CHARACTERIZATION OF THE LIFE HISTORY AND ECOLOGY OF THE HUMPBACK CHUB IN THE GRAND CANYON

A Project Summary By R.A. Valdez

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INTRODUCTION

BIO/WEST, Inc. of Logan, Utah was granted a contract by the Bureau of Reclamation on September 1, 1990, to conduct investigations on the endangered humpback chub (Gila cypha) in the Colorado River in Grand Canyon. The project is entitled **Characterization of the Life History and Ecology of the Humpback Chub in the Grand Canyon**. Field work began October 1990 with 39 monthly trips scheduled through December 1993 and The Final Report due October 15, 1994. Two field trips remain in 1991 (October and November) and The 1991 Annual Report is due February 28, 1992 (Figure 1).

Purpose

To conduct in cooperation with the U.S. Fish and Wildlife Service and Arizona Department of Game and Fish ecological studies to determine the relationship between operations of Glen Canyon Dam and the ecology and life history requirements of the endangered humpback chub population in Grand Canyon.

This 4-year investigation will focus on the collection and analysis of biological information to test hypotheses about the ecology and life history of the humpback chub. The research will be conducted in conjunction with the Glen Canyon Environmental Studies (GCES) and conservation measures arising from a biological opinion on Glen Canyon Dam in 1978. These include Conservation Measure 5, **"Conduct Research to Identify Impacts of Glen Canyon Dam Operations on the Humpback Chub in the Mainstem and Tributaries"** and Conservation Measure 7, **"Establish a Second Spawning Population of Humpback Chub in the Grand Canyon".**

Objectives

This work is being conducted by BIO/WEST concurrent with studies by the U.S. Fish and Wildlife Service (FWS), Arizona Department of Game and Fish (AGF), and Arizona State University, all in cooperation with the National Park Service, Navajo Nation and the Hopi Tribe. The objectives and subobjectives of the combined investigations are:

Objective 1: To determine the ecological and limiting factors of all life stages of humpback chub in the mainstem Colorado River, Grand Canyon, and the effects of the Glen Canyon Dam operations on the humpback chub.

1A: Determine resource availability and resource use (habitat, water quality, food, etc.) of humpback chub in the mainstem Colorado River.

1B: Determine the reproductive capacity and success of humpback chub in the mainstem Colorado River.

1C: Determine the survivorship of early stages of the humpback chub in the mainstem Colorado River.

1D: Determine the distribution, abundance and movement of the humpback chub in the mainstem Colorado River, and effects of dam operations on the movement and distribution of humpback chub.

1E: Determine important biotic interactions with other species for all life stages of humpback chub.

Objective 2: Determine the life history for the Grand Canyon humpback chub population.

2A: Develop or modify an existing population model from empirical data collected during the study for use in analyses of reproductive success, recruitment and survivorship.

STUDY AREA

The study area (Figure 2) is divided into three reaches (1) The LCR Reach from Kwagunt Rapid (RM 56) to Red Canyon (RM 76.5), (2) The Granite Gorge Reach from Red Canyon to Havasu Creek (RM 156), and (3) The Havasu Creek Reach from Havasu Creek to Diamond Creek (RM 226). Sampling the LCR Reach focuses on life history and habitat use of humpback chub, while sampling the Granite Gorge and Havasu Creek reaches is to determine distribution and habitat use in the mainstem and at the inflows of Bright Angel, Shinumo, Kanab, Tapeats, and Havasu creeks.

FIELD METHODS

Monthly trips are alternated as 12 or 20 days in duration. The 20 day trips consist of two field teams of 6 people each with one 37-foot S-rig and one 23-foot Snout. One team spends 10 days at the LCR inflow with three research boats while a second team samples the Granite Gorge Reach for 10 days using two research boats (Figure 3). Sampling in Reaches 2 and 3 is conducted in randomly-selected subreaches of similar geomorphic types (Schmidt and Graf 1988). The teams meet below Havasu Creek and jointly sample the Havasu Creek Reach for 5 days. Research boats are rolled and loaded where possible. Select adult humpback chub in the LCR Reach are implanted with 11-gm radiotransmitters with a battery life of about 120 days. The weight of the transmitter is not allowed to exceed 2% of the weight of the fish, so the minimum implantable fish weighs 550 gm. Five to eight chubs are implanted every other month on the 20-day trips. The fish are tracked every trip, and two remote telemetry stations monitor movement of the fish to and from the LCR. A nondirectional station was established in August, 1991 to monitor vertical movement of radiotagged chubs between RM 60 and RM 61.2.

