GLEN CANYON ENVIRONMENTAL STUDIES
COLORADO RIVER NATIVE FISH STUDY
1995 ANNUAL REPORT

Submitted by:

Mark J. Brouder, Timothy L. Hoffnagle, Martin A. Tuegel, and William R. Persons
Arizona Game and Fish Department
Research Branch
2221 West Greenway Road
Phoenix, AZ 85023

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Bureau of Reclamation
Upper Colorado Region
Glen Canyon Environmental Studies
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Flagstaff, AZ 86002

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INTRODUCTION

This report summarizes the results of the 1995 Glen Canyon Environmental Studies Fisheries Investigation by the Arizona Game and Fish Department (AGFD) to meet the research objectives identified by Cooperative Agreement 9-FC-40-07940 between AGFD and the Bureau of Reclamation. We integrate findings of three sampling trips conducted during 1995: 28 March - 14 April (Trip 95-1), 13 - 28 June (Trip 95-2), and 15 - 30 September (Trip 95-3) 1995. All sampling trips during 1995 were conducted in conjunction with Bio/West, Inc. Arizona Game and Fish concentrated efforts on all life stages of all fishes in backwaters, mainchannel beachfaces, and tributaries throughout the Colorado River, Grand Canyon. Bio/West concentrated their efforts on young-of-year (YOY), juvenile, and adult life stages of all species, particularly humpback chub (*Gila cypha*), in mainchannel habitats, except backwaters, throughout the Colorado River, Grand Canyon (Valdez and Cowdell 1995).

STUDY AREA

We examined fishes in the Colorado River and its tributaries in Marble and Grand Canyons between Lee's Ferry (RK 0) and Diamond Creek (RK 363.16; Figure 1). (Note: river locations are denoted as distance (river kilometer; RK) below Lee's Ferry and 'L' (left) or 'R' (right), the side of the river when facing downstream). This section of river has been divided into eight sampling reaches of varying lengths, based on known fish populations and the availability of backwater habitat and spawning tributaries (Figure 1).

Discharge from Glen Canyon Dam in 1995 averaged 12,000 cfs until the end of May (Figure 2). Over Memorial Day, (23 - 25 May) an experimental steady flow of 8,000 cfs was released from Glen Canyon Dam. Discharge dramatically increased after Memorial Day to 23,000 cfs then decreased and averaged approximately 18,000 cfs until late September. For the remainder of the year, Glen Canyon Dam discharge was averaged approximately 14,000 cfs.

METHODS

Several methodologies, gear types, and techniques were used to collect fishes, measure habitat variables, and characterize habitats. Use of these methods depended on the habitat and the objectives of a particular part of this study. A list of all data codes used by AGFD in 1995 is presented in Appendix 1.

Type A Sampling

Type A samples were designed to provide an extensive characterization of a backwater and its associated mainchannel beachface at a point in time. These data included estimates of fish populations, zooplankton and benthic invertebrate densities, and physical and chemical habitat variables (depth velocity, temperature, substrate, turbidity, dissolved oxygen, conductivity, pH, redox potential, and light intensity).

A block net was first placed at the mouth of the backwater to prevent fish from escaping while samples and data were collected. Next, light intensity and turbidity were measured and zooplankton were collected. Total station surveys, benthos collections, and collection of temperature and water chemistry data were then conducted in the backwater. In the mainchannel, a seine haul along the beachface was completed before any other data were collected, followed by zooplankton, benthic invertebrates and habitat measurements.

In each habitat (backwater and mainchannel) three plankton and three benthic invertebrate collections were made. In backwaters, one sample was collected from each of the mouth, center, and foot. In the mainchannel, samples were collected within the seined area along a transect perpendicular to shore. Each zooplankton sample was collected by filtering 50 L of water through an 80 μm plankton net. The collection was then placed in a nalgene bottle and preserved in 95% ethanol. In the laboratory, samples were enumerated and organisms were identified to lowest practical taxonomic level. Zooplankton densities (#/m^2) were then calculated for each taxon. Benthic invertebrates were collected using a petite PONAR dredge. Benthos samples were then sieved through a # 30 mesh-bottom bucket and the remaining large particles were placed in a nalgene bottle and preserved in 95% ethanol. In the laboratory, benthos samples were sorted and identified to lowest practical taxonomic level. Invertebrate densities (#/m^3) were then calculated for each individual taxonomic group. Biomass (ash-free dry weight) was not calculated

due to our sorted samples being lost in a laboratory fire.

Habitat data were collected along transects in the backwater and mainchannel. In the mainchannel, a single transect was set perpendicular to shore within the area seined. In the backwater, three transects were set across the backwater: foot, center, and mouth. Along these transects, depth, velocity, and temperature were measured, and substrate characterized at three equidistant points. At the midpoint of each transect, turbidity, dissolved oxygen, conductivity, pH, redox potential and light penetration were also measured.

Total station surveys were conducted at each Type A site. Maps generated from these surveys provided information on the morphology of the backwater, including length of wetted perimeter, total surface area, area of cover, area of depth contours, total volume, and volume of depth contours.

After all habitat data and invertebrate collections were completed, fish collections proceeded in the backwater. At least three passes were made through the backwater using a bag seine (33' x 6' x ¼" mesh; with a bag measuring 6' x 6' x 6' x ⅛ " mesh). Further passes were made if depletions on the first three were insufficient and continued until few or no fish were captured, allowing us to estimate population size. Catch-per-unit-effort (CPUE) was calculated using only the first seine haul.

Type O Sampling

Type O samples were less detailed than Type A samples and were employed where a Type A sample was not practical; including extremely large or isolated backwaters, mainchannel sites without associated backwaters, tributaries, and night samples in backwaters. Fish data collected provided distributional data and allowed calculation of CPUE.

The backwater was first blocked off using a seine to prevent fish from escaping. Turbidity, light intensity, and other water quality data were collected at a single point near the middle of the backwater. A single seine haul through the backwater was then conducted. No zooplankton, benthic invertebrate or sediment samples were collected.

Larval Light Trap

Larval light traps were deployed in a backwater during Trip 95-2 in an attempt to examine the presence or absence of larval fish. Traps were illuminated using plastic glow strips inserted

into the plexiglass trap.

Tributary Sampling

A winged hoop net (4' x 5' x ⅜" with 40' wings) was placed in the mouths of Shinumo, Kanab, and Havasu Creeks to determine tributary use by juvenile and adult fishes (particularly spawners). Depth, velocity, and water quality parameters were measured at the mouth of the hoop net when the hoop net was deployed and checked. Discharge was calculated in each tributary sampled using methods described in Wetzel (1983).

Minnow traps were also deployed in these same tributaries to determine tributary use by YOY and juvenile fishes. Each minnow trap set consisted of four traps set in close proximity in similar habitat. Between two and four sets were deployed in each tributary. Depth and velocity were measured at the mouth of each trap at the time the traps were set and run.

Seining (15' x 4' x ¼" mesh seine) was conducted in the Little Colorado River (LCR), Nankoweap Creek, and Bright Angel Creek. Seining was conducted for collection of fishes for parasitological surveys.

Parasite Sampling

Parasite sampling consisted of collecting at least five speckled dace and five fathead minnows from each reach and tributary during each sampling trip (95-1, 95-2, and 95-3). Fish were collected by seining (Type A, O, and tributary sampling), hoop net with wings (tributary sampling), electrofishing (Bio/West), or minnow trapping (tributary sampling and Bio/West). Fish collected were preserved in 95 % ethanol for later examination in the lab. In the laboratory, entire gastrointestinal (G.I.) tracts were removed from the fish and examined for parasites under a dissecting microscope.

Fish Handling Methods

Every effort was made to minimize stress to fish. All fish collected were placed in buckets with fresh water from the habitat in which they were collected and water freshened as necessary. All fish were identified to species, measured for total length (TL, mm; both total and standard length (SL) for humpback chub), and weighed (0.0 g). Additionally, all bluehead sucker, (*Catostomus discobolus*), flannelmouth sucker, *(C. latipinnis)*, and humpback chub ≥ 150 mm TL were checked for the presence of a PIT-tag. If a PIT-tag was present, the number was

recorded. If the fish had not been previously PIT-tagged, one was inserted and the number recorded. Fish were then released alive at the site of capture.

Catch-per-Unit-Effort

Catch-per-unit effort was calculated for all species captured in all gear types for comparison of catches within a specific gear type among trips and reaches. Seining CPUE was calculated as the number of fish captured/100 m^2 seined. Hoop net CPUE was calculated as the number of fish captured/24 hours and minnow trap CPUE was calculated as the number of fish caught/100 hours/group of 4 traps.

RESULTS & DISCUSSION

Sampling Effort and Catch

A total of 39 Type A samples and 67 Type O samples were conducted in the mainstem Colorado River, Grand Canyon, during 1995. Nine hoop net sets and 22 minnow trap sets were deployed in three tributaries (Shinumo, Kanab, and Havasu Creeks) of the Colorado River during 1995. Four larval light traps were set in mainstem habitats during Trip 95-2. Detailed information on the sample type and location of each sample is presented in Appendix 2. A summary of the amount of effort expended by AGFD for each type of sampling gear is presented in Appendices 3a-c.

Seines

A total of 4,347 fish was caught using seines in the Colorado River, Grand Canyon, during 1995. A total of 118 seine hauls was conducted in backwaters and associated mainchannel beachfaces for a total effort of 14,696 m^2 seined. A total of 3,869.5 m^2 was seined in backwaters and 3,187 m^2 in the mainchannel during Trip 95-1, 1,663.5 m^2 in backwaters and 2,558 m^2 in the mainchannel during Trip 95-2, and 1,204 m^2 in backwaters and 2,214 m^2 in the mainchannel during Trip 95-3.

Hoop Nets

A total of 279 fish was caught in nine hoop net sets in the three major tributaries sampled

in 1995. The total amount of effort expended using hoop nets in tributaries in 1995 was 124.1 hours. Two mini-hoop nets (1.5' X 4' X ⅜") were also set in a warm spring at RK 48.28 R on Trip 95-2, for a total effort of 23.2 hours but no fish were caught. A total of 44.2 hours was expended in tributaries in Trip 95-1, 40.6 hours in Trip 95-2, and 39.2 hours in 95-3.

