 had a strong, direct impact on nesting birds in the form of nest inundation. Discharges of 40,000 cfs inundated 90% of common yellowthroat (Geothlypis trichas) nests. Above 40,000 cfs, nests of Bell's vireo, yellow-breasted chat (Icteria virens), black phoebe (Sayornis nigricans), Say's phoebe (S. saya), and violet-green swallow were affected.

Bird species which prefer marsh habitat, such as the common yellowthroat, would be most at risk from fluctuating flows and flood releases. Major uncontrolled floods are expected to occur an average of once in 40 years which, depending on the timing and duration of flows, could significantly impact riparian bird nests and habitat.

Riparian Birds With the Project

Maximum Powerplant Capacity

Impacts on riparian birds under this alternative would be similar to those under the No Action Alternative.

Other Fluctuating Flow Alternatives

The HFF and MFF Alternatives would affect riparian birds and habitat similarly to the No Action Alternative because of the 31,500 cfs maximum flow, but effects would be of less magnitude due to reductions in daily fluctuations and constrained ramp rates. The ILFF and MLFF Alternatives would enhance bird habitat by reducing maximum flow and daily fluctuations and constraining ramp rates resulting in an expansion of marsh and riparian vegetation. Provisions for flood control would reduce the frequency of major uncontrolled floods, such as that which occurred in 1983, to once in 100 years. Beach/habitat building flows and habitat maintenance flows may impact riparian birds depending on the timing, magnitude and duration of flows.

Steady Flow Alternatives

Lower maximum flows would encourage expansion of woody riparian vegetation into the fluctuating zone creating larger, more stable, contiguous patches of riparian habitat. However, steady flows and flood protection would result in dryer conditions and may alter plant species composition in the NHWZ. The zone of emergent marsh vegetation is expected to shift to the area along the river edge and a net balance in overall coverage is expected. The increased woody vegetation production under the steady flow alternatives is expected to enhance bird habitat. Beach/habitat building flows and habitat maintenance flows may impact breeding riparian birds, if they occur during nesting season.

MAMMALS

Twenty-six species of mammals occur along the Colorado River corridor in the Grand Canyon (Carothers and Brown 1991). Rodents are abundant in Grand Canyon. The deer mouse (Peromyscus maniculatus) depends upon the riparian zone exclusively for its existence.

The beaver (Castor canadensis) is a large rodent that utilizes riparian vegetation for food and lodging. Beaver food and houses are likely protected by the presence of the dam. Although the river corridor through Grand Canyon may not appear to be good beaver habitat, Larry Stevens, NPS (unpublished data 1991) developed a conservative estimate of 200 animals between Lees Ferry and Diamond Creek (226 miles). Beavers may locally affect plant species composition and coverage by their foraging and building activities.

Six species of bats occur along the river corridor (Carothers and Brown 1991). While these species also inhabit desert habitats, they may be attracted to the river corridor by abundant insect prey associated with riparian vegetation. Bats are important prey for peregrine falcons (Brown 1991a).

Ringtail (Bassariscus astutus) and the western spotted skunk (Spilogale gracilis) are common small mammals within the river corridor. Whether riparian vegetation has contributed to an increase of these animals or human use at beach camp sites has increased their food supply is speculative.

Bighorn sheep (Ovis canadensis) and mule deer (Odocoileus hemionus) are the largest mammals present in the river corridor. Mule deer are more commonly found in Grand Canyon. Bighorn sheep reside on the steep slopes but may descend to the river to drink and feed during the heat of summer. Bobcats (Lynx rufus), coyotes (Canis latrans), gray foxes (Urocyon cineroargentatus), mountain lions (Felis concolor), and raccoons (Procyon lotor) are very rare (Carothers and Brown 1991). The last raccoon documented in the Grand Canyon was in 1966 (John Ray, NPS, pers. comm.).

Mammals Without the Project

No Action

Deer mice were not recorded along the river prior to construction of Glen Canyon Dam. Riparian vegetation may have provided a competitive edge for deer mice over cactus mice (Peomyscus eremicus) along the river banks. Both the brush mouse (P. boylii) and pinyon mouse (P. truei) have increased in numbers since closure of the dam and subsequent development of the NHWZ. Beavers would likely continue benefiting from the reduction in floods and increase in riparian vegetation.

Rapidly changing discharges may limit bighorn sheep and mule deer access to the river. However, their size, strength, and mobility make it unlikely that changes in river discharge would adversely affect these species.

Mammals With the Project

All Action Alternatives

Impacts on mammals are likely to be indirect for all other alternatives, although low flows under the MPC Alternative may expose beaver burrows. Flows which would provide sufficient moisture and nutrients to maintain riparian vegetation in the NHWZ and support its expansion into suitable sites made available by reduced flows would be most suitable for mammals. Depending upon the seasonal timing of beach/habitat building and habitat maintenance flows, either tamarisk or native plants or both would germinate on suitable wetted sites and may affect habitat structure. Beaver populations are likely to benefit from the protection consequences of a decrease in flood frequency. Changes in species composition is not likely to result in a change in beaver populations.

SPECIAL STATUS SPECIES

HUMPBACK CHUB

The humpback chub (Gila cypha) is listed as federally endangered (March 11, 1967) with critical habitat in the Grand Canyon (Colorado River, Nautiloid Canyon, RM 34.5 to

Granite Park, RM 209; LCR, confluence upstream to RM 8) (March 21, 1994). The species is endemic to the Colorado River System and evolved three to five million years ago. The humpback chub is one of the most recently described large, North American fish (Miller 1946) based on a specimen collected in the Grand Canyon. The humpback chub inhabits relatively remote and inaccessible canyons in the Colorado River Basin where historical collections were extremely limited.

The Grand Canyon humpback chub population is the only one in the Lower Colorado River Basin. The LCR is thought to be especially important to the recovery of the species (USDI, Service 1990). In addition, the LCR is the only known area of reproduction by the species in the Grand Canyon (Kaeding and Zimmerman 1983, Valdez et al. 1992).

Humpback chub are found in a variety of habitats but their habitat preferences are only partially understood. In general, the species is associated with canyon reaches that exhibit fast currents, large deep eddies, and boulder or ledge habitats (Karp and Tyus 1990, Minckley 1991, Valdez et al. 1992). Maddux et al. (1987) reported the highest numbers of humpback chub in the mainstem Colorado River from eddies, runs, and along cliffs and boulders. Preliminary data in the Grand Canyon indicate that the humpback chub in the mainstem river primarily used eddies, slow runs, and reattachment channels (Minckley 1991, Valdez et al. 1992). Juvenile chubs were captured in the same locations as adults and appear to utilize similar habitat. Young-of-year were often captured apart from juvenile and adult humpback chubs along talus shorelines with emerged boulders and benches or ledges and intermittent sand pockets. Young fish were not found along adjacent areas (Valdez et al. 1992). Valdez et al. (1990) summarized habitat suitability information for young humpback chub in the Upper Basin which indicated that newly hatched larvae typically use shallow, rocky shorelines, ephemeral backwaters, and tributary mouths, moving into deeper water as they grow larger.

In portions of the Colorado River which still exhibit relatively natural hydrograph and temperatures (e.g., Black Rocks in the upper Colorado River Basin), the humpback chub typically spawns in mainstem reaches at or shortly after the peak of the spring run-off (Valdez et al. 1992). Research in Black Rocks in the upper Colorado River Basin has indicated that spawning occurs between 11.5°C and 23°C.

In the Grand Canyon, spawning and recruitment of humpback chub has only been documented in the LCR, even though significant numbers of adults inhabit the mainstem river for much of the year. Spawning in the LCR ranges from March to July, depending on flow and water temperatures (Kaeding et al. 1990, Valdez et al. 1992). Spawning in the LCR in 1992 primarily occurred in April (Masslich and Cowdell 1993). According to the AGFD (1993), spawning in 1992 primarily occurred during late April through early May with another spawn in July.

Although the humpback chub has not been known to reproduce in any of the other tributaries of Glen and Grand Canyons outside of the LCR, the potential use of these other tributaries cannot be discounted. One or more such tributaries may be vital in the establishment of a second spawning population of humpback chub in Grand Canyon. Access to tributaries may be precluded by flows less than 5,000 cfs (Valdez 1992).

Under laboratory conditions, Hamman (1982) and Marsh (1985) found that the highest egg hatching success occurred at temperatures of 19-20°C. Very low hatching success and survival of young fish was found at temperatures of 12-13°C (Hamman 1982) (Table 11).

Table 11. Hatching rates and survival of humpback chub at four water temperature ranges at Willow Beach National Fish Hatchery (Adapted from Hamman 1982).

Temperature (°C)	Incubation Time (Days)	Hatching Success (%)	Young Survival (%)
21-22	4.3-6.1	79	99
19-20	4.8-6.7	84	95
16-17	7.0-11.0	62	91
12-13	12.7-19.0	12	15

Specific spawning locations for humpback chub in the LCR are unknown. Females are suspected to broadcast their eggs locally in small gravel pockets among cobble and boulder substrates in moderate to high velocity currents (Valdez et al. 1992).

Food habits of humpback chub in the Grand Canyon have not been extensively studied. Kaeding and Zimmerman (1983) examined stomachs of fish from the LCR and mainstem Colorado River and found higher densities of food organisms in mainstem fish. This suggests that a greater abundance of food is available in the mainstem. Primary food items were chironomid larvae (midges) and simuliid larvae (blackflies). Gammarus were also significant in the diets of mainstem fish, occurring in 22% of the fish examined. Drift samples collected by BIO/WEST in the Grand Canyon during 1991 showed that Simuliidae, Chironomidae larvae and Gammarus were the most abundant aquatic invertebrates (Valdez et al. 1992). Leibfried (1993) analyzed the stomach contents of adult humpback chubs and found the dominant food items to be simuliids (61.7%), Gammarus (24.1%), and chironomids (12.6%). Cladophora was found in some chub stomachs and averaged 0.16 milliliter per fish. Cladophora, Gammarus, simuliids, and chironomids were dominant in drift samples.

The apparent decline of humpback chub in the Colorado River Basin is due to a combination of factors which include alteration of historical riverine habitats and competition with and predation by introduced fish species (USDI, Service 1990, Minckley 1991). Fragmentation of the Colorado River system by dams has isolated populations and restricted gene flow, which reduces the ability of subpopulations to adapt to changing conditions.