The 12-day trips consist of one field team of 8 people spending 6 days at the mouth of the LCR (Figure 4). The primary purpose of this trip is to radiotrack previously tagged fish and to implant additional fish if necessary. The radiotagged fish are surveyed daily for location and monitored at least once during the trip to relate their activity to flow, turbidity, time of day, and season. The trip launches at Lees Ferry with two or three research boats and gear rolled in one 37-foot S rig and one 23-foot snout. The research boats are unpacked for the 6 days of research and repacked for the trip to the takeout.

Fish are sampled with electrofishing (Coffelt Complex Pulse System Mark XX); 100'x6'x 1.5, 2.0-inch and experimental gill nets; 75'x6'x 1.0 and 1.5-inch trammel nets; hoop nets (2, 3, and 4-foot); minnow traps; and seines. Of 569 humpback chub captured from October 1990 through August 1991,

454 were taken with gill or trammel nets, 32 with minnow traps or hoop nets, 81 with electrofishing, and 2 with seines.

Water chemistry (temperature, pH, conductance, TDS, dissolved oxygen) is recorded with a constant-recording Datasonde during each trip and with daily readings from a Hydrolab. River stage is also recorded at regular (about 2 hour intervals) periods during each trip.

SCIENTIFIC APPROACH

BIO/WEST's basic approach to addressing the objectives of this investigation is hypothesis-testing. The following hypotheses (Ho) were developed for each of the objectives and subobjectives identified above:

Objective 1: To determine the ecological and limiting factors of all life stages of humpback chub in the mainstem Colorado River, Grand Canyon, and the effects of the Glen Canyon Dam operations on the humpback chub.

A thorough literature review will be conducted to determine the known ecological requirements of the humpback chub. This literature review will focus on known habitat use, water quality conditions, and biological needs of the species in the lower and upper Colorado River basins. This background information will help identify ecological factors essential to the life history of the species in the Colorado River in Grand Canyon. A comprehensive literature review of humpback chub is being conducted by C.O. Minckley. A summary of ecological factors for four life stages is presented in Appendix A.

Field investigations will fill data gaps and identify informational needs on critical life history requirements as well as determine which ecological factors affect and possibly limit specific life stages. Radiotelemetry is a major tool for evaluating habitat use, movement, and activity of adult humpback chub. From October 1990 through September 1991, 48 adults were implanted with radiotransmitters. PIT (Passive Integrated Transponder) tags are injected in all native fish over 175 mm TL. From October 1990 through August 1991, 468 of 569 humpback chub were PIT tagged and 38 (8.1%) were

recaptured. Altogether, 125 (21.9%) chubs with marks (by B/W, AGF, ASU, etc.) have been captured.

Subobjective 1A: Determine resource availability and resource use (habitat, water quality, food, etc.) of humpback chub in the mainstem Colorado River.

Ho 1A-1: Habitat is limited under certain flow conditions to humpback chub in the mainstem Colorado River, Grand Canyon.

This hypothesis will be tested by identifying the macrohabitats used by radiotagged adult humpback chub and quantifying changes to and availability of these and microhabitat parameters at different flows. Sixty-two monitoring maps were developed in 1990 and 1991 for radiotagged adult humpback chub. From these, four frequently-used sites were targeted for macro and microhabitat measurements in 1992.

Macrohabitat availability will be determined for each of the three study reaches with the aid of 1:1200 scale aerial photographs. The area of each macrohabitat type (backwaters, eddies, pools, runs, riffles, rapids, slackwaters, etc.) will be delineated on mylar overlays at different water levels using a technique employed by Valdez and Masslich (1989) in the Green River, Utah. Changes in surface area of macrohabitats will be interpreted between mylar overlays with the aid of MIPPS, and the relationship between area of each macrohabitat type and flow described by regression analysis. Twenty-one macrohabitat maps have been developed at various flows for six sites near the LCR and two maps for the Shinumo inflow.