Minnow Traps

A total of 233 fish was caught in 22 minnow trap sets in the three major tributaries sampled in 1995. The total amount of effort expended using minnow traps in 1995 was 315.2 hours. A total of 91.6 hours was expended during Trip 95-1, 112.5 hours during Trip 95-2, and 111.1 hours during Trip 95-3.

Larval Light Traps

Larval light traps were set during Trip 95-2 only. No fish were captured using larval light traps. Four traps were set for a total effort of 30.5 hours.

Species Composition, Distribution and Abundance

Ten species of fish were captured in the Colorado River, Grand Canyon, in 1995 (Table 1), including four native and six non-native species. Of the four native species, two are endemic to the Colorado River, the flannelmouth sucker and humpback chub. The six non-native species represent five families. A summary of species composition by reach for backwater, mainchannel, and tributary habitats is presented in Appendices 4a-c. Mean, minimum, and maximum total length, standard length (for humpback chub only), and weight of both native and non-native fishes caught during each trip in the mainstem Colorado River are presented in Appendices 5a-c.

Mainstem Colorado River

Bluehead Sucker

A total of 264 bluehead suckers was captured in backwaters or their associated mainchannel beachfaces in 1995, comprising 7.1% of the total fish captured (Figure 3.). Bluehead suckers caught in the mainstem had a mean total length of 45.2 mm (12 - 97 mm TL). A total of 141 (mean TL = 52.2 mm), 67 (mean TL = 26.1), and 54 (mean TL = 52.7 mm) bluehead

suckers was caught during Trips 95-1, 95-2, and 95-3, respectively.

All bluehead suckers were captured downstream from the LCR (Figure 3). Of the 264 bluehead suckers caught, 228 were caught in backwaters and 36 in the mainchannel. Bluehead suckers were most commonly caught in Reach 8 (127; 48.1%) and 79 (29.9%) were caught in Reach 7. The remaining 58 (22.0%) bluehead suckers were caught in Reach 3 (31; 11.7%), Reach 4 (15; 5.7%), and Reach 6 (12; 4.5%).

Flannelmouth Sucker

A total of 277 flannelmouth suckers was captured in the mainstem Colorado River in 1995. Flannelmouth suckers comprised 7.4% of the total fish captured. Flannelmouth suckers caught in the mainstem had a mean total length of 51.5 mm (11 - 240 mm TL). A total of 164 (mean TL = 59.9 mm), 93 (mean TL = 33.4 mm), and 20 (mean TL = 78.6 mm) flannelmouth suckers was caught during Trips 95-1, 95-2, and 95-3, respectively.

Flannelmouth suckers (86 - 149 mm TL) first appeared in our samples in Reach 2 in the backwater at RK 71.24 L (Figure 3) and were caught throughout the remainder of the river to Diamond Creek. Of the 277 flannelmouth suckers caught, 160 (57.7 %) were caught in Reach 8, 62 (22.5 %) were caught in Reach 7. The remaining 55 were caught in Reach 3 (27; 9.7 %), 2 (15; 5.4 %) and 4 (13; 4.7 %). The highest catch of flannelmouth sucker was in Reach 8 (109), during Trip 95-1. During Trip 95-2, the highest catch of flannelmouth sucker was in Reach 7 (52), and during Trip 95-3, in Reach 3 (19).

Humpback Chub

Humpback chub comprised 3.6% of the total fish caught in the mainstem during 1995. A total of 133 humpback chub was captured in backwaters or their associated mainchannel beachfaces. Humpback chub caught in the mainstem had a mean total length of 47.9 mm (18 - 135 mm TL). A total of 31 (mean TL = 45.1 mm), 71 (mean TL = 43.1 mm), and 31 (mean TL = 63.4 mm) humpback chub was caught during Trips 95-1, 95-2, and 95-3, respectively.

Humpback chub were caught in three sections of the Colorado River: RK 71.24 - 121.10 (Reaches 2 - 4), RK 193.60 - 204.24 (Reaches 5 - 7), and RK 270.09 - 301.79 (Reaches 7 - 8; Figure 3). Of the 133 humpback chub caught, 64 (48.1 %) were caught in Reach 3 and 41 (30.8

%) were caught in Reach 4. The remaining 28 were caught in Reach 7 (11; 8.3 %), 2 (9; 6.7 %), 8 (7; 5.3 %) and 6 (1; 0.8 %). The highest catch of humpback chub was in Reach 3 (35) during Trip 95-2. During Trip 95-1, the highest catch was in Reach 4 (5), and during Trip 95-3, in Reach 3 (26).

Speckled Dace

Speckled dace (*Rhinichthys osculus*) were collected in all reaches except Reach 1, where little sampling was conducted. A total of 738 speckled dace was captured in backwaters or their associated mainchannel beachfaces in 1995, comprising 19.8% of the total fish captured in these habitats. Speckled dace caught in the mainstem had a mean total length of 45.2 mm (17 - 89 mm TL). A total of 400 (mean TL = 42.3 mm), 238 (mean TL = 52.1 mm), and 100 (mean TL = 40.3 mm) speckled dace was captured during Trips 95-1, 95-2, and 95-3, respectively.

Of the 738 speckled dace caught, 644 were caught in backwaters and 94 were caught in the mainchannel (Figure 3). Of the 738 speckled dace, 361 (48.9 %) were caught in Reach 8 and 140 (18.9 %) were caught in Reach 7. The remaining 237 were caught in Reach 4 (126; 17.2 %), 3 (91 (12.4 %), 6 (10; 1.4 %) and 2 (10; 1.4 %). The highest catch of speckled dace was in Reach 8 (710) during Trip 95-1. During Trip 95-2, the highest catch of speckled dace was in Reach 4 (111), and during Trip 95-3, in Reach 3 (68).

Fathead Minnow

Fathead minnows (*Pimephales promelas*) were the most commonly caught species of fish in 1995. A total of 2,182 fathead minnows was captured in the mainstem in 1995, comprising 58.7% of the total fish captured in these habitats. Fathead minnows caught in the mainstem had a mean total length of 42.4 mm (19 - 86 mm TL). A total of 1,055 (mean TL = 43.5 mm), 215 (mean TL = 50.3 mm), and 912 (mean TL = 40.5 mm) fathead minnows was collected during Trips 95-1, 95-2, and 95-3, respectively.

Of the 2,182 fathead minnows caught, 1,611 were caught in backwaters and 571 were caught in the mainchannel (Figure 4). Of the 2,182 fathead minnows caught, 1,103 (46.4 %) were caught in Reach 3 and 606 (27.8 %) were caught in Reach 4. The remaining 563 were caught in Reach 7 (181; 8.3 %), 2 (162; 7.4 %), 8 (141; 6.5 %) and 6 (79; 3.6 %). The highest catch of fathead minnows was in Reach 3 (696) during Trip 95-3. During Trip 95-1, the highest catch of fathead minnows was in Reach 8 (319), and during Trip 95-2, in Reach 4 (163).

Plains Killifish

In 1995, plains killifish (*Fundulus zebrinus*) comprised 2.2% of the total fish captured. Eighty-two plains killifish were captured in backwaters or their associated mainchannel beachfaces in 1995. Plains killifish caught in the mainstem had a mean total length of 40.5 mm (26 - 55 mm TL). A total of 39 (mean TL = 39.8 mm), four (mean TL = 45 mm), and 39 (mean TL = 41.2 mm) plains killifish was collected during Trips 95-1, 95-2, and 95-3, respectively.

Of the 82 plains killifish caught, 65 were caught in the backwaters and 17 were caught in the mainchannel (Figure 4). Of the 82 plains killifish caught, 37 (45.1 %) were caught in Reach 3 and 15 (18.3 %) in Reach 8. The remaining 30 plains killifish were caught in Reach 4 (12; 14.6), 7 (9; 10.9 %), 6 (4, 4.9 %), 2 (4; 4.9 %) and 5 (1; 1.2 %). The highest catch of plains killifish was in Reach 3 (36) during Trip 95-3. During Trip 95-1, the highest catch of plains killifish was in Reach 8 (16), and during Trip 95-2, in Reach 4 (4).

Rainbow Trout

Thirty-six rainbow trout (*Onchorynchus mykiss*) were captured in backwaters or their associated mainchannel beachfaces in 1995, comprising < 1% of the total fish caught in these habitats. Rainbow trout collected in the mainstem had a mean total length of 191.8 mm (26 - 411 mm TL). A total of 10 (mean TL = 96.9 mm), 12 (mean TL = 184.6 mm), and 14 (mean TL = 291.2 mm) rainbow trout was collected during Trips 95-1, 95-2, and 95-3, respectively.

Of the 36 rainbow trout collected, 29 were caught in backwaters and seven in the mainchannel (Figure 4). Of the 36 rainbow trout caught, 17 (47.2 %) were caught in Reach 2 and 9 (25 %) were caught in Reach 3. The remaining 10 fish were caught in Reach 7 (5; 13.8 %), 4 (2; 5.6 %), 1 (2; 5.6 %) and 6 (1; 2.8 %). The highest catch of rainbow trout was in Reach 1 (7) during Trip 95-3. During Trip 95-1, the highest catch of rainbow trout was in Reach 7 (2), and during Trip 95-2, in Reach 2 (5).

Other Exotic Fishes

Common carp (*Cyprinus carpio*) was the only other non-native species collected in the mainstem Colorado River during 1995. Nine common carp were collected, all in backwaters. Five carp were collected in Reach 7, three in Reach 3, and one in Reach 8.

Tributaries

Shinumo Creek

Bluehead Sucker

Four bluehead suckers were caught in Shinumo Creek in 1995, comprising 4.2% of the total catch. During Trip 95-1, (4 - 5 April) two bluehead suckers (234, 259 mm) were caught in the hoop net set in the mouth and were both implanted with a PIT-tag (Appendix 6). During Trip 95-2, (20 - 21 June) no bluehead suckers were caught in Shinumo Creek. The remaining two bluehead suckers (62 mm each) were caught in a minnow trap set approximately 15 m upstream from the mouth of Shinumo Creek during Trip 95-3 (22 - 23 September).