The concern for the humpback chub is emphasized by the Service's 1978 jeopardy Biological Opinion on the operation of Glen Canyon Dam (USDI, Service 1978). This Biological Opinion concluded that operation of the dam is jeopardizing the continued existence of the humpback chub and is limiting the recovery of the extirpated Colorado squawfish. Jeopardy is attributed to the cold water temperatures and altered seasonal hydrograph. The Service recommended that Reclamation investigate the following: (1) the potential impact of warming the river below Glen Canyon Dam on endangered species, (2) the ecological needs of the endangered species downstream of Glen Canyon Dam, (3) methods of reducing known constraining factors of low water temperature and frequent flow fluctuation on endangered species, and (4) the relationship between mainstream and tributary habitats and their utilization by endangered species.

Studies have been done since the 1978 Biological Opinion, but many of the same conditions and questions listed above persist today as reiterated in the draft Biological Opinion issued October 1993 (USDI, Service 1993a). This draft Biological Opinion states that the humpback chub and razorback sucker are in jeopardy. Interactions between these endangered fish with non-native fish are also of concern, as are interactions of non-native fish with all other native fishes. Seven elements are listed in the 1993 Biological Opinion that are to be followed in an effort to alleviate jeopardy.

Humpback Chub Without the Project

No Action

Since closure of Glen Canyon Dam, the range of the humpback chub in the Colorado River mainstem has become restricted to the reach near the confluence with the LCR (Maddux et al. 1987, Valdez et al. 1992). The cold water temperatures appear to inhibit spawning in the mainstem Colorado River and are partially responsible for the decline of the species in the Grand Canyon. Humpback chub spawning and larval rearing has been restricted to the relatively warm waters of the LCR. Spawning has not been documented in other tributaries, although water temperatures sufficient for spawning occur. Adult fish have been collected near the mouths of Bright Angel, Shinumo, and Havasu Creeks during the spring months (Valdez et al. 1992). Postlarval humpback chub found downstream to RM 161 (approximately four miles downstream from Havasu Creek) suggest occasional successful reproduction in mainstem or lower tributaries (Kubly 1990). The cold water temperatures appear to have a beneficial effect by precluding the establishment of warmwater exotic species which may compete with or prey upon humpback chub.

Low flows of 1,000 cfs or 3,000 cfs would likely impede access to tributaries, except the LCR. Low flows may also lead to spawning of fish in tributary confluence areas where eggs and larvae may be subsequently subjected to high flows and reduced temperatures resulting in increased mortality.

Daily flow fluctuations would continue to destabilize backwater and nearshore habitats used as nurseries by early life stages of humpback chub. Fluctuations may inundate areas and reduce water temperatures resulting in decreased growth or increased mortality. Fluctuations may also desiccate backwaters and force larvae and young fish into mainstem areas, exposing them to reduced temperatures and food and increased predation. Daily fluctuations may displace juvenile chubs from sheltered shorelines and tributary mouths, forcing young chubs into mainstem river habitats where they could be at risk to greater predation and energy expenditure (Valdez et al. 1992, Angradi et al. 1992b).

Periodic fluctuations could increase the photic zone for aquatic vegetation, resulting in higher production near the dam. Fluctuations would also increase drift to downstream areas occupied by humpback chub. Conversely, fluctuations could dewater Cladophora and associated organisms and expose them to drying or freezing, thus leading to decreased production of food for downstream areas.

Daily fluctuating flows would continue to limit the availability of adequate habitat components of the aquatic ecosystem upon which the humpback chub and other native fishes depend (USDI, Reclamation 1989). Maximum flows of 31,500 cfs followed by low flows of 1,000 cfs or 3,000 cfs disrupt portions of the life cycle of the species and may have short and long-term effects on the population.

Humpback Chub With the Project

Maximum Powerplant Capacity

Impacts to humpback chub would likely be similar to those under the No Action Alternative.

All Remaining Alternatives

Cold water releases would continue to inhibit spawning in the mainstem and limit growth and survival under all alternatives. Cold water may have a beneficial effect by inhibiting the establishment of warmwater exotic species which may prey on or compete with the humpback chub. Food resources would be affected differently under each alternative (see AQUATIC VEGETATION and NATIVE FISHES sections).

All remaining alternatives would have the provision of beach/habitat building flows. Three alternatives, MFF, MLFF, and SASF, would include the provision of habitat maintenance flows. Consistent low water years with high sediment inflow may result in the filling of some backwaters. Greater stability in backwaters may result in establishment of vegetation in the long-term, ultimately eliminating existing backwater areas. This should be offset by periodic moderate or high water years, beach/habitat building flows, habitat maintenance flows, and to some extent fluctuating flows, which would scour and reform backwater areas.

High Fluctuating Flows

Impacts to humpback chub would likely be similar to those under the No Action Alternative. Low flows below 5,000 cfs would likely impede access to tributaries, except the LCR.

High daily fluctuations would continue to destabilize nursery areas. Higher flows may inundate areas and reduce water temperatures resulting in decreased growth or increased mortality. Lower flows may desiccate backwaters and force larvae and young fish into mainstem areas with reduced temperature and food and increased exposure to predation. Daily fluctuations may displace juvenile chub from sheltered shorelines and tributary mouths, thus forcing young chubs into the mainstem and subjecting them to greater predation risk and energy expenditure (Valdez et al. 1992).

Moderate Fluctuating Flows

Many of the effects of this alternative would be similar but with slight improvement to those under the previous alternatives. Minimum flows of 5,000 cfs would allow fish access to most tributaries during the year. Cold water temperature, daily fluctuations, and displacement factors would continue to limit humpback chub in the mainstem.

Modified and Interim Low Fluctuating Flows

Many of the effects of the MLFF and ILFF Alternatives would be similar to but of lesser magnitude than those under previous alternatives. Minimum flows of 5,000 cfs would allow fish access to most tributaries. The 8,000 cfs minimum requirement during the day may allow an increase in food base above the 5,000 cfs reliable minimum level. Cold water temperature, daily fluctuations, and displacement factors would continue to limit humpback chub in the mainstem.

Daily fluctuations are sufficient to continue to destabilize smaller backwaters and force movements of fish from preferred sites (G. Doster, AGFD, pers. comm.) affecting energy expenditures and potentially reducing survival and reproduction (Angradi et al. 1992b, Valdez 1992). Also, under interim operations during 1993, daily fluctuations negatively affected the larval and young-of-year humpback chubs amassed at the mouth of the LCR by causing the young fish to be swept into the mainstem when the river level dropped (G. Doster, AGFD, pers. comm.).

There is evidence of mainstem spawning near or above RM 30 and RM 204 under interim operations during 1993 (AGFD 1994). A few larval humpback chub were found near these river locations. These spawning areas are thought to be associated with warm springs in the mainstem. However, there is still no evidence of recruitment in the mainstem.

Existing Monthly Volume

Impacts to humpback chub would be similar to those under the low fluctuating flows alternatives, although less detrimental. Reliable minimum flows of 8,000 cfs should not impede access to tributaries. Tributary confluences would not be subjected to daily changes in stage, and thus would be improved as nursery habitats.

Decreased flow fluctuations would stabilize shoreline and tributary confluence habitats. Increased permanence would benefit young chubs. Increased stability and temperature of some backwaters would increase their value for young humpback chub as nursery habitat. River flows are projected for the summer months of July and August to be 16,200 cfs for a low volume year and 27,600 cfs for a high volume year. Since backwaters currently occur primarily at flows lower than proposed by this alternative during the summer months, overall existing backwater habitat would be reduced.

Seasonally Adjusted Steady Flows

This alternative would more closely resembles the natural, pre-dam flow pattern of the Colorado River. Several effects of this alternative would be different than those of other alternatives. Access to tributaries would be facilitated by the high, spring steady flows. Tributary confluences would not be subjected to daily changes in stage, and thus would be improved as nursery habitats.

Backwaters would be more prominent, stable, and warmer during lower flows of the summer rearing period. These backwater habitats would support development of food resources such as zooplankton for larval and young-of-year humpback chub. Nearshore habitats would be improved for young-of-year and juvenile life stages of humpback chub.

Year-Round Steady Flows

Effects of this alternative would be similar to the EMV Alternative but without monthly flow adjustments. Flows would not impede access to tributaries. Tributary confluences would not be subjected to daily changes in stage, and thus would be improved as nursery habitats.

The YRSF Alternative would have variable effects on juvenile chub habitat. These flows may lead to increased stability and temperatures in backwaters and would increase their value to young humpback chub as nursery habitat. However, in the absence of periodic floods or high water years, backwaters would not likely persist under stable flow conditions due to sediment filling.

Flow levels of 11,400 cfs scheduled for low volume years may be too high for the occurrence of many backwaters. Overall, available habitat may decrease since backwaters appear primarily at flows lower than those proposed by this alternative.

RAZORBACK SUCKER

The razorback sucker (Xyrauchen texanus) was recently listed as endangered throughout its range (October 23, 1991) with critical habitat in the Grand Canyon (100 year flood plain from the Paria River to Hoover Dam) (March 21, 1994). A commercial fishery existed for the species in Arizona up until about 1949 (Minckley 1973). During recent times, the distribution and abundance of the razorback sucker has declined dramatically. Currently, the species in the Lower Colorado River Basin is common only in Lake Mohave. This population represents the largest known remaining population of the species (Minckley 1983). Small numbers of razorback suckers have also been collected in Lake Mead, Senator Wash Reservoir, California, and irrigation canals connected to the Lower Colorado River (Minckley et al. 1991). Small numbers of razorback suckers and possible hybrid razorback suckers have been captured in the Grand Canyon in surveys conducted since the mid 1980's (Valdez et al. 1990). Minckley (1991), however, indicates that pre-dam sampling was rare for this species. Those surveys did not prove that razorback suckers were ever common in Marble and Grand Canyon above Lake Mead (Minckley et al. 1991).

The razorback sucker is a long-lived species. Estimated ages of fish caught in Lake Mohave have ranged from 24 to 44 years (McCarthy and Minckley 1987). Eighty-nine percent of the 70 fish aged by McCarthy and Minckley (1987) were estimated to have hatched prior to or coincident with reservoir construction in the lower basin of the Colorado River. This information indicates a loss of the species ability to reproduce, recruit, or survive following impoundment of the river.