Microhabitat will be described in terms of depth, velocity, substrate, overhead cover, and lateral structure for the complex of habitats associated with four sites frequented by radiotagged fish. GIS will be used to interface isopleths for each parameter in order to quantify cells or regions of useable habitat. These microhabitat measurements will be taken at high, medium, and low flows.

Habitat of YOY and juveniles will be assessed at capture sites; along shallow shoreline habitats where fish have been captured with electrofishing and minnow traps. Macrohabitat will be

delineated to characterize habitat complexes and microhabitat (depth, velocity, substrate, cover) will be measured at various flows to quantify changes. This sampling will be done concurrently with the AGF backwater program.

Ho 1A-2: Water quality is limiting under certain flow conditions to humpback chub in the mainstem Colorado River, Grand Canyon.

Water quality parameters include temperature, turbidity, salinity, TDS, and dissolved oxygen. Semipermanent water quality stations are established during field trips (Datasonde II set at camp sites) and diel measurements taken with a Hydrolab Surveyor. This will provide information on basic water chemistry over 24-hour periods as well as seasonally while long-term water quality characteristics are monitored through established USGS gaging stations.

Turbidity is considered an important variable that may affect behavior and distribution of humpback chub in the Grand Canyon. Since the species evolved in a highly turbid river system and has been shown to be negatively phototrophic (Bulkley et al. 1982), removal of silts and sands through settlement in Lake Powell may be affecting its life history. Activity relative to turbidity will be monitored for radiotagged fish using their occurrence in the uppermost 4 m of water as an index of near-surface use. Since radiosignal extinction occurs at about 4 m (Yard et al. 1990), the occurrence of radiotagged fish near the surface can be separated from use of deep water during different levels of water clarity. Direct and remote telemetry surveillances will be conducted during day and night to determine if near-surface habitat use is related to light penetration and therefore turbidity. Also, stomach contents of the fish will be examined to determine if feeding periodicity is affected by turbidity (See hypothesis Ho 1A-3). A total of 215 surveillance runs were conducted October 1990 through August 1991 during day, night, and crepuscular periods.

Ho 1A-3: Food is limiting under certain flow conditions to humpback chub in the mainstem Colorado River, Grand Canyon.

Stomach content analysis is critical in characterizing the life history and ecology of the

humpback chub in the Grand Canyon. Food habits, combined with food availability as indicated by drift and benthic samples, will be assessed to determine if dam operations are affecting the availability of food resources as well as the timing of availability. Stomach contents of humpback chub will be sampled (with nonlethal stomach pump) during various flow scenarios to determine if changes in activity (i.e. additional movement) are induced by greater food availability or changes in habitat.

Leibfried (1988) found that rainbow trout below Glen Canyon Dam ingest large quantities of Cladophora, deriving nutritional benefit through digestion of lipid-rich epiphytic diatoms. It is important to know if humpback chub exhibit similar feeding strategies since Cladophora production and diatom communities are closely linked to stream flow and hence dam operation.

Ho 1A-4: Food for humpback chub is progressively limited downstream of the Little Colorado River.

Volume of river drift as well as stomach contents and condition factor of humpback chub will be quantified longitudinally downstream of the Little Colorado River by season to determine if food of humpback chub is limited in the mainstem Colorado River. Drift samples will also be taken above and below major tributaries to determine the contribution of these to the energetics of the mainstem.

Subobjective 1B: Determine the reproductive capacity and success of humpback chub in the mainstem Colorado River.

Ho 1B-1: Humpback chub spawn in the mainstem Colorado River, Grand Canyon.

Main channel reproduction by humpback chub in the Grand Canyon is at best extremely limited, or more likely nonexistent as a result of cold water temperatures (Maddux et al. 1987). Attempts will be made to determine if spawning occurs in the mainstem by observing the nuptial condition of captured fish and by following closely the movements of radiotagged fish suspected of being in spawning condition. Sudden movements and aggregations of radiotagged fish may lead to specific spawning locations that can be confirmed by intensively sampling the area with various gears for gravid females and ripe males. Discovery of such an area will invoke intensive sampling for eggs

and larvae.

It is also possible that radiotagged fish will ascend to spawn in one of several tributaries in the Grand Canyon (Little Colorado River, Shinumo Creek, Havasu Creek, Kanab Creek, Bright Angel Creek, Tapeats Creek). Two remote telemetry stations were established on the mainstem at the mouth of the LCR in February 1991 to monitor fish moving to and from this tributary. Radiotagged fish that ascend these tributaries will be followed and data collections will be coordinated with the Service and AGF.