Flannelmouth Sucker

Four flannelmouth suckers were caught in Shinumo Creek in 1995 and comprised 4.2% of the total catch. No flannelmouth suckers were caught in Shinumo Creek during Trip 95-1. During Trip 95-2, four flannelmouth suckers were caught. One flannelmouth sucker (361 mm) had been previously PIT-tagged (Table 2). The remaining three flannelmouth suckers (45 - 56 mm) were too small (< 150 mm TL) to be PIT-tagged. No flannelmouth suckers were caught during Trip 95-3.

Humpback Chub

One humpback chub (33 mm TL) was caught in Shinumo Creek in 1995, which comprised < 1% of the total catch. The humpback chub was caught in a minnow trap set approximately 60 m upstream from the mouth of Shinumo Creek during Trip 95-2.

Speckled Dace

Speckled dace was the most common species captured in Shinumo Creek in 1995. Seventy speckled dace (25 - 100 mm) were caught, comprising 74.4% of the total catch. Of the 70 speckled dace caught, 63 were caught in minnow traps set upstream of the mouth and three were caught in the hoop net set in the mouth of Shinumo Creek. During Trip 95-1, five speckled dace (65 - 100 mm) were caught in minnow traps. During Trip 95-2, 12 speckled dace (52 - 97 mm) were caught in minnow traps. During Trip 95-3, 50 speckled dace (25 - 47 mm) were caught in minnow traps and three speckled dace (45 - 70 mm) were caught in the hoop net set in

the mouth of Shinumo Creek.

Non-native fishes

Non-native fishes comprised the remaining 17.2 % of the total catch in Shinumo Creek in 1995: seven fathead minnows (32 - 55 mm), seven rainbow trout (174 - 370 mm), and one brown trout (*Salmo trutta*; 310 mm) were caught. All fathead minnows were caught in minnow traps set from 5 - 100 m upstream from the mouth, while the rainbow and brown trout were caught in the hoop net set in the mouth of Shinumo Creek.

Kanab Creek

Bluehead Sucker

Twenty-four bluehead suckers were caught in Kanab Creek in 1995, comprising 12.9% of the total catch. Of these, 23 (158 - 271 mm) were caught in the hoop net set in the mouth and one (27 mm TL) was caught in a minnow trap set 4 m upstream of the mouth in Kanab Creek. During Trip 95-1 (7 - 8 April), 23 bluehead suckers (158 - 271 mm) were caught in the hoop net set in the mouth of Kanab Creek. During Trip 95-2 (23 - 24 June), no bluehead suckers were caught in the hoop net set in the mouth; however, one bluehead sucker (27 mm) was caught in a minnow trap upstream of the mouth. During Trip 95-3 (24 - 25 September), no bluehead suckers were caught in Kanab Creek. One adult bluehead sucker had been previously PIT-tagged (Table 2) and we implanted PIT-tags in the remaining 22 caught (Appendix 6). Adult bluehead suckers were observed spawning in Kanab Creek on 7 and 8 April 1995 (Trip 95-1).

Flannelmouth Sucker

A total of 108 flannelmouth suckers (174 - 446 mm) was caught in the hoop net set in the mouth of Kanab Creek, comprising 58.0% of the total catch. During Trip 95-1, 58 flannelmouth suckers (174 - 446 mm) were caught in the hoop net set in the mouth. During Trip 95-2, 50 flannelmouth suckers (234 - 423 mm) were caught in the hoop net, and no flannelmouth suckers were caught in Kanab Creek during Trip 95-3. Of the 108 flannelmouth suckers caught, eight had been previously implanted with a PIT-tag (Table 2) and we PIT-tagged 93 fish (Appendix 6). One larval sucker (15 mm; identified by D. Snyder, Larval Fish Laboratory, Colorado State University, as either a bluehead or flannelmouth sucker) was collected in Kanab Creek on 8 April

1995 (Trip 95-1).

Humpback Chub

One humpback chub (56 mm TL) was caught in a hoop net set in the mouth of Kanab Creek during Trip 95-1 (7-8 April), comprising < 1% of the total catch in Kanab Creek in 1995. Humpback chub were not caught during any other trip in Kanab Creek in 1995.

Speckled Dace

Twenty speckled dace (22 - 75 mm) were caught in Kanab Creek in 1995, comprising 10.7% of the total catch. During Trip 95-1 (7 - 8 April), five speckled dace (57 - 75 mm) were caught in minnow traps. During Trip 95-2 (23 - 24 June), 12 speckled dace (22 - 34 mm) were caught in the minnow traps and one speckled dace (85 mm) was caught in the hoop net set in the mouth. During Trip 95-3 (24 - 25 September), two speckled dace (35 and 36 mm) were caught in minnow traps in Kanab Creek.

Non-native fishes

Non-native fishes comprised 17.7% of the total catch in Kanab Creek in 1995. Fathead minnow was the most abundant (30 fish, 41 - 80 mm) non-native species collected. Two common carp (404, 448 mm) were also collected in Kanab Creek. Of special note and concern is the collection of one green sunfish (*Lepomis cyanellus*) in the hoop net set in the mouth of Kanab Creek. This is the first collection of a green sunfish in lower Kanab Creek and this fish probably originated from upper reaches of Kanab Creek outside of Grand Canyon National Park. Invasion by this predator could have negative effects on larval suckers spawned in this tributary and will continue to be monitored.

Havasu Creek

Bluehead Sucker

Sixty-nine bluehead suckers were caught in Havasu Creek in 1995, comprising 31.3% of the total catch. Of the 69 bluehead suckers caught, 61 (150 - 330 mm) were caught in the hoop net set in the mouth, and the remaining eight (43 - 95 mm) were caught in minnow traps set upstream from the first waterfall, approximately 200 m from the mouth. During Trip 95-1, 62

bluehead suckers (95 - 330 mm) were caught in Havasu Creek. During Trip 95-2, six bluehead suckers (43 - 54 mm) were caught in minnow traps in Havasu Creek, and one bluehead sucker (68 mm) was caught in a minnow trap set in Havasu Creek during Trip 95-3. One of the 61 bluehead suckers had been previously marked with a PIT-tag (Table 2) and we PIT-tagged 26 fish (the remainder were too small to be PIT-tagged; Appendix 6). Adult bluehead suckers were observed spawning in Havasu Creek on 8 and 9 April 1995 (Trip 95-1).

Flannelmouth Sucker

A total of 54 flannelmouth suckers (160 - 511 mm) was caught in Havasu Creek in 1995, comprising 24.5% of the total catch. All of these fish were caught in the hoop net set in the mouth. During Trip 95-1, 47 flannelmouth suckers (160 - 511 mm) were caught in the hoop net set in the mouth of Havasu Creek. During Trip 95-2, six flannelmouth suckers (424 - 478 mm) were caught in the mouth of Havasu Creek, and one flannelmouth sucker (480 mm) was caught in the mouth during Trip 95-3. Of the 54 flannelmouth suckers caught, three had been previously PIT-tagged (Table 2) and we PIT-tagged 50 fish (Appendix 6).

Humpback Chub

No humpback chub were collected in Havasu Creek in 1995.

Speckled Dace

A total of 98 speckled dace was caught in Havasu Creek, comprising 44.4% of the total catch. All speckled dace were captured in minnow traps set above the first set of falls. During Trip 95-1, 56 speckled dace (51 - 94 mm) were caught, during Trip 95-2, 32 speckled dace (22 - 89 mm) were caught, and during Trip 95-3, ten speckled dace (43 - 89 mm) were caught.

Non-native fishes

No non-native fishes were caught in Havasu Creek in 1995.

Summary

The most frequently collected native fish species in backwaters of the Colorado River,

Grand Canyon, in 1995 was speckled dace. Speckled dace were widely distributed and collected in every reach except for Reach 1, where they are known to occur (AGFD 1996) but where little effort was expended in 1995. The most abundant non-native and overall species collected in backwaters of the Colorado River, Grand Canyon, in 1995 was fathead minnow.

The majority of the fish (native and non-native) were collected in Reaches 3 and 4 (just below the LCR) and Reaches 7 and 8 (below Kanab and Havasu Creeks). Both of these stretches of river are below important spawning tributaries for native fishes. Bluehead sucker, flannelmouth sucker, and speckled dace catches were highest in Reach 8, followed by Reach 7, probably reflecting spawning in Kanab and Havasu Creeks. Humpback chub catch was highest in Reaches 3 and 4, followed by Reach 7. The LCR is the major spawning area/site for humpback chub. Therefore, Reaches 3 and 4 having the highest catches of humpback chub is not surprising. AGFD (1996) reports consistent low catches of humpback chub in Reaches 7 and 8, however indicating possible spawning somewhere in the lower reaches. Fathead minnow and plains killifish were also most common in Reaches 3 and 4, further indicating that these non-native species probably invaded the Colorado River in Grand Canyon through the LCR.

There appears to be a relationship between backwater catch rates of YOY native fishes and location of tributaries. The highest catch rates of YOY native fishes were found in backwaters located downstream and close to major spawning tributaries for each species. The LCR is a major spawning tributary for humpback chub and all other native species, hence we saw our highest catch rates of YOY humpback chub in backwaters located downstream of the LCR (Reaches 3 and 4). Adult bluehead and flannelmouth suckers also utilize Kanab and Havasu Creeks for spawning. Again, our highest catches of YOY bluehead and flannelmouth sucker were in backwaters located downstream of these tributaries (Reaches 7 and 8). Both bluehead and flannelmouth suckers drift, as part of their life cycle, soon after hatching.

Another point of interest is the high catches of fathead minnow and plains killifish in backwaters where YOY humpback chub catch was highest (Reaches 3 and 4). Minckley (1991) suggests that competition by and behavioral aspects of exotics may be a contributing factor to the demise of native fishes in the Colorado River, Grand Canyon, while Marsh and Douglas (1997) showed that predation on native fishes by exotics had a negative affect on native fishes in the Little Colorado River. Also, AGFD (1996) showed extensive overlap in diet of native and non-native fishes, indicating the potential for competitive exclusion.

Tributaries were utilized by all life stages of native fishes in 1995 as spawning (adults) and rearing areas (YOY and juveniles). Tributary temperatures were seasonally warmer than the mainstem Colorado River and often provide fishes with additional food resources (primarily macroinvertebrates).