The razorback sucker occupies a wide range of habitats in the Colorado River system. Young fish utilize shallow, warm, low velocity areas and backwaters as nursery habitats, moving to deeper and swifter water as they mature (Valdez and Wick 1981, Tyus 1987, Bestgen 1990, Minckley 1991, Valdez et al. 1992). Adult fish have been known to use a variety of habitats including eddies, deep runs, pools, backwaters, flooded riparian areas, and tributary confluence zones (Valdez and Wick 1981, Tyus 1987, Bestgen 1990, Tyus and Karp 1990, Minckley 1991, Valdez et al. 1992). During winter, adult razorback suckers are relatively sedentary, occupying slow runs, eddies and other low velocity habitats (Valdez and Masslich 1989). During the spring, adult fish are consistently captured in inundated lowlands, backwaters, and gravel pits. Fish appear to stage in these areas before spawning and may also use these areas to feed and recuperate after spawning (McAda and Wydoski 1980, Tyus 1987, Tyus and Karp 1990).

Ripe razorback suckers have been captured in the Green River when water temperatures were between 14°C and 16°C and spring flows were increasing toward their peak (Tyus and Karp 1990). During peak flows Tyus and Karp (1989) observed ripe adults moving from the cooler mainstem Green River (15-16.5°C) to warmer, flooded lowlands (17-21°C). Spawning in Lake Mohave has been known to occur over cobble/gravel shorelines (Marsh and Langhorst 1988) from late winter to early summer at temperatures ranging from 10-20°C

(Bestgen 1990). The habitat of juvenile razorback suckers is not known but inferred to be similar to that of adults.

Reasons for the decline of the razorback sucker are not certain but have been attributed primarily to modification of historical habitats and introductions of non-native fish species (Minckley 1991). Natural riverine habitats have been altered by impoundments and modification of historical hydrologic patterns. Riverine temperatures have been altered by controlled reservoir releases. Introductions of non-native fish species into the Colorado River system have resulted in changes in trophic interactions that may be detrimental to razorback suckers due to increased competition and predation by introduced species.

Razorback Sucker Without the Project

No Action

The cold water temperatures that occur in the mainstem river appear to inhibit spawning of the razorback sucker and may be partially responsible for the decline of the species in the Grand Canyon. The low temperature of water releases under this alternative would continue to preclude the establishment of warmwater exotic species which may compete with razorback suckers.

Water temperatures sufficient for spawning occur primarily in the tributary streams and may also exist in the lower canyon areas. Use of tributaries by razorback suckers for spawning in the Grand Canyon has not been documented, but the potential of such tributary use cannot be discounted. Access to tributaries would be precluded by the low flows of this alternative (flows less than 5,000 cfs), except perhaps the LCR.

In the mainstem river, lack of consistently inundated lowlands during the spring limits or prevents successful reproduction. Lack of nursery areas or the occurrence of daily fluctuations which result in destabilization of backwater habitats may limit or prevent successful recruitment of the species.

Razorback suckers may survive in the Grand Canyon only as adults and in extremely low numbers under this alternative. The combination of low river temperatures and relatively large flow fluctuations would likely continue to limit the availability of adequate habitat components of the aquatic ecosystem upon which the razorback sucker and other native fish depend (USDI, Reclamation 1989). Maximum flows of 31,500 cfs followed by low flows of 1,000 cfs or 3,000 cfs may disrupt portions of the life cycle of the species and may have short and long-term effects on the population.

Razorback Sucker With the Project

Maximum Powerplant Capacity

Impacts to the razorback sucker under this alternative would be similar to those under the No Action Alternative.

All Remaining Alternatives

Cold water releases would continue to inhibit spawning in the mainstem under all alternatives. Cold water may have a beneficial effect by inhibiting the establishment of warmwater exotic species which might prey on or compete with the razorback sucker.

All remaining alternatives would have the provision of beach/habitat building flows. Three alternatives, MFF, MLFF, and SASF, would include the provision of habitat maintenance flows. Consistent low water years with high sediment inflow may result in the filling of some backwaters. Greater stability in backwaters may result in establishment of vegetation in the long-term, ultimately eliminating existing backwater areas. This would likely be offset by periodic moderate or high water years, beach/habitat building flows, habitat maintenance flows, and to some extent fluctuating flows, which would scour and reform backwater areas. Flooded lowlands and riparian areas may be present during moderate and high water years and may provide spawning habitat for razorback suckers.

High Fluctuating Flows

Impacts to the razorback sucker would be similar to those under the No Action Alternative. Access to potential spawning tributaries, except the LCR, may be impeded by low flows. Flow fluctuations would continue to destabilize potential backwater and nearshore nursery habitats.

Moderate Fluctuating Flows

Many of the effects of this alternative would be similar but with slight improvement to those under the previous alternatives. Access to potential spawning tributaries would not likely be impacted by low flows of 5,000 cfs. Razorback suckers may benefit from the rising limb of the habitat maintenance or beach/habitat building releases that may enhance access to spawning areas. Flow fluctuations would continue to destabilize potential backwater and nearshore nursery habitat.

Modified and Interim Low Fluctuating Flows

Many of the effects of the MLFF and ILFF Alternatives would be similar to but less severe than those under previous alternatives. Access to potential spawning tributaries would not be impeded by low flows. Razorback suckers may benefit from the rising limb of the habitat maintenance or beach/habitat building releases that may enhance access to spawning areas including lowland areas. Flow fluctuations would continue to destabilize potential backwater and nearshore nursery habitats.

Existing Monthly Volume

Impacts to the razorback sucker would be similar to those under the low fluctuating flow alternatives, although less detrimental. Access to potential spawning tributaries would not be impeded. Flooded lowlands and riparian areas may be present during moderate and high water years and may provide spawning habitat for razorback suckers. Relatively stable flows would likely lead to increased stability and water temperatures of potential backwater and nearshore nursery habitat areas, thus benefiting the razorback sucker.

Seasonally Adjusted Steady Flows

This alternative would more closely resembles the natural pre-dam flow pattern of the river. Several effects of this alternative would be different than those of other alternatives. Low flows would not preclude access to potential spawning tributaries. The relatively high constant flows during the spring would enhance access to tributaries and to flooded lowland areas for spawning. Razorback suckers may benefit from the rising limb of the habitat maintenance or beach/habitat maintenance releases that may enhance access to spawning areas.

Steady flows may lead to increased stability and temperatures in backwaters and would increase their value as nursery habitat. Given the geomorphology of the Grand Canyon, it is likely that lowland spawning and nursery areas would be inundated during high water years.

Year-Round Steady Flows

Effects of this alternative would be similar to the EMV Alternative but more stable with minor or no monthly flow adjustments. Flows would not preclude access to potential spawning tributaries. Access to flooded lowland areas for spawning may occur only during moderate and high water years. Stable flows would likely lead to increased stability and temperatures of potential backwater and nearshore nursery habitat areas. However, in the absence of periodic floods or high water years, backwaters would not likely persist under stable flow conditions due to sediment filling.

PEREGRINE FALCON

Grand Canyon National Park supports the largest known breeding population of the endangered peregrine falcon (Falco peregrinus) in the conterminous United States, with the majority nesting in the canyon 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). Extrapolation estimates indicate that 96 pairs of peregrine falcons may exist in the project area (Brown 1991a).

<u>**Peregrine Falcons Without the Project**</u>

No Action

A dependent relationship between river flow regime and water turbidity, insect and insectivorous birds, and densities of breeding peregrine falcons in Grand Canyon has not been documented. The greatest factor contributing to the increase in peregrine falcons in the U.S. is the restricted use of pesticides such as DDT. 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 would be significant enough to adversely impact peregrine falcon populations. If dam operations have affected peregrine falcon populations through changes in insect abundance and consequent changes in insectivorous bird abundance, the current status of peregrine falcons would not be expected to change in response to this alternative.

<u>**Peregrine Falcons With the Project**</u>

All Action Alternatives

For reasons similar to the previous discussion, it is unlikely that any of the action alternatives would affect peregrine falcons in Grand Canyon.

BALD EAGLE

The Colorado River corridor within the Grand Canyon may be an important winter concentration area for the endangered bald eagle (<u>Haliaeetus leucocephalus</u>). While eagles are capable of taking fish from a river system with characteristics similar to the Colorado River before Glen Canyon Dam, they were not observed in concentrations in the Grand Canyon until after establishment of the rainbow trout fishery. 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 (Brown and Leibfried 1990; USDI, NPS 1992). Eagles were first documented in the winter of 1985-1986 (four birds, B. Brown pers. comm.) and have increased to a high of 26 birds counted in a single day at Nankoweap Creek in late February 1990 (USDI, NPS 1992). The number of eagles in early 1993 and 1994 are comparable to figures recorded in the 1980's, possibly due to the heavy run-off and debris that periodically changes the channel of Nankoweap Creek (Tim Tibbitts, Service, pers. comm.).

The number of eagles at Nankoweap Creek may be directly related to the abundance of spawning trout. More than 500 trout have been recorded at Nankoweap Creek during a recent year, with the spawning run peaking at 1,500 fish in 1990. 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. The bald eagle concentration at Nankoweap Creek was down in 1991, as was 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 (Brown and Leibfried 1990; USDI, NPS 1992). However, an examination of fish health during the same time period indicated parasitic nematodes and low body fat in rainbow trout (Landye 1993).

Bald Eagles Without the Project

No Action

Some 70-100 bald eagles may have moved through the Grand Canyon in February and March of 1990 (Brown and Leibfried 1990, USDI, NPS 1992). Eagles took trout stranded by fluctuating discharges in isolated pools along the river near the creek mouth, but the focus of feeding activity was in Nankoweap Creek (Brown and Leibfried 1990; USDI, NPS 1992). The peak of the bald eagle-trout concentration occurred in late February, early March of 1990 with over 1,000 trout in the creek and 26 bald eagles in the Nankoweap area. This peak seemed to occur when creek temperatures equalled river temperatures and was not directly related to Glen Canyon Dam flows (USDI, NPS 1992).