Spawning locations, aggregation areas, and staging areas identified in the mainstem will be mapped in detail at various flow stages. Cross sectional profiles will be taken with stadia rods and sonar units, substrate will be assessed, and velocities will be measured where possible. Shoreline habitats near and below suspected spawning areas will be sampled intensively to confirm the presence of age-0 chubs and to assess their relative densities as well as habitat use.

Subobjective 1C: Determine the survivorship of early stages of the humpback chub in the mainstem Colorado River.

Ho 1C-1: Survival of early life stages of humpback chub is low in the mainstem Colorado River, Grand Canyon.

Survival of early life stages of humpback chub will initially be assessed primarily on age-0 fish entering the mainstem from the LCR. Intensive sampling will be conducted at the mouth of the LCR in late May and early June to capture large numbers of age-0 humpback chub for mark and release. These fish will be marked by clipping a small portion of the caudal fin. A mark of longer duration is urgently needed in order to follow the survival of these fish over several years, but none has been developed to date. Ideally, the age-0 fish from the LCR should be permanently marked within the system by investigators from ASU and AGF so that these marked fish can be followed into the mainstem and the proportion of escapement and residence determined for the LCR as well as survival rates in the two systems.

Survival rates of humpback chub will be determined separately for age-0, age-1, age-2, age-3, and age-4 fish while survival of all adults is treated as a group. Survival of age-1 and age-2 fish will be difficult to assess without the aid of a permanent mark. These fish are too small to PIT tag and fin clips retain their identity for only short time periods. Fish that are age-3 and older should be large enough to PIT tag (>175 mm TL) and assessing survival of age-3 and age-4 fish is possible. However, distinguishing age-5 fish and older is difficult because of variable and inconsistent growth rates. Length-frequency analyses will be performed for fish captured in this investigation and others in the Grand Canyon to relate survival of known length fish to age group survival. It is anticipated that age-0 through age-4 fish will be distinguishable from length-frequency analysis, but older fish may not be distinguishable because of the affect of maturation and spawning on growth.

The number of age-0 and juvenile fish captured in the mainstem Colorado River below the LCR in 1990 and 1991 include: October (1), November (2), January (2), March (3), April (0), May (34), June (16), July (52), September (176). In September, 3 young chubs were captured above the LCR, 157 were within 5 miles downstream, 7 were 15 miles downstream (Papago), and 9 were 47 miles downstream (Shinumo).

Subobjective 1D: Determine the distribution, abundance and movement of the humpback chub in the mainstem Colorado River, and effects of dam operations on the movement and distribution of humpback chub.

Ho 1D-1: The distribution and abundance of humpback chub in the mainstem Colorado River, Grand Canyon, is limited by Glen Canyon Dam operations.

The above hypothesis will be tested by assessing the potential effects of dam operation on the distribution and abundance of the species. First, the distinction must be made between the effect of the presence of the dam and the effect of its operation. Most investigators (Carothers et al. 1981, Maddux et al. 1987) believe that cold water releases, irrespective of fluctuating flows, have reduced the pre-dam distribution and abundance of the species.

The pre-dam and current post-dam distribution and abundance of humpback chub in the

mainstem Colorado River, Grand Canyon, are not accurately known. Pre-dam data from the mainstem are nonexistent except for some sampling at the LCR inflow (Kolb and Kolb 1914, Miller 1946, Wallis 1951). Post-dam information is primarily from the LCR inflow but scant from other reaches (Maddux et al. 1986). This study will attempt to refine known seasonal distribution and abundance information on humpback chub in the mainstem Colorado River, Grand Canyon.

The effect of dam operations on the distribution and abundance of the species will focus on habitat dynamics and tributary access. Habitat availability will be assessed by geologic reach (Schmidt and Graf 1988) for occurrence of associated shoreline types (e.g. tapeats ledges). Selected areas within each reach will be mapped for macrohabitat and assessed for microhabitat for all life stages. Access by fish into six key tributaries (LCR, Bright Angel, Tapeats, Shinumo, Kanab, Havasu) will be evaluated by measuring water depth and velocity at each stream mouth for fish passage at various flow stages. Passable depth and velocity measurements will be related to mainstem flows in order to identify water conditions that allow access by adults into these tributaries for spawning.