The same conditions that make tributaries beneficial to native fishes of the Colorado River, Grand Canyon, however, also apply to non-native species. Several piscine predators were found in tributaries in 1995. Rainbow and brown trout were collected in Shinumo Creek. Brown trout are primarily piscivorus and have been documented to prey on humpback chub and other native species in the Colorado River, Grand Canyon (Valdez and Ryel 1995; Marsh and Douglas 1997). Also, this was the first year that green sunfish, another piscivore (Minckley 1973), were collected in the lower reaches of Kanab Creek. The presence of both of these predators in tributaries where YOY native fishes are found may prove to be detrimental to the recruitment and survival of native fishes in the Colorado River, Grand Canyon.

Age and Growth

Mainstem Colorado River

Bluehead Sucker

Bluehead suckers collected in backwaters in 1995 contained fish from the 1994 (age 1) and 1995 (YOY) year classes. Bluehead sucker YOY first appeared in backwaters in June (Figure 5). Young-of-year bluehead suckers were 1-2 cm in length in June and their modal size class was 6 cm in September. Age 1 bluehead suckers caught in backwaters were of the 5 cm modal class in late March to early April and in the 7 cm modal class in June. Age 1 bluehead suckers largely vacate backwaters in late spring, as noted by the low catches in June and no fish caught in September. Lack of age bluehead suckers caught in September has been documented in the past as well (AGFD 1996).

Flannelmouth Sucker

Flannelmouth suckers collected in backwaters in 1995 also contained fish from the 1994 (age 1) and 1995 (YOY) year classes, and possibly from the 1993 (age 2) year class (Figure 6). Young-of-year flannelmouth suckers first appeared in backwaters of the Colorado River in June

as 1 cm fish. Age 1 flannelmouth sucker were of the 5 cm modal length class in late March to early April. Age 2 flannelmouth suckers were caught during all three trips in 1995. These fish probably represent the sizes 10 - 15 cm. Young-of-year flannelmouth suckers appeared to reach approximately 5 cm in September.

Humpback Chub

Humpback chub collected in backwaters in 1995 contained fish from the 1994 (age 1) and 1995 (YOY) year classes (Figure 7). Young-of-year humpback chub first appeared in backwaters of the Colorado River in June with a modal length class of 3 cm and had a modal length class of 4 cm in September. Age 1 fish had a modal length class of 3 cm in late March to early April, and may also have been collected in June and September as fish 9 - 14 cm.

Speckled Dace

Speckled dace collected in backwaters in 1995 contained fish from the 1994 (age 1) and 1995 (YOY) year classes (Figure 8). Young-of-year speckled dace first appeared in backwaters of the Colorado River in June as 1-3 cm fish. Age 1 speckled dace were of the 4 cm modal length class in late March to early April and 6 cm modal length class in June. Young-of-year speckled dace were of the 4 cm modal length class in September.

Fathead Minnow

Fathead minnows collected in backwaters in 1995 contained fish from the 1994 and 1995 year classes (Figure 9). Fish caught during Trips 95-1 and 95-2 represent age 1 fish. During Trip 95-3, YOY fathead minnows were abundant with few remaining age 1 fish. Fathead minnows ranged from 30 - 60 mm TL during each trip.

Summary

Fish collected in the mainstem Colorado River in 1995 represented several year classes. Age 1 (1994), YOY (1995), and in some instances, age 2 (1993) fishes were collected throughout the year. Fish collected during Trip 95-1 (28 March - 14 April) were mostly age 1 and age 2 fish. Young-of-year fish of all species were first collected during Trip 95-2 (13 - 28

June). Fish caught during Trip 95-3 (15 - 30 September) consisted primarily of YOY with some age 1 fish.

Tributaries

Shinumo Creek

Bluehead Sucker

Two adult and two YOY bluehead suckers were caught in 1995 (Figure 10). The adult bluehead suckers caught during Trip 95-1 were ripe, representing spawning adults. No YOY were caught during Trip 95-2. Only two YOY were caught during Trip 95-3, both were in the 6 cm size class on 22 September.

Flannelmouth Sucker

Two adult and three YOY flannelmouth suckers were collected in 1995 (Figure 11). The adult flannelmouth suckers caught during Trip 95-2 were also ripe, representing spawning adults. The YOY were caught during Trip 95-3 and were in the 4 - 5 cm size class on 22 September.

Humpback Chub

Only one humpback chub (33 mm) was caught in Shinumo Creek in 1995. It was caught on 20 June (Figure 12). This chub may be a representative of the 1995 year class. However, no adults were caught in the spring of 1995 in Shinumo Creek. The presence of YOY humpback chub in Shinumo Creek is unusual. Humpback chub have not been documented to spawn in Shinumo Creek, but have occasionally been caught in and around this tributary (Valdez and Ryel 1995; AGFD 1996).

Speckled Dace

Speckled dace from both the 1994 (age 1) and 1995 (YOY) year classes were present in Shinumo Creek in 1995 (Figure 13). Speckled dace YOY also first appeared in our samples in September, ranging from 20 - 50 mm on 22 September. Age 1 fish collected in Shinumo Creek ranged from 60 - 110 mm TL on 4 April and 60 - 100 mm TL on 20 June.

Kanab Creek

Bluehead Sucker

Young-of-year, juvenile, and adult bluehead suckers were present in Kanab Creek in 1995 (Figure 10). Bluehead sucker YOY first appeared in our samples on 23 June when one YOY bluehead sucker (32 mm TL) was captured. Juvenile and adult bluehead suckers collected in Kanab Creek ranged from 150 - 270 mm TL on 8 April.

Flannelmouth Sucker

No YOY flannelmouth suckers were caught in Kanab Creek in 1995 (Figure 11). Flannelmouth suckers caught in Kanab Creek ranged from 170 - 450 mm TL on 8 April and 230 - 430 mm TL on 23 June. Most of the fish caught in Kanab Creek were adult fish moving into Kanab Creek to spawn or feed.

Humpback Chub

One humpback chub was also caught in Kanab Creek in 1995 (Figure 12). This fish was 56 mm TL on 8 April. This fish is likely a representative of the 1994 (age 1) year class.

Speckled Dace

Speckled dace from both the 1994 (age 1) and 1995 (YOY) year classes were captured in 1995. Speckled dace YOY first appeared in our samples in June (Figure 13). Speckled dace YOY collected in Kanab Creek were 20 - 40 mm TL on 23 June and 30 - 40 mm TL on 25 September. Age 1 fish collected ranged from 50 - 80 mm TL on 8 April and 80 - 90 mm TL on 23 June.

Havasu Creek

Bluehead Sucker

Young-of-year, juvenile, and adult bluehead suckers were captured in Havasu Creek in 1995 (Figure 10). Young-of-year bluehead suckers first appeared in June and were 40 - 60 mm TL. Only one bluehead sucker was captured in September (63 mm TL). Juvenile and adult bluehead suckers collected in Havasu Creek ranged from 90 - 330 mm TL on 9 April.

Flannelmouth Sucker

No YOY flannelmouth sucker were captured in Havasu Creek in 1995 (Figure 11). Juvenile and adult flannelmouth suckers collected ranged from 160 - 520 mm TL on 9 April and 420 - 482 mm TL on 24 June. One adult flannelmouth sucker (482 mm TL) was collected in September.

Humpback Chub

No humpback chub were captured in Havasu Creek in 1995.

Speckled Dace

Speckled dace YOY first appeared in June (Figure 13). Young-of-year speckled dace collected were 20 - 40 mm on 24 June and ranged from 40 - 80 mm on 25 September. Juvenile and adult speckled dace ranged from 50 - 100 mm TL in April, 50 - 90 mm TL in June, and 70 - 90 mm TL in September.

Summary

All life stages of native fishes were collected in tributaries sampled in 1995. The presence of adult spawners indicated continued use of tributaries as spawning grounds, larval fish indicated successful spawning, and continued capture of YOY indicated successful growth with the potential for recruitment. Tributary use varied temporally and with the specific life stage of each species. Adult bluehead sucker were caught in tributaries only during Trip 95-1, whereas adult flannelmouth sucker were collected during Trips 95-1 and 95-2 in Kanab Creek and Trips 95-1, 95-2, and 95-3 in Havasu Creek. Young-of-year bluehead and flannelmouth suckers were primarily collected starting in June (Trip 95-2) and continued to be present during September (Trip 95-3) but in very small numbers.

Relative Condition (Kn)

Length-weight relationships and relative condition (Kn) were calculated for bluehead sucker, flannelmouth sucker, and humpback chub in 1995. A length-weight relationship for 306

bluehead suckers caught was calculated and represented by:

$$\log_{10}W = -5.257 + 3.092 \log_{10}TL \ (R^2=0.99)$$

An exponent of 3.092 indicates that these bluehead suckers exhibit approximate isometric growth. Mean condition factors throughout 1995 showed a downward trend (Figure 14). The highest Kn was during Trip 95-1 and decreased throughout the remainder of the year. Low mean Kn values are common following spawning (Valdez and Ryel 1995).

A length-weight relationship for 375 flannelmouth suckers was calculated and represented by:

$$\log_{10}W = -5.318 + 3.119 \log_{10}TL \ (R^2=0.99)$$

As with bluehead suckers, an exponent of 3.119 indicates that these flannelmouth suckers exhibit approximate isometric growth. Mean condition factors for flannelmouth sucker throughout 1995 also showed a decrease in relative condition throughout the year (Figure 14) with the highest mean Kn being during Trip 95-1.

Lastly, a length-weight relationship for 106 humpback chubs was calculated and represented by:

$$\log_{10}W = -5.433 + 3.149 \log_{10}TL \ (R^2=0.95)$$

Again, an exponent of 3.149 for these humpback chub indicates approximate isometric growth for this species. Although humpback chub change shape dramatically with age with the development of a nuchal hump, the length to weight relationship was constant, as seen in the past for this species (Valdez and Ryel 1995). Mean condition factors for humpback chub throughout 1995 showed a different pattern than that of bluehead and flannelmouth sucker (Figure 14). Humpback chub used to calculate mean Kn were < 200 mm TL and had the highest mean Kn during Trip 95-2.