During this survey, there was a physical barrier at the mouth of Nankoweap Creek that impeded trout from ascending the creek when river discharge was below approximately 4,000 cfs (B. Leibfried, pers. comm.). At discharges between 4,000 and 15,000 cfs, the creek mouth and the lower 100 ft 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 eagles. When discharges ranged from approximately 15,000 to 20,000 cfs, these areas were deeply inundated and eagles foraged further up Nankoweap Creek.

Operations under the No Action Alternative do not appear to affect eagle spatial foraging patterns. Fluctuating flows would continue to provide stranded fish for eagles near the mouth of Nankoweap Creek. High flows may limit foraging opportunities and success in the mainstem.

Bald Eagles With the Project

Fluctuating Flow Alternatives

Some effects to eagles would be similar to those under the No Action Alternative. Eagles foraged 11 to 18% of all trout recorded taken at Nankoweap from individuals stranded in pools in 1990 and 1991, respectively (USDI, NPS 1992). As daily fluctuations decrease, foraging opportunities may be shifted from the tributary to the mainstem. The reduced stranding of fish would decrease the availability of easily accessible forage. Low flows are expected to increase foraging opportunities throughout the river. A beach/habitat building flow, habitat maintenance flows, and high water years with high steady flows in early March, may facilitate trout access to tributaries but limit eagle foraging.

Steady Flow Alternatives

All three steady flow alternatives would result in flows of 8,000 cfs or greater during a low water year and should not influence foraging in the river or creek. The reduced stranding of fish would decrease the availability of the easily accessible forage resource. The overall effects of steady flows on foraging opportunities and success would depend on the importance of stranding associated with the opportunistic response of eagles. A beach/habitat building flow, and habitat maintenance flows under the SASF Alternative, or other conditions with high steady flows in March may provide cover for trout and make eagle foraging more difficult as isolated pools and nearshore habitats are inundated.

SOUTHWESTERN WILLOW FLYCATCHER

The southwestern willow flycatcher (Empidonax traillii extimus) is a proposed species under the Endangered Species Act, and is one of the most rare birds in the Grand Canyon corridor. Proposed critical habitat in the Grand Canyon includes the surface water throughout the May through September breeding season, and areas within 100 m of the edge of surface water from river mile 39 to 71.5 (USDI, Service 1993b).

The Service was petitioned to list this species in January of 1992. The 90-day finding determined that the petition may be warranted. A one-year finding was published July 23, 1993. Nesting pairs in the Grand Canyon may have increased following closure of Glen Canyon Dam (Brown 1991b). Carothers and Brown (1991) attribute this response to increases in riparian vegetation following reductions in major flood discharges. In the Grand Canyon, this species feeds on insects and nests in tamarisk in the NHWZ (Brown 1991b) and is generally associated with marsh areas (Sogge and Tibbitts 1992).

Southwestern Willow Flycatchers Without the Project

No Action

In the 1980's, the population of Southwestern willow flycatchers in Arizona was believed to have been no more than a few dozen pairs, with the largest number of individuals in the Grand Canyon (Unitt 1987). However, only two pairs were located in the Grand Canyon in 1991 (Brown 1991b). In 1992 two pairs and three single birds were located in Grand Canyon (Sogge and Tibbitts 1992). At this time, these few pairs are considered important to the subspecies viability due to the current low number of known breeding pairs throughout its range. Possible causes for apparent decline in the numbers of nesting pairs include habitat fragmentation and loss, reduced patch size through habitat erosion, brood parasitism by the brown-headed cowbird (Molothrus ater) (Brown 1991b, Sogge et al. 1993), and the invasion of tamarisk which may not provide the thermal protection created from native plants (Hunter et al. 1988). High daily fluctuations and ramp rates may continue to deteriorate Southwestern willow flycatcher habitat through sediment erosion and resultant decline in shoreline vegetation. Decline of the willow flycatcher in Grand Canyon is compounded by the decline in the species on a regional level.

Southwestern Willow Flycatchers With the Project

Maximum Powerplant Capacity and High Fluctuating Flows

Impacts to the Southwestern willow flycatcher under these alternatives would be similar to those under the No Action Alternative, or exacerbated due to increased maximum flow associated with the MPC Alternative.

Interim Low Fluctuating Flows

In 1993, 13 individuals were located in Glen and Grand Canyons. Nests were located at two sites, but no Southwestern willow flycatcher young fledged. The maximum flows associated with this alternative (20,000 cfs) have the potential to directly impact willow flycatcher nests sites or substrate. However, this was not observed during the 1992 or 1993 willow flycatcher monitoring seasons which were low water years. Nests were generally 3.5 m or more above the ground. The actual patches where the nests were located were at least 1.0 m above the highest flows observed. During high water years the impacts would likely be similar to other alternatives.

Other Action Alternatives

The MLFF and MLFF Alternatives, with decreased daily fluctuations and ramp rates, and the addition of beach building flows and habitat maintenance flows have the potential to adversely affect Southwestern willow flycatcher habitat through habitat erosion and fragmentation. The steady flow alternatives may best benefit the flycatcher by reducing erosion of shoreline vegetation that is important for production of food and nesting needs. However, it is not known whether or not this gain will be sufficient to supplement losses of marsh sites drying during low water years or being inundated during high water years or the addition of beach/habitat building flows or habitat maintenance flows.

Over the long term, with occasional high water years and the addition of habitat maintenance flows or beach building flows, flow related vegetation changes may occur. Possible changes include habitat fragmentation, changes in plant species composition, and changes in patch size or configuration (Sogge et al. 1993). Habitat suitability factors are not well known for this species, but alternatives that decrease habitat fragmentation should also decrease brown-headed cowbird parasitism. Habitat fragmentation is strongly correlated with increased rates of brood parasitism by brown-headed cowbirds (Brittingham and Temple 1983). Under any alternative, affects of flow may not be apparent until a cowbird control program is instituted.

SPOTTED BAT

There has been one river corridor record of the spotted bat (Euderma maculatum), a Category 2 species under the Endangered Species Act in the Grand Canyon. The survey records are limited, the sighting is considered accidental, and this species will not be treated further in this document.

KANAB AMBERSNAIL

The endangered Kanab ambersnail (Oxyloma haydeni kanabensis) is a terrestrial snail in the family Succineidae. The Kanab ambersnail was known to occur in two populations, one near Kanab, Utah, and one in Grand Canyon National Park. One of the two Kanab populations has been extirpated leaving only one known population in Utah (J. Larry England, Service, Salt Lake City, Utah, pers. comm.) and one in the Grand Canyon. Some snail populations probably occurred in Grand Canyon in the pre-dam environment because populations are so widely separated and fossilized remains have been found in various locations (Spamer and Bogan 1993, Spamer 1993).

In Utah, the species is associated with permanently wet soil or shallow standing water and the presence of cattail, or at least permanently wet soil which indicates the potential for cattail (Clarke 1991). Vegetative cover is also a necessity for this species (Clarke 1991). In Arizona, the Kanab ambersnail in the Grand Canyon is associated with cardinal monkey flower (Mimulus cardinalis). Since the species has been found below the 30,000 cfs water level, individuals and/or the associated habitat may be affected by uncontrolled or controlled floods or flows above 30,000 cfs.

Kanab Ambersnail Without the Project

No Action

In the Grand Canyon, the Kanab ambersnail population is restricted to the wetted area created by a perennial stream. This stream flows from a spring in the wall of the canyon at the base of limestone cliffs. The wetland where this population is currently known to reside is approximately 100 m long and 10 to 30 m wide with most of the habitat and population occurring above the fluctuating zone, although individuals have been located at or below 30,000 cfs. Since the marsh area where this species occurs is spring fed, changes in marsh development along the river corridor would not likely affect this species.

It is not known if this species occurred in Grand Canyon prior to the 1983 flood or is capable of withstanding floods. However, samples identified as Lymnaea (Cole and Kubly 1976) may have been the Kanab ambersnail (Kubly, AGFD, pers. comm., Spamer and Bogan 1993).

The Kanab ambersnail may be affected by this alternative. Maximum allowable releases of 31,500 cfs are expected to occur. In addition, floods greater than 40,000 cfs are expected to occur once in 40 years. Individuals within the flood zone may be adversely affected under both of these scenarios. The extent of this impact is not known. Higher flows may limit the expansion of the population down towards the river's edge, and also limit the number of snails or amount of suitable habitat found at lower levels.

Kanab Ambersnail With the Project

Maximum Powerplant Capacity

Since this alternative would be similar to the No Action Alternative, impacts would be similar to those described under that alternative. In addition, the possible maximum flow of 33,500 cfs may exacerbate the situation.

Other Action Alternatives

Limiting uncontrolled floods and limiting fluctuations may allow for the expansion of the population down to the river's edge. Habitat maintenance flows and beach/habitat building flows could then potentially impact individuals in the expanded areas. Individuals may be impacted by daily flows during high water years. Major uncontrolled floods or beach/building flows may affect the species and/or their habitat. Flood releases may impact individuals through direct mortality or displacement, and distribute individuals or egg masses further downstream. This method of distribution is not known for this species and would more than likely result in mortality. Since the marsh area where this species occurs is spring fed, changes in marsh development along the river corridor would not likely affect this species.

OTHER SPECIAL STATUS SPECIES WITHOUT THE PROJECT

The State of Arizona lists three species of concern that may occasionally use the river corridor in the Grand Canyon: osprey (Pandion haliaetus), belted kingfisher (Ceryle alcyon), and the southwestern river otter (Lutra canadensis sonorae).

Both birds are uncommon in the Grand Canyon. The osprey is an uncommon fall or spring migrant (T. Corman, AGFD, pers. comm.) listed as a "State Threatened" species (AGFD 1988). The belted kingfisher is a "State Candidate" species found in low numbers year-round in the canyon and its tributaries.

The southwestern river otter is considered "State Endangered" by the State of Arizona. River otters have always been considered rare in the Grand Canyon (Hoffmeister 1971), with the last sighting reported in 1983 (J. Ray, NPS, pers. comm.). The southwestern river otter is listed as a Category 2 species under the Federal Endangered Species Act, but it has long been believed to be extirpated from this system. However, an unconfirmed sighting of a river otter by the NPS was noted in October of 1993.