From October 1990 through August 1991, 96% (544 of 569) of the humpback chub were captured in a 9-mile reach from RM 57.0 (Malagosa Crest) to RM 65.9 (below Chuar Rapid); the LCR is midway in the reach at RM 61.5. Approximately 45% of these fish were captured upstream of the LCR and 55% were captured downstream. Twenty-five chubs were captured (+ 5 recaptures) in Reaches 2 and 3 in the following regions: 1 from RM 87.5 (Bright Angel); 12 from RM 108.1-108.6 (Shinumo Creek); 1 from RM 118.6 (119 Mile Creek); 3 from RM 127.0 (127 Mile Creek); 4 from RM 156.2-155.8 (Havasu Creek); and 4 from RM 212.5-221.8 (Pumpkin Spring to Granite Spring). The upstream-most capture location is at RM 57.0 and the downstream-most capture is at RM 219.7.

Ho 1D-2: Cold water releases from Glen Canyon Dam limit the distribution and abundance of humpback chub in the mainstem Colorado River, Grand Canyon, independent of dam operations.

The influence of cold water releases (8-12°C) on the distribution and abundance of humpback

chub in the Colorado River, Grand Canyon, independent of fluctuating flows, will be evaluated in order to determine if the presence of Glen Canyon Dam alone determines distribution and abundance or if these factors are determined by fluctuating flows as a result of dam operations.

This hypothesis will be tested by examining the temperature requirements of each life stage of the species, and comparing with existing temperature regimes in the Grand Canyon. Consideration will also be given to balancing detrimental effects of cold temperature on the species with the beneficial effect of excluding predators and competitors.

Ho 1D-3: Movement and activity of humpback chub in the mainstem Colorado River, Grand Canyon, is greater during fluctuating flows than during stable flows.

Radiotagged adult humpback chub will be monitored during various flow scenarios to determine if their movement and activity increases with changes in habitat parameters (e.g. nose velocity is violated by increased flow) or because of increased feeding. This activity will be monitored during increased ramping, decreased ramping, and high and low steady flows, and movement rate related to flow change. Macro and microhabitat changes will be assessed to determine if increased activity is caused by changes in habitat parameters. Furthermore, river drift will be sampled during different flow scenarios and stomachs of adult humpback chub nonlethally evacuated to determine if the increased activity is related to food availability and feeding. A total of 62 maps of radiotagged adult humpback chub activity have been developed. Most fish observed from October 1990 through August 1991 remained within 0.5 miles of their capture/release point with maximum movement of 3.0 miles downstream. One fish radiotagged in October 1990 and released at RM 65.0 was recaptured (looking healthy) at RM 127.0 for a downstream movement of 62.0 miles.

A general pattern of diel behavior has been identified with greatest activity during the crepuscular periods, especially from about 5 to 10 pm. Since extinction level for the 11-gm external-antennae radiotransmitters is 4.5 m at 50 m horizontal distance, activity of fish near the surface and in deep water can be distinguished by signal reception. All near-surface activity has been within

about 50 m of the riverbank. Fish moving from one riverbank to another apparently move along the bottom of the river. Changes in activity have been identified with changes in flow and are being evaluated. A distinct movement of adult humpback chub was seen starting in early March to the inflow region of the LCR. This immigration was seen through July. The outmigration was not clearly identified since the radiotags had expired, but mainstem catches of adults indicates that many of the chubs had returned to the mainstem by July. Tubercled fish were found from March through July indicating an expanded spawning period.

Subobjective 1E: Determine important biotic interactions with other species for all life stages of humpback chub.

Ho 1E-1: Introduced non-native fish species have a negative effect on humpback chub in the mainstem Colorado River, Grand Canyon.

Various aspects of the life history of the humpback chub may be affected by certain biotic interactions with other species of fish such as channel catfish, carp, rainbow trout, brown trout, and striped bass. The possible influence of competition and predation by these non-native species will be identified and separated from the effects of dam operations. Stomachs will be examined from sacrificed channel catfish, striped bass, and brown trout year-around to determine the degree of predation on various life stages of humpback chub. Carp will be sacrificed and examined during and shortly after spawning to determine if this species preys on eggs and young.