PIT-tagging

Growth

A total of 224 fish (139 flannelmouth suckers and 85 bluehead suckers) was implanted with a PIT-tag by AGFD in 1995. A total of 16 fish (15 flannelmouth suckers and one bluehead sucker) captured by AGFD in 1995 had been previously marked by AGFD or other researchers. We were able to obtain original PIT-tag mark information for the bluehead sucker and 12 of the

15 flannelmouth suckers and the bluehead sucker. The 12 recaptured flannelmouth suckers had been at large an average of 417 days (range: 296 - 724). All 12 gained weight in the interim: average weight and length (mm) gain of flannelmouth suckers was 144.4 g and 52.1 mm, respectively. The average weight gain of flannelmouth suckers was 4.8 g/30 days and the average length gain was 1.7 mm/30 days. The bluehead sucker PIT-tag recapture had been at large 569 days, and gained 27 g and 16 mm since original marking (1.4 g and 0.84 mm/30 days).

Movement

Twelve flannelmouth suckers and one bluehead sucker were used to examine movement of these fish in the Grand Canyon (Table 2). Of the 12 recaptured flannelmouth suckers, eight were captured in the same location where they were originally marked. The average net displacement of flannelmouth sucker was 3.58 km, and ranged from 0 - 131.9 km. The average net displacement of flannelmouth sucker per 30 days was 0.3 km. One fish (PIT-tag # 7F7D7F4776) was originally marked in the LCR in June 1994 and was recaptured in Kanab Creek in April 1995. Three flannelmouth suckers were originally marked in Kanab Creek and subsequently recaptured in Havasu Creek, while two flannelmouth suckers originally marked in Havasu Creek were recaptured in Kanab Creek. The only bluehead sucker recaptured was both marked and recaptured in the mouth of Havasu Creek.

Lower Trophic Levels

Zooplankton

Zooplankton are an important food resource for larval and juvenile native fishes in the Colorado River system (Maddux et al. 1987; Marsh and Langhorst 1988; Muth and Snyder 1995; AGFD 1996). Most or all zooplankton found in the Colorado River, Grand Canyon, originates in Lake Powell, the mainstem reservoir formed by Glen Canyon Dam (Haury 1981; 1986).

Results of the 1995 zooplankton analyses showed a mean total zooplankton density of 16,385 individuals/m^3. Copepod nauplii were the most abundant zooplankton taxa collected, followed by protozoans, copepod adults, rotifers, and ostracod nauplii (Figure 16). Mean total zooplankton density was significantly higher (P=0.0170) during Trip 95-2 than Trip 95-1 or Trip 95-3 (Figure 15). There were no significant differences in mean total zooplankton density by reach (p=0.2798) or habitat (backwater vs. mainchannel; P=0.3919). These results agrees with

those of Haury (1981, 1986) and AGFD (1996).

Mean densities of individual zooplankton taxa varied significantly by trip and/or reach. Mean protozoan density was significantly higher during Trip 95-1 (P=0.0440) than during Trips 95-2 or 95-3. Mean protozoan density was the only zooplankton taxa that differed significantly by reach; being significantly higher in Reach 8 (P=0.0213) than in any other reach. Mean cladoceran density was significantly higher during Trip 95-3 (P=0.0281) than during Trips 95-1 or 95-2. Mean copepod nauplii density was significantly higher during Trip 95-2 (P=0.0015) than during Trip 95-1 or Trip 95-3. Similar seasonal patterns were observed by AGFD in 1994 where summer zooplankton densities were higher than early spring or late fall. Increases in zooplankton reproduction may have occurred in late spring to early summer, possibly contributing to the higher densities observed during Trip 95-2 (summer) in 1995. The seasonal differences observed in individual zooplankton densities in 1995 can be attributed to differences in reproductive cycles of individual zooplankton taxa.

Benthic Invertebrates

Benthic invertebrates are also a major food resource for juvenile native fishes in the Colorado River, Grand Canyon (AGFD 1996). However fluctuating water levels (Kennedy 1979) and cold water temperatures (Ward 1976) have been found to limit invertebrate production in rivers below hydroelectric dams, thus affecting the biota in the Colorado River, Grand Canyon, as well.

Results of the 1995 analyses of benthic invertebrates showed a mean total benthic invertebrate density of 340.8/m^2 in backwaters and mainchannel beachfaces. Nematodes were the most abundant benthic invertebrate followed by ostracods, chironomid larvae, oligochaetes, and gastropods (Figure 17). Mean benthic invertebrate density was significantly higher (P=0.0001) in backwaters (1138.8/m^2) than mainchannel beachfaces (63.7/m^2; Figure 18) and also varied by reach (P=0.0019; Figure 19). However, multiple comparisons did not show specific differences by reach. There was no significant difference in mean total benthic invertebrate density among the three trips in 1995 (P=0.2132). Nematodes were the most abundant benthic invertebrate followed by ostracods, chironomid larvae, oligochaetes, and gastropods.

These findings agree with past studies (Cole and Kubly 1976, Carothers and Minckley 1981, AGFD 1996) which found the same taxa to be most abundant in backwaters. Backwaters

had significantly higher densities of benthic invertebrates than did mainchannel beachfaces. This, too, agrees with past studies (AGFD 1996) which found higher densities of benthic invertebrates in backwaters than mainchannel beachfaces. Hoffknecht (1981) found that lower velocities and the deposition of detritus in backwater habitats have contributed to increased numbers of benthic invertebrates in backwaters in the Colorado River, Grand Canyon.

Densities of individual taxa differed significantly by habitat and/or trip (P=0.0001) but not by reach (P=0.5238). Mean densities of all benthic invertebrate taxa were also significantly higher (P=0.0001) in backwaters than in the mainchannel beachfaces. Only amphipods and oligochaetes showed a significant difference in mean density by trip and were significantly higher (P=0.0001) during Trip 95-02 than during Trip 95-01 or Trip 95-03. This, too, agrees with past studies (AGFD 1996) which found individual densities of benthic invertebrates in backwaters than mainchannel beachfaces, and seasonal patterns in individual taxa densities.

Water Quality

Since the closure of Glen Canyon Dam in 1963, the water quality of the Colorado River, Grand Canyon has been substantially altered. Water quality in the Colorado River, Grand Canyon is now largely determined by conditions in Lake Powell (Stanford and Ward 1991). The greatest changes to the system were the decreases and loss of seasonality in water temperature and sediment load, and changes in the distribution of particulate organic matter (Valdez and Ryel, 1995).

Water quality parameters examined in this report include temperature, turbidity, dissolved oxygen, specific conductance, and pH, which have been investigated in the past (AGFD 1996) and continued to be monitored in 1995. These parameters were used to characterize the Colorado River, Grand Canyon, and to help monitor factors that affect native fishes. A summary of mean, minimum, and maximum values for all water quality parameters collected in backwater and mainchannel habitats in each reach during each sampling trip in 1995 are presented in Appendix 7.

Water Temperature

Water temperature in backwaters was significantly (P=0.0012) warmer than the mainchannel. Mean water temperature in backwaters varied significantly (P=0.0001) by season;

significantly greater (P=0.0021) during Trip 95-2 than any other trip. Mean water temperature in backwaters during Trip 95-1 was 12.2 °C and ranged from 6.7 - 22.3 °C. Mean water temperature in backwaters during Trip 95-2 was 15.5 °C and ranged from 11.2 - 24.3 °C; while mean water temperature in backwaters during Trip 95-3 was 17.1 °C and ranged from 8.0 - 24.6 °C. Mean water temperature varied significantly (P=0.0001) by reach as well (Figure 20). Mean backwater temperature was lowest in Reach 1 and increased with distance downstream from Glen Canyon Dam.

Mean mainchannel water temperature also varied significantly by season (P=0.0030); greater (P=0.0345) during Trip 95-2. Mean mainchannel temperature during Trip 95-1 was 11.2 °C and ranged from 7.8 - 19.5 °C. Mean mainchannel water temperature during Trip 95-2 was 13.3 °C and ranged from 10.3 - 17.6 °C; while mean mainchannel water temperature during Trip 95-3 was 13.4 °C (12.2 - 14.4 °C). Mean mainchannel water temperature also varied significantly (P=0.0074) by reach (Figure 20). Mean mainchannel water temperature was lowest in Reach 1 and increased with distance downstream from Glen Canyon Dam.

Water temperatures in the Colorado River, Grand Canyon, following the closure of Glen Canyon Dam are constantly cold with little seasonal fluctuation. Summer temperatures at Lee's Ferry are an average of 11°C colder than pre-dam conditions (Stanford and Ward 1991). However, it has been documented that mainchannel water temperature increases with increased distance downstream from Glen Canyon Dam (Valdez and Ryel 1995; AGFD 1996). Arizona Game and Fish Department (1996) estimated that the water temperature of the Colorado River, Grand Canyon increases at an average rate of 1°C/77.7 km; while Valdez and Ryel (1995) calculated the greatest longitudinal warming in the summer to be 1°C/51 km. With these estimated rates of change in water temperature, by the time the Colorado River reaches Diamond Creek in June, mainchannel temperatures would be approximately 17.5°C. However, these temperatures are still below the preferred temperature range (21.0 - 24.4°C) for juvenile (80 - 120 mm) humpback chub (Bulkley et al. 1982).

Turbidity

Mean turbidity did not vary significantly (P=0.9791) by habitat. However, mean turbidity did significantly vary (P=0.0001) by season and reach (P=0.0001; Figure 21). Mean turbidity was significantly higher during Trip 95-3 than any other trip. Mean turbidity during Trip 95-1 was

24.3 NTU and ranged from 3.2 - 210 NTU. Mean turbidity during Trip 95-2 was 8.0 NTU and ranged from 1 - 18 NTU; while mean turbidity during Trip 95-3 was 35.7 NTU and ranged from 8 - 138 NTU. Mean turbidity was significantly higher in Reach 3 than in any other reach and generally decreased with distance downstream from the LCR. Turbidity in Reach 3 is highest due to sediment input from the LCR, and decreases with distance downstream due to deposition of sediments as water moves downstream.

Turbidity (sediment load) in the Colorado River, Grand Canyon, is dependent upon input of sediments from the Paria and Little Colorado Rivers (Cole and Kubly 1976; Andrews 1991). Maddux et al. (1987) found turbidity levels to increase with distance downstream from Glen Canyon Dam. Results of this study show an overall decrease in mainchannel turbidity with distance downstream from Glen Canyon Dam. We also found turbidity to be highest during trips when runoff was most likely entering the mainstem from the Paria and/or Little Colorado Rivers.