Other Special Status Species With the Project

Since the osprey and belted kingfisher are not known to breed in the project area and their presence is transitory in the Grand Canyon region, they do not appear to rely on the mainstem for habitat requirements although they utilize the tributaries for food resources. All action alternatives are, therefore, unlikely to significantly impact these species.

PUBLIC USES OF FISH AND WILDLIFE RESOURCES

Fishing Without the Project

Around 1977, the reputation and importance of the trout fishery grew appreciably, and it was established as a premier fishery. With the growth of its reputation, the desires and expectations of anglers also grew. Those desires have to do with a range of values including the size and numbers of fish that can be caught, the source of the fish (either hatchery spawned or naturally spawned), and the aesthetic quality of the fishing experience. Natural reproduction in the changing environment of the Lees Ferry reach has not significantly contributed to the rainbow trout fishery. Evaluations conducted during GCES Phase I indicated that stocked fish dominated the sport catch during the high steady flows of 1983 and 1984 (Maddux et al. 1987).

Fishing With the Project

Rainbow trout utilize specific gravel sizes to make redds. Maddux et al. (1987) reported that spawning conditions in the Lees Ferry reach varied from year to year based upon accessibility to spawning bars. Daily flow fluctuations and armoring of the riverbed, adverse to trout spawning, were lessened in downstream reaches where fluctuations in river stage were attenuated or tributaries could provide stable sources of spawning materials and protected areas for emerging larvae. Flows that improve the quality and quantity of available spawning habitat should increase the potential for naturally spawned trout. In fact, since the implementation of interim flows in August 1991, a reduction in trout stranding and an improvement in trout weight has occurred (AGFD 1993). Also, the Lees Ferry trout population is reported to be comprised of 78% naturally reproduced trout based on August 1992 electrofishing data (AGFD 1993).

The quality of the outdoor experience may be decreased through periodic exposure and/or the erosion of gravel bars, beaches, and campsites. Navigational hazards may increase at gravel bars intermittently exposed due to low and fluctuating flows. Hazardous conditions may also exist during flood flows.

Nonconsumptive Recreation Without the Project

Wildlife-related recreation continues to be popular with more than half of all adults in the United States participating in such activities as photography, wildlife viewing and birdwatching (USDI, Service 1992). In 1991, more than 76 million adults participated in nonconsumptive wildlife related activities (USDI, Service 1992). In the Grand Canyon, recreationists take advantage of the opportunity to view a variety of non-game and game species on the river and in the adjacent riparian areas. Beavers, ring-tails, peregrine falcons, and various neotropical migratory songbirds are examples of species which contribute to the non-use values in Glen and Grand Canyons.

Nonconsumptive Recreation With the Project

Preliminary results from non-use valuation indicate that some members of the general public, who may never visit the Grand Canyon, receive value from knowing that these resources exist. If the resources were degraded, their value would decline (HBRS, Inc. 1992). Flows which protect fish and wildlife species are most likely to protect the non-use values associated with fish and wildlife resources. During the EIS scoping process conducted in 1990, many people expressed concerns for the overall condition of the ecosystem. Many requested to make the integrity of the ecosystem the top priority (Bear West 1990). Maintaining the integrity of ecosystem processes is the critical element.

DISCUSSION

The complexity of the Grand Canyon ecosystem makes it difficult to manage Glen Canyon Dam to optimize all resources present. The presence of the dam has changed the hydrology of the river, decreased the range in water temperatures, and reduced sediment load in the canyon. These changes affect the aquatic and terrestrial systems. Ecosystems are characterized by a variety of physical and biological processes under which native species have evolved. The preservation and promotion of native species wherever possible would ensure the best chances for viability. Acknowledging this, the goal of management of this project area should be to maintain, as closely as possible, pre-dam ecosystem processes under which fish and wildlife resources have evolved. Clarkson et al. (1994) corroborate this point in an unpublished report. The Service believes the SASF Alternative is the alternative that would most closely resembles pre-dam conditions and would best meet this objective. The Service believes this objective would focus on the natural resources most vulnerable to dam operations at this time, specifically endangered and native fish populations. This alternative would also benefit other fish and wildlife resources and the Lees Ferry trout fishery.

However, dam operations alone may not be sufficient to allow recovery of the endangered humpback chub due to the incompatibility of the cold water temperatures in the mainstem. The Service believes a selective withdrawal structure such as a multilevel intake structure (MLIS), in conjunction with flows which would protect and maintain backwater and nearshore habitats, has the potential for improving or correcting the current situation by facilitating the establishment of one or more additional spawning populations of humpback chub in tributaries or the mainstem. Before a MLIS is constructed, information should be collected and fisheries experts convened to conduct risk assessment evaluations to determine the potential biological responses from competitive and piscivorous exotic fishes and their interactions with native fishes. A list of potential studies is included in our recommendations.

The Service has prepared a draft Biological Opinion for the MLFF Alternative on species in the project area listed under the Endangered Species Act. The MLFF Alternative was identified as the preferred alternative in the draft EIS. The draft Biological Opinion states that the MLFF Alternative is likely to jeopardize the continued existence of the humpback chub and razorback sucker. The endangered fish research flows recommended as part of the Reasonable and Prudent Alternative (RPA) in the draft Biological Opinion are included as part of the preferred alternative in the draft EIS.

The MLFF Alternative as the preferred alternative has the concurrence of all the cooperating agencies, except the Service. The Service believes that the SASF Alternative would best represent the pattern of the pre-dam natural hydrograph and that it may more thoroughly enhance and maintain ecosystem components. The October 1993 draft Biological Opinion does not fully represent the Service's selection of the SASF Alternative as the preferred alternative. The draft Biological Opinion represents the minimal need to remove jeopardy to humpback chub and razorback sucker within the legal requirements of section 7 of the Endangered Species Act.

At this writing, the Service understands that during five low water years, steady flows would occur from April through October. These steady flows would affect the amount of water available for the fluctuating releases from November through March. A question arises as to whether releases as described under the MLFF Alternative would be realized during the period of November through March. Since different flow patterns would occur during two separate times of low water years, a new alternative has in effect been developed. Additional analysis on the preferred alternative is warranted.

In order to assist in equal consideration for fish and wildlife resources in the process of selecting a plan for operations of Glen Canyon Dam, the Service makes the following recommendations:

RECOMMENDATIONS

1. The historical operations of Glen Canyon Dam have eliminated the features of a natural hydrograph from river operations. To provide conditions more suitable for endangered and other native fish species, a hydrological pattern comparable to the pre-dam hydrograph should be evaluated.

   a. Flows should be as described in the October 1993 Draft Biological Opinion. The preferred alternative would be used as a platform from which to conduct studies of an experimental flow regime that more closely resembles the pattern of the pre-dam hydrograph. Experimental flows should occur from April through October and include high steady flows in the spring and low steady flows in the summer and fall carried out during low water years. High flows should occur during the spring run-off, peaking sometime between April and June. Low flows should follow and continue through October. Flows should include beach/habitat building and habitat maintenance flows to be released during the spring in low water years. Experimental flows should be conducted for a sufficient period of time to allow biological processes to function and for variability inherent in riverine ecosystems to be expressed.

2. In order to maintain the integrity of the Grand Canyon ecosystem, the sediment resource should be maintained or enhanced. Associated resources that provide habitat such as backwaters, substrate, and vegetation depend upon the availability and placement of sediment.

   a. During steady flow periods, daily flows should be steady with the exception of system regulation and adjustments that would allow fluctuations limited to 2,000 cubic feet per second (cfs) per day. Ramp rates for greater flow adjustments should be limited to 2,000 cfs per hour. These restrictions would minimize the rate of sediment erosion.

   b. Annual controlled high flows within powerplant capacity and periodic (approximately once in ten years) controlled high flows that exceed powerplant capacity should be conducted to reform the channel and translocate sediment and nutrients. These high flows should coincide with the pre-dam, spring run-off peak. Implementation of these flows should take into consideration sediment storage and availability, channel configuration, and vulnerable species' life cycles. The frequency and magnitude of these flows should be determined after an assessment is made of resource response to trial flows.

   c. Juvenile native fish may be susceptible to displacement by high volume flows. Therefore, these fish need to be considered when determining the magnitude and timing of controlled floods.

d. 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 the *Gila* taxonomy study (Reclamation contract 1-CS-40-0970), Reclamation, in consultation with the Service, National Park Service, and land management agencies such as the Havasupai Tribe, should 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.

3. Construction of Glen Canyon Dam has greatly modified the aquatic environment and resulted in degraded conditions for native fish species. Every attempt should be made to ensure native fish life stage requirements are met. These requirements include a reliable food resource and availability of and access to suitable spawning and rearing habitat.

a. Extended periods of flows less than 8,000 cfs should be avoided to protect aquatic food resources. Studies indicate that extended periods of exposure to desiccation or freezing limit occupation of the wetted perimeter of the channel by Cladophora and its associated invertebrate community (Angradi et al. 1992b, Blinn et al. 1992, AGFD 1993). Cladophora production should continue to be monitored.

b. Flows should be steady on a seasonal basis, particularly during the summer months (some variations may exist from tributary input or forecast changes), to provide warmer, stable backwaters and other low velocity sites suitable for native fish rearing habitat.

c. Information on the life stage requirements, distribution, and abundance of non-native warmwater fishes should be collated and analyzed. Native and non-native fish interactions and responses to changes in dam operations should be evaluated in both the lab and the field. If operations are found to be detrimental or offer no improvement in conditions for native fishes, operations should be reevaluated and modified if necessary.

4. Trout health problems in the Lees Ferry reach are significant. Infestation by nematode parasites (Bulbodacnitis ampullastoma), possibly transmitted by a copepod or amphipod intermediate host, continues to be the prime factor.

a. The life cycle of this parasite should be verified.

b. Environmental stressors such as flow regime, food reduction, water temperature, angling pressure, and stocking rate that may exacerbate parasitic infestations should be quantified.

5. A high incidence of the Asian tapeworm (Bothriocephalus acheilognathi) occurred in humpback chub in 1990 to 1992, and in speckled dace in 1991 and 1992 (AGFD 1993). This parasite was not detected before 1990 (Angradi et al. 1992b, AGFD 1993). The intermediate hosts for this parasite are cyclopoid copepods.

a. Effects of this exotic parasite on humpback chub and other native fishes should be assessed.

b. Effects related to flow regime, food availability, water temperature, and density-dependent factors should be quantified.