Other interspecific interactions such as overlap in habitat use and food resources will be evaluated by keeping records of all fish captured during sampling. These interactions will be described by reach, habitat type, tributary influence, and size of fish.

Overall catch in Reach 1 shows that rainbow trout dominated the fauna with 57%, followed by humpback chub (20.9%), flannelmouth sucker (13.5%), bluehead sucker (2.0%), carp (1.9%), and channel catfish (0.6%). Species compostion in Reach 2 was rainbow trout (52.5%), carp (14.2%), flannelmouth sucker (11.0%), bluehead sucker (4.9%), humpback chub (0.7%), and channel catfish

(0.1%). Reach 3 consisted of flannelmouth sucker (29.9%), carp (29.4%), rainbow trout (16.6%), bluehead sucker (14.2%), channel catfish (4.4%), and humpback chub (2.3%).

Objective 2: Determine the life history schedule for the Grand Canyon humpback chub population.

The life history of the humpback chub in the Grand Canyon will be described using the best available scientific information from literature and data gathered in this investigation. Population characteristics will be described including, but not limited to, distribution, abundance, density, growth, and survivorship. Individual statistics will be also be assimilated including, but not limited to, fecundity, growth, survival, and movement. Also, spawning time and conditions, appearance of larvae, habitat use by age group, and movement of fish between the mainstem and tributaries will be described as well as length-weight, length-frequency, catch-per- effort, sex ratios, and age structure statistics. Information on the life history of the humpback chub in the Colorado River, Grand Canyon, will be integrated with information collected on the species in tributaries to gain a better understanding of this endangered species in this region.

Subobjective 2A. Develop or modify an existing population model from empirical data collected during the study for use in analyses of reproductive success, recruitment and survivorship.

Information and data assimilated from literature as well as collected from year-around sampling will be used to describe, as best as possilbe, the life history of the humpback chub in the Grand Canyon. The empirical data collected on various life history aspects will be integrated with other investigations into an existing population model being developed under the guidance of GCES. This model will be used as a tool to identify relationships and functions of components.

Appendix A: ECOLOGICAL FACTORS FOR FOUR LIFE STAGES OF HUMPBACK CHUB (Gila cypha) Miller 1946.

I. SPAWNING/EGG INCUBATION

A. Spawning Times

1. April - May, 1981 - Little Colorado River (Kaeding and Zimmerman, 1983).
2. June 2 - 15, 1980; May 15 - 25, 1981 - Black Rocks (Valdez and Clemmer, 1982).
3. June 20 - July 30, 1983 and 1984 - Black Rocks (Kaeding et al, 1990).
4. Mid-May to late-June, 1987-1989 - Yampa Canyon (Karp and Tyus, 1990).
5. June-July - LCR (Suttkus and Clemmer 1977).

B. Flows

1. -
2. 21,500 - 26,000 cfs; 3,000 - 5,0000 cfs - Black Rocks (Valdez and Clemmer, 1982).
3. 17,000 - 3,000 cfs; 12,000 - 3,000 cfs (Kaeding et al, 1990).
4. 220 - 30 m_3/s. (Karp and Tyus, 1990).
5. -

C. Water Temperature

1. 18 - 22°C - Little Colorado River (Kaeding and Zimmerman, 1983).
2. 11.5 - 16.0°C; 16.0 - 16.5°C - Black Rocks (Valdez and Clemmer, 1982).
3. 14 - 24°C - Black Rocks (Kaeding et al, 1990).
4. 14.5 - 23°C - Yampa Canyon (Karp and Tyus, 1990).
5. 19 - 20°C = optimim egg incubation (84%) (Hamman, 1982) 21-22°C (79%); 16 - 17°C(62%), 12 - 13°C (12%).
6. Eggs in 12-13°C failed to develope (Hamman 1982)
7. 5°C (0%), 10°C (30%-19d), 14°C (50%-16d), 20°C (100%-4d), 26°C (90%-3d) (Bulkley et al. 1982).

D. Incubation Time

1. 115 - 160 hours at 19 - 20°C (Hamman, 1982)
2. 120-160 hours at 20°C - Black Rocks eggs (Hamman 1982).