Turbidity can strongly affect fish behavior because high turbidity is probably used as cover by native fishes. Arizona Game and Fish Department (1996) documented that speckled dace, juvenile humpback chub; and flannelmouth sucker were more likely to use near shore areas when turbidity exceeded approximately 30 NTU. Valdez and Ryel (1995) found similar results for adult humpback chub and flannelmouth sucker.

Dissolved Oxygen

Mean dissolved oxygen (DO) levels did not differ significantly (P=0.1045) by habitat. However, mean DO did significantly (P=0.0001) vary by season. Mean DO during Trip 95-1 was 11.1 mg/L and ranged from 7.6 - 15.1 mg/L. Mean DO during Trip 95-2 was 9.9 mg/L and ranged from 8.3 - 15.5 mg/L; while mean DO during Trip 95-3 was 10.9 mg/L and ranged from 9.5 - 14.2 mg/L. Mean DO also varied significantly by reach (P=0.0001). Reach 1 had the highest mean DO, and overall, mean DO decreased with distance downstream from Glen Canyon Dam (Figure 22). However, dissolved oxygen was never limiting at any time during any of our trips in 1995.

Specific Conductance

Mean conductivity did not vary significantly by habitat (P=0.1348) or reach (P=0.0588). However, conductivity did vary significantly (P=0.0001) by season. Mean conductivity during

Trip 95-1 was significantly higher (P=0.0031) than any other trip. Mean conductivity during Trip 95-1 was 1006.7 μS/cm, 927.7 μS/cm during Trip 95-2, and 853.0 μS/cm during Trip 95-3 (Figure 23). None of the conductivity levels observed in 1995 likely affected native fishes. Pimental and Bulkley (1983) found that humpback chub avoided total dissolved solid (TDS) concentrations > 5100 mg/L. Conductivity levels during 1995 ranged from 740 - 1800 μS/cm or 473 - 1152 mg/L TDS (TDS = 0.64 * conductivity), levels well below those avoided by humpback chub.

pH

Mean pH did not vary by habitat (P=0.0523), season (P=0.8210), or reach (P=0.0628) during any of our trips in 1995. Mean pH in the mainstem ranged from 7.0 - 9.3 (Figure 24). Most fresh waters have a pH of 6.7 - 8.2 (Piper et al. 1982) and most fish have a wide tolerance of pH (Hynes 1970), in general, growing best in waters with a pH between 6.5 - 9.0 (Piper et al. 1982). Therefore, mean pH levels during 1995 did not appear to be limiting to native fishes.

Summary

Overall, as documented by previous studies (Valdez and Ryel 1995, AGFD 1996) water temperature and low levels of turbidity continue to be the environmental factors most limiting larval and juvenile native fish growth and survival in the Colorado River, Grand Canyon. Dissolved oxygen, specific conductance, and pH were all within acceptable levels for fish growth and are unlikely to be limiting.

Parasite Sampling

In 1995, we examined fishes (speckled dace and fathead minnows) of the Colorado River, Grand Canyon, for the presence of the Asian fish tapeworm (*Bothriocephalus acheilognathi).* Data collected in 1995 were added to data collected in 1994 (as part of a stomach content analysis of small fishes) and has been published (Brouder and Hoffnagle 1997).

The Asian fish tapeworm has invaded the lower Little Colorado River (LCR), a tributary of the Colorado River, where it infects humpback chub, speckled dace, plains killifish, and fathead

minnow (Brouder and Hoffnagle 1997, Clarkson et al. 1997). In 1995, 2.4% of fathead minnow and 1.4% of speckled dace were infected. Nearly all infected fish (66.7 - 100% of each species) were captured in areas near the LCR and were probably the result of infected fish emigrating from that tributary. Because *B. acheilognathi* requires high water temperatures (> 20 °C) for completion of its life cycle, this species is largely confined to the LCR by the cold water of the mainstem Colorado River. However, four infected fish (one plains killifish, one speckled dace, and two fathead minnows) were caught 92.8 - 202.1 km downstream from the LCR. Another speckled dace was caught in the lower section of Kanab Creek, a warm tributary, indicating a potential expansion of the parasite's range. Infection of humpback chub by *B. acheilognathi* is of concern due to the endangered status of this fish. Seasonal warming of the Colorado River through proposed construction of a multi-level intake structure at Glen Canyon Dam, may allow *B. acheilognathi* to quickly expand its range within the Grand Canyon, further endangering the remaining native cyprinids.

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Table 1. Fish species captured in the Colorado River, Grand Canyon, during joint AGFD/BioWest monitoring trips, 1995.

Common Name	Scientific Name	Family
Native Species		
Bluehead sucker	*Catostomus discobolus*	Catostomidae
Flannelmouth sucker	*Catostomus latipinnis*	Catostomidae
Humpback chub	*Gila cypha*	Cyprinidae
Speckled dace	*Rhinichthys osculus*	Cyprinidae
Non-native Species		
Green sunfish	*Lepomis cyanellus*	Centrarchidae
Common carp	*Cyprinus carpio*	Cyprinidae
Fathead minnow	*Pimephales promelas*	Cyprinidae
Plains killifish	*Fundulus zebrinus*	Cyprinodontidae
Brown trout	*Salmo trutta*	Salmonidae
Rainbow trout	*Oncorynchus mykiss*	Salmonidae

Table 2. Date, location, total length, weight and sex of recaptured fish at time of recapture and initial implantation of a PIT-tag, if known, from the mainstem and tributaries of the Colorado River, Grand Canyon, during joint AGFD/BioWest monitoring trips, 1995.

		Recapture					Mark			
Species	PIT Tag Number	Date	Capture Location	Total Length	Weight	Sex	Date	Capture Location	Total Length	Weight
Bluehead Sucker	1F0F6E451F	9 APR 95	HAV	283	193	M	15 APR 93	HAV	267	166
Flannelmouth Sucker	7F7A16702C	8 APR 95	KAN	257	175	F	5 MAY 94	KAN	207	85
Flannelmouth Sucker	7F7D7F4069	8 APR 95	KAN	270	192	F	28 May 94	KAN	226	109
Flannelmouth Sucker	1F3C1D6820	8 APR 95	KAN	280	199	U	5 MAY 94	KAN	229	106
Flannelmouth Sucker	7F7D7F4776	8 APR 95	KAN	282	247	M	16 JUN 94	LCR	229	104
Flannelmouth Sucker	7F7B104501	8 APR 95	KAN	353	555	M	26 MAY 93	KAN	284	241
Flannelmouth Sucker	7F7F157D45	9 APR 95	HAV	346	199	F	16 APR 94	KAN	265	199
Flannelmouth Sucker	7F7B1B640B	9 APR 95	HAV	428	897	F	16 APR 94	KAN	369	533
Flannelmouth Sucker	7F7B1A0463	14 JUN 95	RK 71.24	240	121	U	15 AUG 94	RK 71.24	195	74
Flannelmouth Sucker	1F0937326F	24 JUN 95	KAN	286	204	U	unk	unk	unk	unk
Flannelmouth Sucker	1F7A3C6A41	24 JUN 95	KAN	305	300	U	9 APR 95	HAV	280	231
Flannelmouth Sucker	7F7B183979	24 JUN 95	KAN	312	265	U	8 APR 95	KAN	296	241
Flannelmouth Sucker	7F7F1F1246	24 JUN 95	KAN	350	365	U	unk	unk	unk	unk
Flannelmouth Sucker	7F7A12395B	24 JUN 95	KAN	423	629	U	9 JUL 94	KAN	392	535
Flannelmouth Sucker	7F7B130020	24 JUN 95	KAN	420	647	U	16 APR 94	KAN	319	314
Flannelmouth Sucker	7F7D080D4F	25 JUN 95	HAV	471	963	U	unk	unk	unk	unk

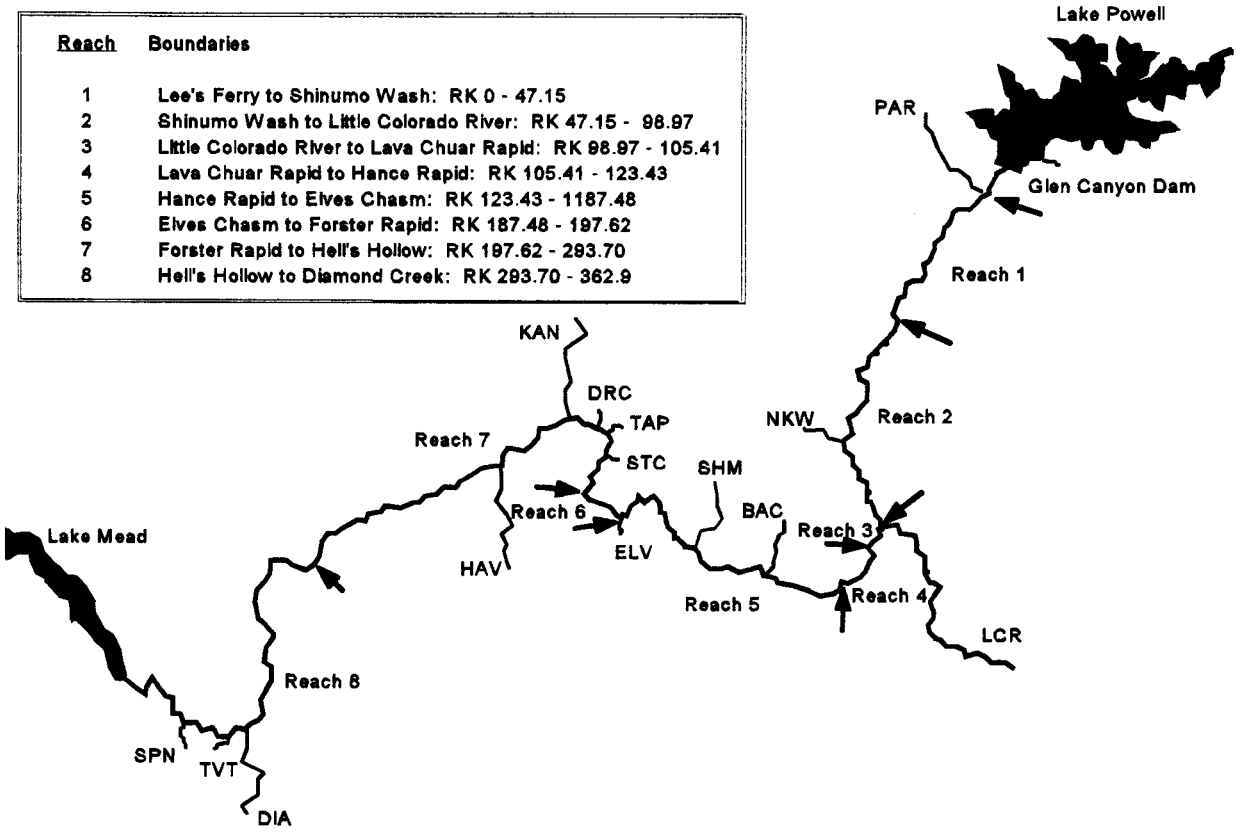

Figure 1. Tributaries and AGFD sampling reaches in the Colorado River, Grand Canyon, 1995. Arrows denote reach boundaries. See Appendix 1 for tributary codes.