6. Special status species and their habitats should continue to be monitored, taking measures to protect species and promote their recovery as information is developed.

a. The minimum patch-size and vegetation-structure requirements of nesting Southwestern willow flycatchers should be determined. The rates of cowbird parasitism on Southwestern willow flycatchers as a function of patch-size should also be determined. Population numbers and associated habitats should continue to be monitored.

b. Wintering and migrating bald eagle habitat utilization and foraging patterns should continue to be monitored.

c. The northern leopard frog should be considered during the experimental high flows or floods which have the potential to negatively impact the frogs and/or their habitat.

7. Neotropical and other avifauna that may be potentially affected by operations of Glen Canyon Dam should continue to be monitored in association with shoreline emergent marsh and other riparian vegetation they utilize.

8. Reclamation should continue to evaluate alternatives characteristic of the BIO/WEST proposal which include high spring flows, stable summer flows, temperature modification, and sediment augmentation.

9. The Service recommends that Reclamation pursue a risk assessment and other necessary studies to determine the feasibility of a MLIS. We believe Reclamation should seek authorization to complete a feasibility study. The completion of these studies would be necessary in order for the Service and AGFD to make a recommendation for Reclamation to pursue congressional authorization. We offer the following guidelines for inclusion in the risk assessment and feasibility studies.

a. 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 change of the mainstem.

b. Determine from the literature, experimentation, and/or consultation with the scientific community, the 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, young-of-year and juvenile growth and temperature.

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

d. Assess the effects of elevated temperature on water quality, Cladophora and associated diatoms, Gammarus, aquatic insects, and fish parasites and diseases.

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

f. Investigate the effects of reservoir withdrawal level on fine particulate organic matter to understand the relationship between withdrawal level and reservoir and downstream resources, including aquatic invertebrates and fish species.

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APPENDICES

Appendix 1. Arizona Game and Fish Department letter

THE STATE OF ARIZONA

GAME & FISH DEPARTMENT

2221 West Greenway Road, Phoenix, Arizona 85023-4399 (602) 942-3000

June 8, 1994

Mr. Sam F. Spiller
State Supervisor
Arizona Ecological Services State Office
Fish and Wildlife Service
US Department of the Interior
3616 W. Thomas Rd., Suite 6
Phoenix, AZ 85019

Re: Operation of Glen Canyon Dam - Final Fish and Wildlife Coordination Act Report, AESO/FA

Dear Mr. Spiller:

The Arizona Game and Fish Department (Department) has reviewed the Fish and Wildlife Coordination Act Report for Operation of Glen Canyon Dam. Specific comments addressing clarifications and editorial changes are attached. These specific changes are requested in order to present a more accurate report to the Bureau of Reclamation and to facilitate the Department's concurrence with the recommendations of the report.

Approximately one year ago, the Cooperating Agencies associated with the Glen Canyon Dam Environmental Impact Statement (EIS) convened to discuss selection of a preferred alternative for the Draft EIS. The Department supported the Low Fluctuating Flow Alternative as the preferred alternative because we recognized that:

a) some uncertainty exists in predicting the long term response of native fishes (including the endangered humpback chub) to low, steady flow conditions that are outside of our experimental experience, and

b) the cost of implementing Seasonally Adjusted Steady Flows may not be justifiable in light of the uncertainty of endangered species responses.

Subsequently, the October 13, 1993, Draft Biological Opinion regarding the preferred alternative was issued. It included Endangered Fish Research Flows (steady flows as described in elements 1 and 3) as part of the Reasonable and Prudent Alternative. These Endangered Fish Research flows were included in the preferred alternative immediately before the Draft EIS was released. The Department supports Endangered Fish Research Flows to address the responses of native and endangered fishes to steady flows. The Department recommends that such research be conducted and evaluated within the forum of Adaptive Management, as described in the Draft EIS.

We advocate working towards expanding the population of humpback chub in the Grand Canyon ecosystem. Establishment of a second spawning population of humpback chub in the Colorado River mainstem and/or tributaries should be an important objective for the management of the species in Grand Canyon. We suggest adding a recommendation to this effect.

The Department can concur with the recommendations of the Fish and Wildlife Coordination Act Report with clarification of some of those recommendations. We indicate our concurrence with each recommendation based upon the indicated clarifications.

Recommendation 1

We concur with Recommendation 1 with the stipulation that the meaning be clarified. We understand that this recommendation supports **evaluation** of Endangered Fish Research Flows, steady flows from April through October, for a number of low water years. The number of research years is indeterminate. Experimental design would dictate the duration of these research years.

Recommendations 3b and 8 are tied to the research flows described under Recommendation 1. Both of these recommendations identify flow features and could be incorporated into Recommendation 1.

Recommendation 2

Sediment is an important component of the Grand Canyon ecosystem. We concur with Recommendation 2a for the ramp rate to be 2,000 cfs/day if flows are steady. Otherwise ramp rates should be as described for Low Fluctuating Flows, 2,500 cfs/hour up and 1,500 cfs/hour down, or as modified through Adaptive Management.

We concur with Recommendation 2b regarding controlled high flows. The desired magnitude of such flows is unknown. This issue is best addressed under the Adaptive Management forum.

We concur with Recommendation 2c stating juvenile native fishes, particularly the endangered humpback chub, be considered when scheduling controlled high flows. However, timing of controlled high flows is a critical issue and consideration of effects to young-of-year trout and riparian associated wildlife should also be considered in scheduling efforts.

Recommendation 3

Regarding Recommendation 3a, the Department advocates an absolute minimum flow of 5,000 cfs and minimizing releases below 8,000 cfs for fluctuating flow releases (as indicated in the preferred alternative). Prolonged weekend low flows should be avoided.

Recommendation 3b regarding steady flows is addressed above under Recommendation 1. We concur with Recommendation 3c.

Recommendations 4 and 5

The Department agrees that significant fish health problems exist. We concur with Recommendations 4 and 5 to assess the effects of the noted parasites on trout and native fishes.

Recommendations 6 and 7

The fishes are the species most directly affected by dam operations and are of primary concern, therefore efforts should be focused at this level. We have not documented significant effects to the special status species and avifauna mentioned in Recommendations 6 and 7. While some degree of monitoring may be appropriate, intensity of monitoring efforts should be tied to likelihood of effects from dam operations.

Recommendation 8

Flow features of Recommendation 8 were noted under Recommendation 1. In addressing the other components of this recommendation, some evaluation of sediment augmentation may be appropriate under the Adaptive Management forum. We conclude that sediment augmentation, in this context, is primarily to address turbidity as cover for native fishes. We concur that sediment augmentation to enhance turbidity as a cover element for native fishes has not been fully addressed. Sediment augmentation to offset erosion was evaluated in the Draft EIS and dismissed. Turbidity as a cover element could be further evaluated, and determination should be made if a feasibility level analysis is warranted. Temperature modification included herein is addressed under Recommendation 9.

Recommendation 9

We concur with all items of Recommendation 9. Under the Adaptive Management forum, a step-wise approach to evaluating and potentially implementing of a selective withdrawal structure is appropriate.

The Department appreciates the opportunity to comment on the Final Fish and Wildlife Coordination Act Report. We reserve the option to update this letter based on changes in the pending Final Environmental Impact Statement, pending Final Biological Opinion, and any supplement to the Final Fish and Wildlife Coordination Act Report regarding operations of Glen Canyon Dam.

Sincerely,

Duane L. Shroufe
Director

DLS:dkm

cc: John Rogers, Regional Director, US Fish and Wildlife Service, Albuquerque, NM
Charles Calhoun, Regional Director, Bureau of Reclamation, Salt Lake City, UT

Attachment

SPECIFIC COMMENTS

Executive Summary

Page 1, para 1, AGFD letter of concurrence: AGFD concurs with stipulations. Refer to the attached letter, dated June 8, 1994, as being Appendix 1 of the Substantiating Report.

Page 2, para 5, line 2: Insert a comma after Canyon - "...from Glen Canyon Dam to Separation Canyon, river mile..."

Page 3, para 4, line 2: Addition to the sentence to read - "The presence of the dam has **changed the hydrology of the river,** decreased the range in water temperatures..."

Page 3, para 5, line 8: Change occupied to collected - "...information should be collected and fisheries experts convened..."

Page 3, para 5, line 9: Addition to the sentence to read - "...determine the potential biological responses..."

Page 4, para 2, line 2: Delete the last four words of the first sentence and have the sentence read - "The MLFF Alternative as the preferred alternative has the concurrence of all the cooperating agencies, except the Service."

Page 4, para 2: Delete the last two sentences - ("The draft EIS includes the endangered fish research flows... These research flows would be required as an element of the...") - as the statements are already made in the previous paragraph.

Page 4, para 3: Add the following sentence to the end of the paragraph - Additional analysis on the preferred alternative is warranted.

Page 4, Recommendation 1, line 4: Change implemented to evaluated - hydrological pattern "...should be evaluated."

Page 4, Recommendation 1a: For a clear understanding, use the wording as in the draft Biological Opinion (underlined) and incorporate it into this recommendation with changes (in bold or strikeout) to read as follows - "Flows ~~during low water years~~ should be as described in the October 1993 Draft Biological Opinion. The preferred alternative will be used as a platform from which to conduct studies of an experimental flow regime that more closely resembles the pattern of the **pre-dam** hydrograph. Experimental flows **should occur from April through October and** ~~will~~ include high steady flows in the spring and low steady flows in the summer and fall carried out during low water years. High flows should occur during the spring run-off, peaking sometime between April and June. Low flows should follow and continue through

October. Flows **should** include beach/habitat building and habitat maintenance flows to be released during the spring in low water years. Experimental flows will be conducted for a sufficient period of time to allow biological processes to function and for variability inherent in riverine ecosystems to be expressed.

Page 5, Recommendation 2a: Addition to the beginning of the first sentence - "**During steady flow periods,** daily flows ..."

Page 5, Recommendation 2b: Insert a space before the word Implementation.

Page 5, Recommendation 3b: Change for to as - "... and other low velocity sites suitable **as** native fish rearing habitat."

Page 6, Recommendation 3c: Delete the following from the first sentence - "...collected by the scientific community...".

Substantiating Report

Cover letter: remove header A (DRAFT).