E. Fecundity/Egg Diameter

1. 2.2 - 2.9 mm; 100, 4850,4000,4200,5760,250/fish (Hamman, 1982).
2. 2.5 - 3.0 mm; 48/ml; 4000, 4000, 10000 - Black Rocks (Valdez and Valdes - Gonzales, 1991).

F. Habitat

1. ***

II. LARVAE/AGE-0

A. Size at Hatching

1. 6-7 mm (Hamman, 1982)
2. 6.5-7.5 mm -hatched from Black Rocks eggs (Hamman 1982).

B. Temperature Tolerance

1. Mortality at changes of 6° C from 10 to 4°C (USFWS 1979).

C. Habitat

1. Small quiet pockets along steep rock walls (Valdez and Clemmer, 1982).
2. Backwaters and runs with firm silt (Holden, 1978).
3. Larvae; 1.4', 0.1 fps; Age-0; 2.1; 0.2 fps (Valdez et al, 1990).
4. 24 cm depth, 0.34 fps - Colorado River, GC (Maddux et al. 1986).

D. Food Habits

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E. Growth Rates

1. LCR (Kaeding and Zimmerman 1983).
2. Dexter NFH (Hamman 1982).
3. Cataract Canyon (Valdez 1990).

III. JUVENILE (1 year to maturity)

A. Size Range

1.
2.
3.
4.

B. Temperature/Chemical Tolerance

1. 24°C = final preferendum (Bulkley et al. 1982).
2. TDS preference = 1.3-3.0 mmhos (1.0-3.5 mg/l); TDS avoidance = >8.5 mmhos

C. Habitat

1. Backwaters and runs with firm silt, 0.6 m, 0 - 0.15 mps (Holden, 1978).
2. 2.3', 0.6 fps (Green R.); 11.1', 0.6 fps (Colorado/Yamps)(Valdez, et al, 1990).
3. SA/SI, BO/BE, 0.4 - 10.7 m, 0.06 - 0.60 mps, small eddies and pools (Valdez and Clemmer, 1982).

D. Growth Rates

1. Reach 250 - 300 mm at 3 years - LCR (Kaeding and Zimmerman, 1983).

E. Swimming Ability

1. Sustained speed 2.2 fps (0.66 mps); 2 h at 0.32 mps, minutes at 0.78 mps (Bulkley et al. 1982).

F. Food Habits

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G. Parasites

1. Lernaea cyprinacea in 17% of 36 - (Valdez and Clemmer, 1982).

H. Associated Species

1. CC, CP, RS, FH, SS, BH, FM, RT, CS (Valdez and Clemmer, 1982).
2. FH, SD, CC, RB, CP, FM, BH, PK (Maddux et al. 1986).

IV ADULT

A. Size Range

1. 250 - 300 mm TL at maturity, smallest male 205 mm - LCR (Kaeding and Zimmerman, 1983).
2. 232 mm TL smallest male - Yampa Canyon (Karp and Tyus, 1990).
3. 180 mm TL smallest male - Cataract Canyon (Valdez 1990).

B. Temperature Tolerance

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C. Habitat

1. Eddies, deep runs, 0.7 - 12.2 m (x=4.3), 0.03 - 1.16 mps (x=0.18) (Valdez and Clemmer, 1982).
2. Eddies 2.5 - 40.1' (x=10.3'), 0-3.9 (x=0.6 fps) (Valdez et al, 1990).
3. Large shoreline eddies, 1.3 m deep, SA/BO - Yampa (Karp and Tyus, 1990).

D. Growth Rates

1. Grand Canyon (Maddux et al. 1986).
2. Cataract Canyon (Valdez 1990).

E. Swimming Ability

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F. Food Habits

1. Immature chironomidae and simuliidae (Kaeding and Zimmerman, 1983).

G. Parasites

1. Systemic Aeromonas hydrophila, Lernaea cyprinacea - LCR (Kaeding and Zimmerman, 1983).
2. Lernaea cyprinacea on 31% of 182 - Black Rocks, Westwater (Valdez et al, 1982).

H. Associated Species

1. CC, CP, RT, BH, FM, CS - Black Rocks, Westwater (Valdez and Clemmer, 1982).
2. RS, SS, CC, CP, CS, RT, BH, FM in eddies - Cataract (Valdez 1990).
3. CC, FM, BH, SD, CP RB - Grand Canyon (Maddux 1986).

*** = no information available