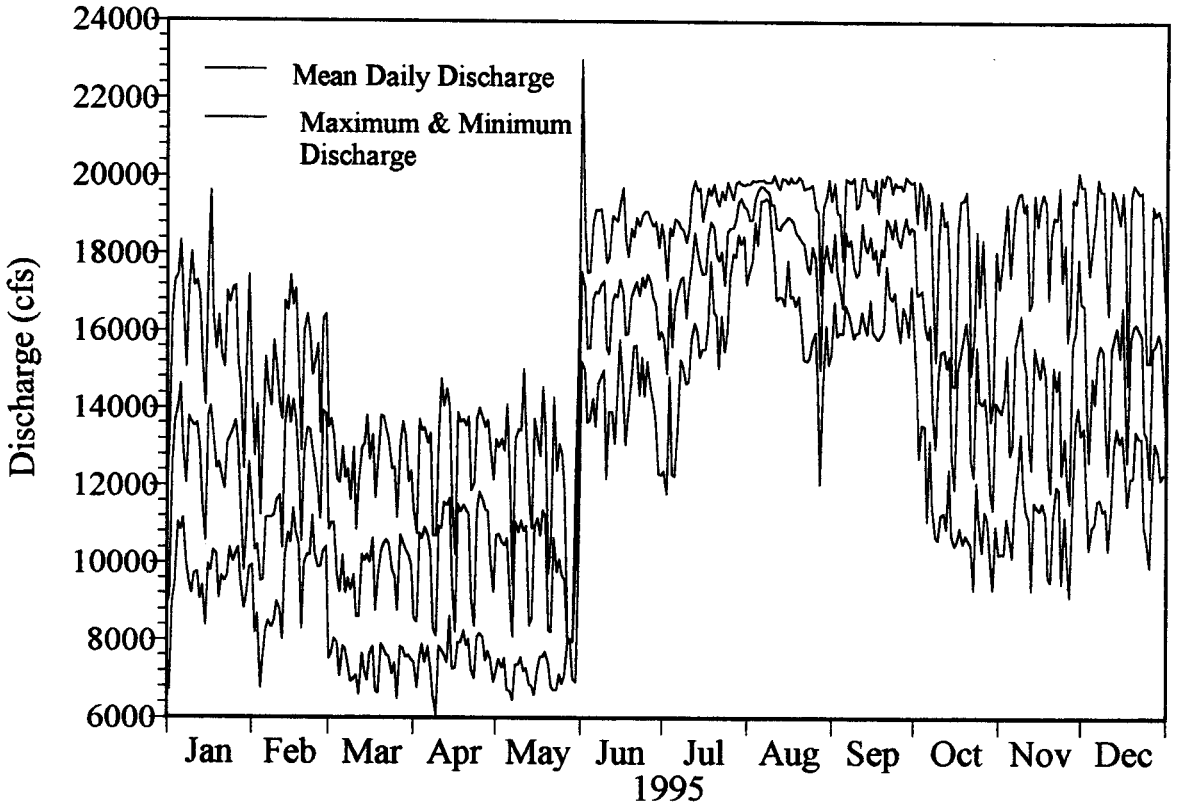

Figure 2. Mean, minimum, and maximum daily discharges from Glen Canyon Dam, 1995.

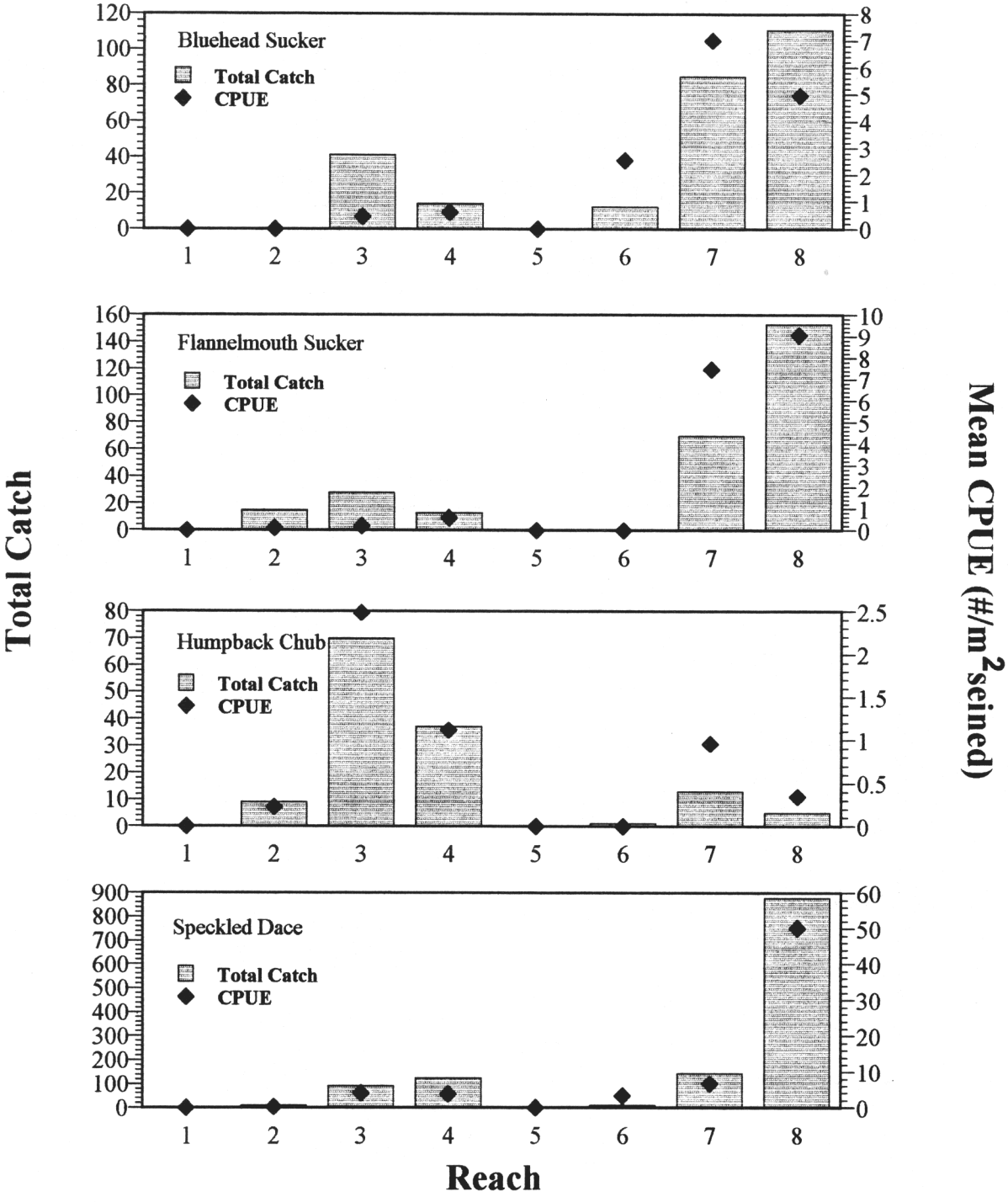

Figure 3. Total catch and catch-per-unit-effort (CPUE = number of fish/100 m^2 surface area seined) for native species in backwaters in each reach of the Colorado River, Grand Canyon, during AGFD/BioWest joint monitoring trips, 1995.