Make sure there are no "orphans" or "widows" in the document.

After all corrections are made and immediately before printing, regenerate the Table of Contents and List of Tables.

Page 1, para 2, line 3: AGFD concurs with stipulations.

Page 1, para 2, line 4: The AGFD letter is dated June 8, 1994.

Page 1, para 2, last line: There is no opening quotation mark to coincide with this closing quotation mark.

Page 2, para 3, lines 3 & 4: Deletion ('for this project') to have the sentence read - "Therefore, no EIS was prepared before the construction of the dam."

Page 3, para 2, first sentence: Addition, deletion and change to have it read - "Interim Operating Criteria were tested from August through October 1991 and implemented on November 1, 1991, by the direction of the Secretary."

Page 6, Common Elements: Include or not a blank line between each bullet, be consistent.

Page 7, Table 3: Column 1 - delete 'Beach/Habitat'. Make a solid line across the page under the headings (Alternative, Standard Operations, etc.). Insert a blank line below the line that will be across the page under the headings.

Page 7, para 2, line 1: Delete a space before the word flexibility.

Page 7, para 3, line 1: Addition - "The HFF **Alternative** would..."

Page 8, Table 4: The table is adapted from the 1994 EIS, not 1993.

Page 8, footnotes: Line up the footnotes so they appear to have the same margins.

Page 10, para 3, line 2: Addition - "...from the draft BO, **additional** analysis of the MLFF..."

Page 10, para 3, last line: Addition - "...year **for a number of low water years**, a new alternative has..."

Page 10 para 4, penultimate line: Addition - "...not exceed 2,000 cfs/**day**."

Page 11, para 1, line 2: Addition - "...more closely resemble **the pattern of** the natural pre-dam..."

Page 11, Table 5, heading, line 2: Deletion - "...for low water years (Reclamation files)."

Page 11, Table 5: Insert a solid line across the page to go under Month and Mean Water Release for Low Water Years (cfs). Remove the solid line under the October information line.

Page 13, para 1, line 2: Addition - "... tributaries at Lees, Ferry, **pre-dam** annual suspended..."

Page 13, para 1, line 3: Insert a hyphen between post and dam - "...post-dam loads between..."

Page 15, para 7: Please double check the numbers for stage differences under habitat maintenance flows and beach/habitat building flows for Moderate Fluctuating Flows.

Page 15, para 8, line 2: Change to - "...under **these alternatives** than under..."

Page 16, para 1, penultimate line: Delete 'percent' - "Under the ILFF Alternative, the probability of net gain in riverbed sand..."

Page 16, para 3, line 2: Addition - "...river stage for **the**..."

Page 16, para 3, last line: One of the mentioned alternative should be MLFF - "...0 to 1.0 ft under the ILFF **Alternative** and 3 to 4 ft higher under the ILFF Alternative."

Page 19, para 2, line 4: Addition - "...have been recorded **as high as** ~~at~~ 16°C..."

Page 19, para 4, line 3: Citation should be Angradi et al. 1992**b**, not 1992a.

Page 19, para 4, line 7: Addition and deletion - "...associated mainstem eddy **ranged from** ~~was~~ 12-15°C."

Page 19, para 5, item b: The proliferation of Cladophora is likely due to the clarity of the water, not the cold water temperatures.

Page 20, para 1, line 1: Addition - "...backwaters and differential warming for the various alternative**s** are addressed..."

Page 20, para 5, line 1: Correction - "...fish and wildlife resources **as** forage, cover and substrate..."

Page 21, para 1, line 3: Delete 'a freshwater amphipod' - "...non-native amphipod, Gammarus lacustris."

Page 21, para 1, line 6: Delete 'as this organic food source' - "...the river, is transported downstream..."

Page 21, para 4, line 1: Addition - "Downstream from the confluence of **the** Paria and Colorado rivers..."

Page 23, para 1, last sentence: Delete this sentence ('This information...Low Fluctuating Flows.') as it is already stated previously.

Page 23, para 1: This paragraph is part of Table 6 and should be on the same page as the rest of the table.

Page 23, para 5, line 5: Addition - "...vegetation occurs below the 23,000 cfs **level**."

Page 24, para 2, last sentence: Break this sentence into two - "...allow for the expansion of marsh vegetation. **An** overall change..."

Page 24, para 3, line 3: Correction - "...backwater marshes **by** disrupting woody plant..."

Page 24, para 3, last line: Addition - "...according to **the** individual action alternative."

Page 24, para 5, penultimate line: Correction and addition - "...this alternative is based on **the** reduced maximum **flow** of 22,300 cfs."

Page 25, para 2, penultimate line: Delete 'also' - "...below the 22,300 cfs stage may be buried or scoured."

Page 25, para 3, Modified and Low Fluctuating Flows: Please clarify how plants above 20,000 cfs level can be watered every three days if the maximum flow is 20,000 cfs.

Page 25, para 4, lines 5 and 6: Delete this sentence (Emergent dry marsh...support wet marsh plants.) as this statement is indicated so in the first sentence of this paragraph.

Page 25, para 4, last sentence: Please clarify the meaning of material in this sentence (This material would...inundation or erosion.). Is this material emergent marsh vegetation, and is the loss due to high flows? Also, place this sentence before the penultimate sentence in the paragraph (In the low water years...).

Page 25, para 5, line 3: Addition - "Minimal fluctuations of 2,000 cfs/**day**..."

Page 26, para 3, penultimate line: Should reference to marsh sites below the 11,400 cfs or 21,400 cfs mark be made here?

Page 26, para 4, line 2: Corrections - "Biological and structural diversiti**es make the riparian zone** the most important..."

Page 26, para 4, lines 4 & 5: Delete ', a critical food chain component'.

Page 26, para 4: Add a new sentence to the end of this paragraph - "These insects are critical food chain components."

Page 33, para 4: LFF has not been defined in the document. Correction - "Within the array of fluctuating alternatives, the low fluctuating flow (LFF) alternatives would...".

Page 33, para 6, line 2: Addition - "...blackflies feeding on drift **that** require..."

Page 35, Table 7: This table will stand alone on a single page. Correction under coho salmon information - insert a space between never established.

Page 36, para 1, line 2: Correction - "**An** amphipod...".

Page 36, para 5, line 5: Correction - "...because they **are** extirpated...". There should be a blank line to separate this paragraph from paragraph 6 on this page.

Page 37, para 3, lines 10 & 11: Delete 'Rearing habitat and' and combine the two sentences with a semicolon - "...suitability of native fish; information on the quality of backwaters..."

Page 43, para 2, lines 3 & 4: Delete this sentence 'Adults primarily...Angradi et al. 1992b)." as it is repeated below at a more appropriate location.

Page 43, para 2, line 7: Correction - "Angradi et al. (1992**b**)...", not 1992a.

Page 44, para 1, line 1: Delete 'to' - "Impacts would likely be similar...".

Page 44, para 2, lines 3 and 5, and para 3, line 3, and para 6, line 5: Correction - citations should be Angradi et al. 1992**b**, not 1992a.

Page 45, para 2, line 3, and para 4, line 6, and para 5, line 3: Correction - citations should be Angradi et al. 1992**b**, not 1992a.

Page 46, para 3, line 3, and para 7, line 2: Correction - citations should be Angradi et al. 1992**b**, not 1992a.

Page 47, para 5, line 2: Correction - citation should be Angradi et al. 1992**b**, not 1992a.

Page 51, para 2, line 3, and para 3, line 3: Addition - "...due to cold **water** releases..."

Page 53, para 4, line 2: Add a comma - "...on harvester ants, stranded Gammarus...".

Page 54: Add a blank line between the penultimate and last paragraphs.

Page 58, Table 10: Add a solid line across the page under the headings Common Name and Scientific Name. Insert a blank line above these headings. Put this table near the top of a page so it will fit properly.

Page 68, para 2, penultimate line: Addition - "...occurrence of **many** backwaters."

Page 72, para 2, line 7: Add a comma - "unknown,but unlikely..."

Page 73, para 2, line 8: Change the comma to a semicolon - "...Brown and Leibfried; USDI, NPS..."

Page 75, last para, line 3: Addition - "...habitat erosion **and** fragmentation."

Page 76, para 3: Insert a blank line between the third and fourth paragraphs (there are five paragraphs on this page).

Discussion section of the Substantiating Report

Page 79, para 4, line 2: Addition to the sentence to read - "The presence of the dam has **changed the hydrology of the river,** decreased the range in water temperatures..."

Page 80, para 1, lines 7 & 8: Delete 'studies are needed to evaluate' and insert an addition to read as follows - "Before a MLIS is constructed, **information should be collected and fisheries experts convened to conduct risk assessment evaluations to determine** the potential biological responses..."

Page 80, para 3, line 2: Delete the last four words of the first sentence and have the sentence read - "The MLFF Alternative as the preferred alternative has the concurrence of all the cooperating agencies, except the Service."

Page 80, para 3: Delete the last two sentences - ("The draft EIS includes the endangered fish research flows... These research flows would be required as an element of the...") - as the statements are already made in the previous paragraph.

Page 80, para 4: Add the following sentence to the end of the paragraph - Additional analysis on the preferred alternative is warranted.

Page 81, Recommendation 1, line 4: Change implemented to evaluated - hydrological pattern "...should be evaluated."

Page 81, Recommendation 1a: For a clear understanding, use the wording as in the draft Biological Opinion (underlined) and incorporate it into this recommendation with changes (in bold or strikeout) to read as follows - "Flows ~~during low water years~~ should be as described in the October 1993 Draft Biological Opinion. The preferred alternative will be used as a platform from which to conduct studies of an experimental flow regime that more closely resembles the pattern of the **pre-dam** hydrograph. Experimental flows **should occur from April through October and** ~~will~~ include high steady flows in the spring and low steady flows in the summer and fall carried out during low water years. High flows should occur during the spring run-off, peaking sometime between April and June. Low flows should follow and continue through October. Flows **should** include beach/habitat building and habitat maintenance flows to be released during the spring in low water years. Experimental flows will be conducted for a sufficient period of time to allow biological processes to function and for variability inherent in riverine ecosystems to be expressed.

Page 81, Recommendation 2a: Addition to the beginning of the first sentence - "**During steady flow periods,** daily flows ...". Also, delete 'cubic feet per second' and use cfs as it has already been defined.

Page 81, Recommendation 2b: Insert a space before the word Implementation.

Page 82, Recommendation 3a: Citation for Angradi et al. should be 1992**b**, not 1992.

Page 82, Recommendation 3b: Change for to as - "... and other low velocity sites suitable **as** native fish rearing habitat."

Page 82, Recommendation 3c: Delete the following from the first sentence - "...collected by the scientific community...".

Page 82, Recommendation 5: Citation for Angradi et al. should be 1992**b**, not 1992.

DKM:dkm

Appendix 2. Threatened, Endangered, and Candidate species known to inhabit, or are extirpated from, the river corridors of Glen Canyon Recreation Area (below the dam) and Grand Canyon National Park.

Species	Federal Status	Arizona Status
Kanab ambersnail		
(Oxyloma haydeni kanabensis)	Endangered	
humpback chub		
(Gila cypha)	Endangered	Endangered
bonytail chub		
(Gila elegans)	Endangered	Endangered
Colorado squawfish		
(Ptychocheilus lucius)	Endangered	Endangered
razorback sucker		
(Xyrauchen texanus)	Endangered	Endangered
bald eagle		
(Haliaeetus leucocephalus)	Endangered	Endangered
peregrine falcon		
(Falco peregrinus anatum)	Endangered	Endangered
willow flycatcher		
(Extimus traillii)		Endangered
SW willow flycatcher		
(Extimus traillii extimus)	Proposed Endangered	
osprey		
(Pandion haliaetus)		Threatened
belted kingfisher		
(Ceryle alcyon)		Candidate
southwestern river otter		
(Lutra canadensis sonorae)	Category 2	Endangered

Appendix 3. Life stage habitat requirements for selected fish species found in Glen and Grand Canyons.

Appendix 3. Life stage habitat requirements for selected fish species found in Glen and Grand Canyons. COMPILED BY D. McGuinn-Robbins.

Species	Spawning	Tributary Use	Backwater Use
Native fishes			
<u>Catostomus latipinnis</u> (flannelmouth sucker)	17-23°C[7,10,15,26] winter-early summer[15,35] spring-summer[10,25] Mar-May[26,34], descending limb of spring peak[33] cobble or gravel riffles[26,34] tributaries[10,16,35], backwaters[16] nurseries: backwaters[16,26,35,36] tributary mouths, nearshore slackwater[26,35]	spawning[10,16,26,35] nurseries[16]	nurseries[16,26,35,36] spawning[16]
<u>Gila cypha</u> (humpback chub)	16-22°C[1,15,35] 14-24°C, June-July[13] 19.5°C, shoreline eddies[14] Apr-May[35], Apr-June[15] Descending limb of spring peak[35,38] Gravel pockets among cobbles & boulders, mod-high velocity[35,38] 20°C optimum for eggs[11,15,17,35]	spawn in LCR, spring[35] spawn in spring-summer[10]	nurseries[35]
<u>Pantosteus discobolus</u> (bluehead sucker)	16-20°C[26] 17-23°C[15], 18.5-24°C[7,10] winter-spring[25,35] spring-early summer[10,15] Apr-May[26,34], descending limb of spring peak[33], tribs[16] cobble or gravel riffles[25,26,34] nurseries: backwaters[16,26,35,36] tributary mouths, nearshore slackwater[26,35]	spawning[10,16,26,35] nurseries[16]	nurseries[16,26,35,36]
<u>Rhinichthys osculus</u> (speckled dace)	17-23°C[7,10,15], 18°C[31], Apr-May[15,26] June[5], June-July[31], spring-summer[10] gravel[26,31,35] & cobble[26], bare rock[31] riffles[5] shallow water[26], tribs[16] nurseries: backwaters[16,26,35,36] tributary mouths, nearshore slackwater[26,35] fertilized eggs: 18°C[31]	spawning[10,26,35]	nurseries[16,26,35,36]

Appendix 3. Life stage habitat requirements for selected fish species found in Glen and Grand Canyons.

Species	Spawning	Tributary Use	Backwater Use
Xyrauchen texanus (razorback sucker)	~10-20°C[2,10,15,23,27,28,32,34,35] >15°C[26] Jan-Apr lower basin[25,26,27,35] Apr-June upper basin[23,26,27,28,32,34,35] backwaters[27,28], trib mouths[27] gravel bars[27,35] flooded lowlands[27,33] shallow riffles: sand, gravel, cobble[18,23,26,27,32,34] ascending & highest of spring peak[34] near peak runoff[35] 20°C optimum for eggs[15,17]	rest and feed at tributary mouths, do not spawn in [minor] tributaries[23,32,34]	nurseries[26,36]
Non-native fishes			
Cyprinella lutrensis (red shiner)	15-30°C[10,15,30] summer[5], calm water near objects[25]	use by various age classes?[35]	nurseries[36]
Fundulus kansae (plains killifish)	28-29°C[2,10] Apr-May[10,25], June-Aug[5], summer[31] tributary mouths[10] shallow water[5,24,25,31], sloping bank[24] gravel & sand[5,25,31]	spawning[10]	nurseries[36]
Pimephales promelus (fathead minnow)	15.5-18.5°C[5,10,30], 18°C[31], 15.6-27°C[35] 16-30°C, optimum 25°C[15] May-Aug[5,31], tributaries[35], backwaters[16] fertilized eggs: 25°C[31], 26°C[15] 31-30°C[35]	spawning[35]	nurseries[35,36] spawning[16]

Appendix 3. Life stage habitat requirements for selected fish species found in Glen and Grand Canyons.

Species	Larva	Young-of-Year	Juvenile	Adult
Native fishes				
Catostomus latipinnis (flannelmouth sucker)	backwaters[16,26] shallow, warm, low velocity areas[35] food: inverts, plankton[16]	backwaters[16] riffles[26], sheltered shorelines[25,26], tributaries[26] shallow, warm, low velocity areas[35]	tributaries[6] cobble shorelines, shallow cobble riffles, backwaters, tributary mouths[35]	eddies, deep pools, sheltered shorelines[26,35], backwaters[16] food: aquatic insects, benthic animals[25,26], algae[5], veg[25]
Gila cypha (humpback chub)	19-22°C[11] shallow, rocky shorelines, backwaters, tributary mouths[35,37] food: inverts[1,8]	19-22°C[11] backwaters[16,36,37] silt/sand slackwater[16,35,37,38] talus shorelines with boulders & ledges[38] food: inverts[1,8]	20-25°C[15] backwaters[16,36] boulder/bedrock nearshore areas[16,35,37] high gradients, eddies, and rocky shoreline runs[16,37] food: inverts[1,8]	boulder/sand substrate, eddies, high gradients[14,16,35,37] deep pools & eddies of whitewater canyons[16,26,38] food: invert drift[12,16,26,35] plankton, algae[25]
Pantosteus discobolus (bluehead sucker)	backwaters[16,26] shallow, warm, low velocity areas[35] food: inverts[1,16] plankton[16]	backwaters[16] riffles or below riffles, sheltered shorelines[26], shallow warm[35], low velocity areas[25,35], July-Sept[35] food: inverts[1]	tributaries[6] cobble shorelines, shallow cobble riffles, backwaters, tributary mouths, July-Sept[35] food: inverts[1]	eddies, deep pools, sheltered shorelines[26,35], runs[16,25,31] riffles[31], bottom dwelling[26], food: algae & assoc. inverts[5,25,26,31], diatoms & organic debris[26]
Rhinichthys osculus (speckled dace)	backwaters[26] shallow, warm, low velocity areas[31,35] food: inverts, plankton[1]	backwaters[16] shallow, warm, low velocity areas[35] tributary mouths, mainstem in winter[26] food: inverts[1], plankton[31]	tributary mouths, mainstem in winter[26] food: inverts[1]	tributaries[6,16] riffles, shallow shorelines, tributary mouths, mainstem in winter[26], backwaters[16] 9.5-18°C, cobble riffles, sheltered shorelines[35], swift or slow, cool or warm, shallow water[31] food: benthic inverts (facultative omnivore)[26] detritus[25], plants[5,31] algae, benthos, inverts[5,25,31], plankton[5,31]

Appendix 3. Life stage habitat requirements for selected fish species found in Glen and Grand Canyons.

Species	Larva	Young-of-Year	Juvenile	Adult
Xyrauchen texanus (razorback sucker)	backwaters[36] quiet shorelines[32] shallow, warm, low velocity areas[35] food: diatoms, algae, detritus[27,29], plankton[26,27,29,35]	21.5-24.5°C[27] backwaters[27,34] tributary mouths[27] shallow, warm low velocity areas[2,26,27,32,35,36,38] sheltered shorelines[25]	23-29°C[15] backwaters[27,34] tributary mouths[27] no recent recruitment[26,32] data lacking	23-25°C[2,10] 17-24°C[15] backwaters[25,26,27,32,34] runs, eddies[25,26,27] lowland flooded areas[34], major tribs[27] various mainstem habitats[27,32,35] sand, mud, gravel[25] food: plankton[25,26,27,35], detritus[26,27,35]; algae and insects[25,35]
Non-native fishes				
Cyprinella lutrensis (red shiner)			20-33°C[21] no shade, turbid shallow water, muddy to sand mix bottom[21]	21-31°C[10,15,20,30], to 39.5°C[5] turbid water[5,19,25], muddy bottom, unstable banks, deep-swift[19] & slow[22]-shallow[19] water, low fish species diversity[19] food: plankton[5,10], insects[5,10,25], algae[5,25] young of other fish[25]
Fundulus kansae (plains killifish)				shallow water[4,5,19,24,25,31] (swift or slow)[4,5,19,24,31] low fish species diversity[19] tributaries[6] tributary mouths[10], springs[10], small open sandy bottom streams[4,5,10,24,25,31], food: insects[5,10,24,25,31], diatoms & plant material[31], detritus[10] floating material[5,31]
Pimephales promelas (fathead minnow)	food: plankton and inverts[3]	food: algae and detritus[3]		20-29°C[9,15] tributaries[6] muddy bottom[19], slow turbid[19,25,31] shallow water, unstable shore, backwaters[19] clear or turbid water[5,31] low # fish species[5,19,25] food: aquatic insects[31] detritus, algae and plankton[5,10,25,31]

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