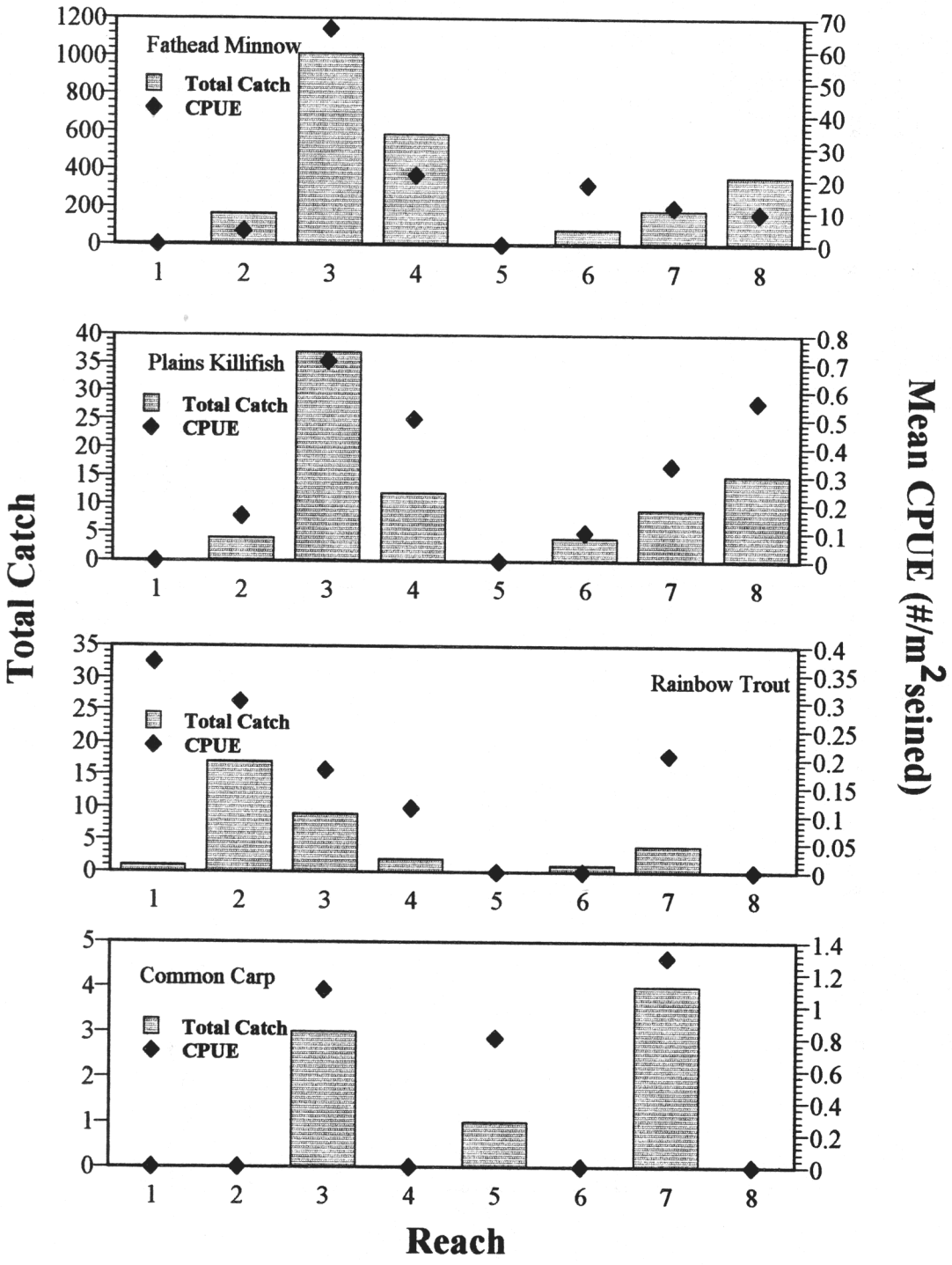

Figure 4. Total catch and catch-per-unit-effort (CPUE = number of fish/100 m^2 surface area seined) for commonly caught exotic species in backwaters in each reach of the Colorado River, Grand Canyon, during AGFD/BioWest joint monitoring trips, 1995.

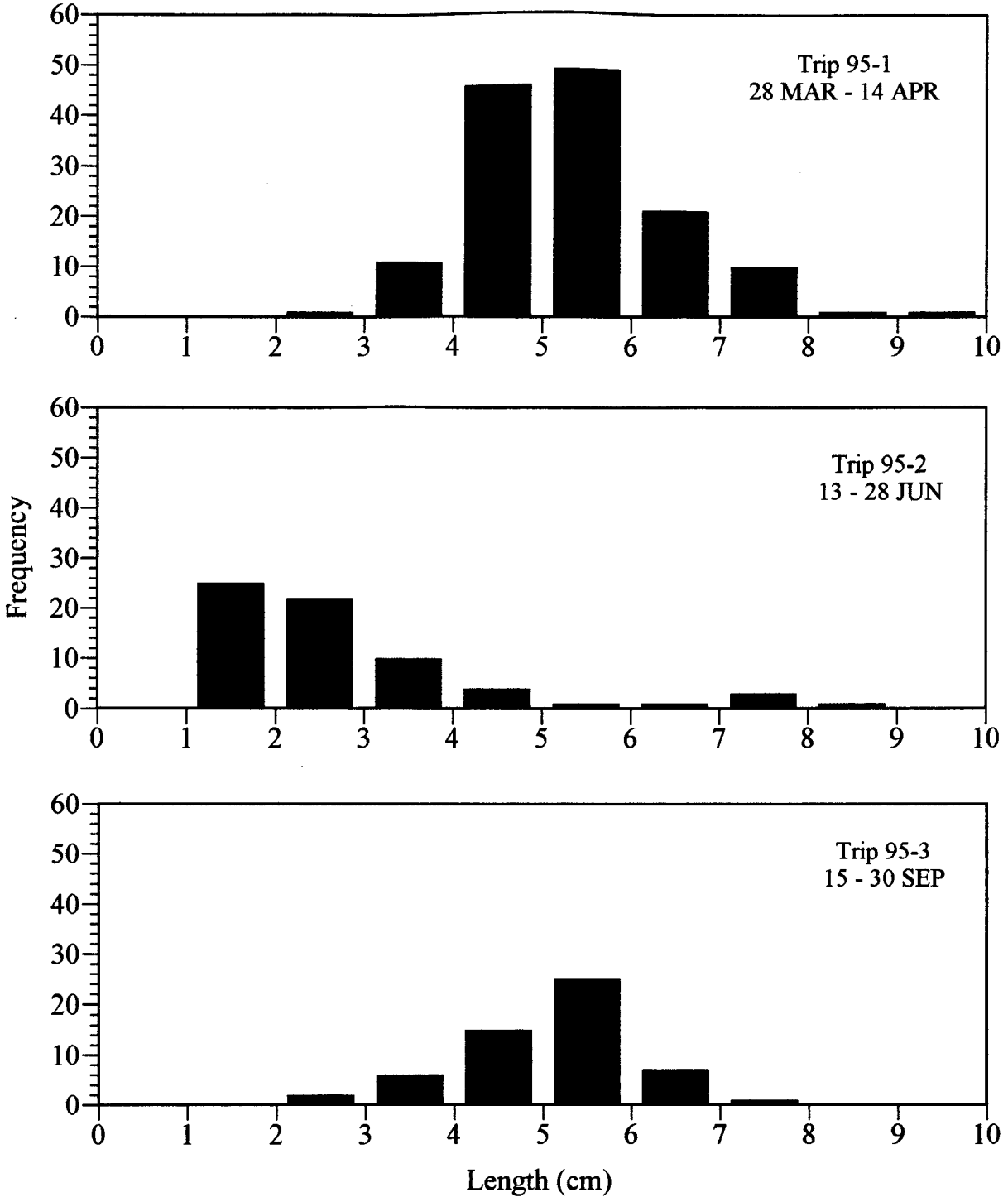

Figure 5. Length frequency of bluehead suckers caught in the mainstem of the Colorado River, Grand Canyon, during joint AGFD/BioWest monitoring trips, 1995.

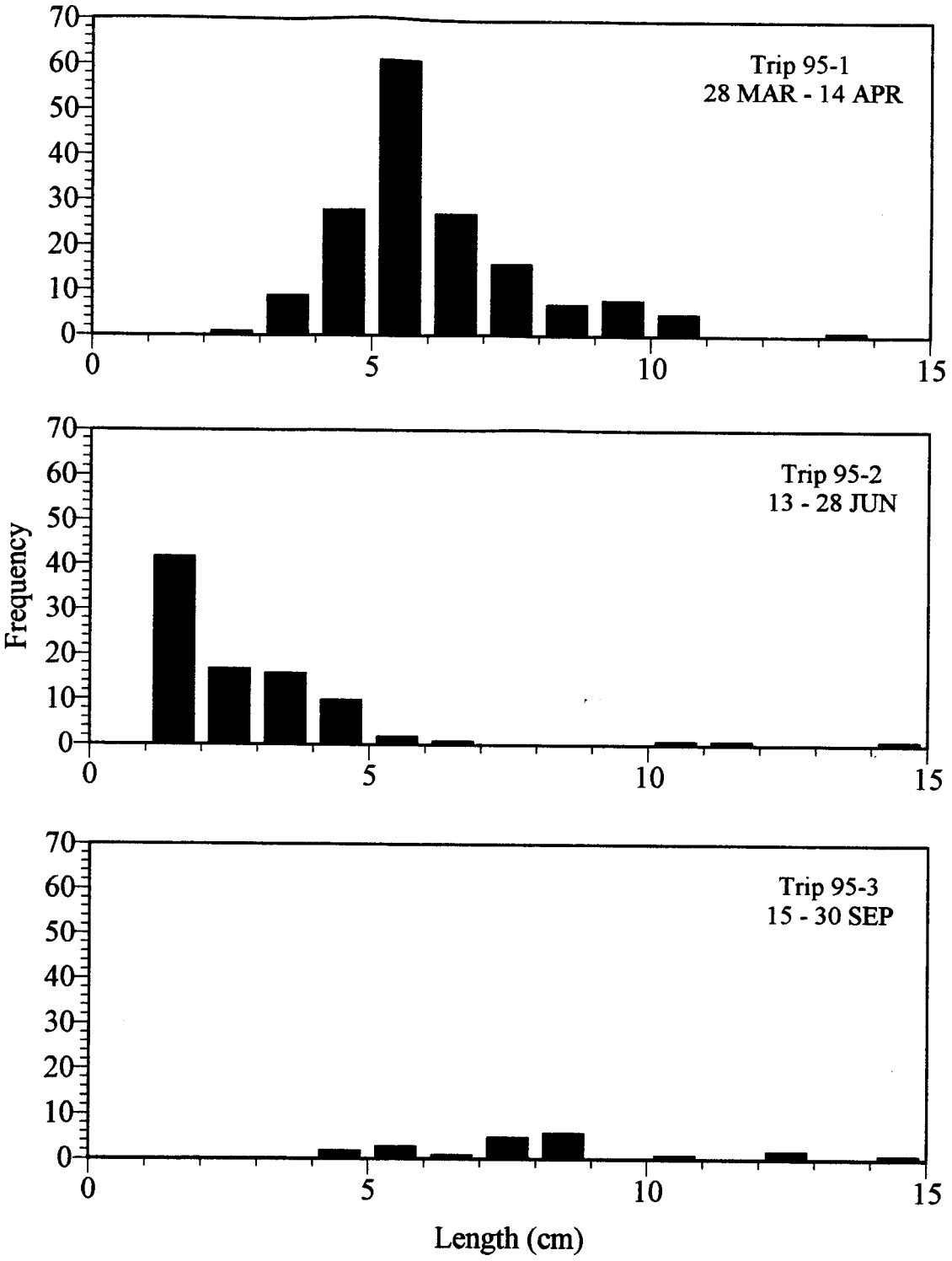

Figure 6. Length frequency of flannelmouth suckers caught in the mainstem of the Colorado River, Grand Canyon, during joint AGFD/BioWest monitoring trips, 1995.

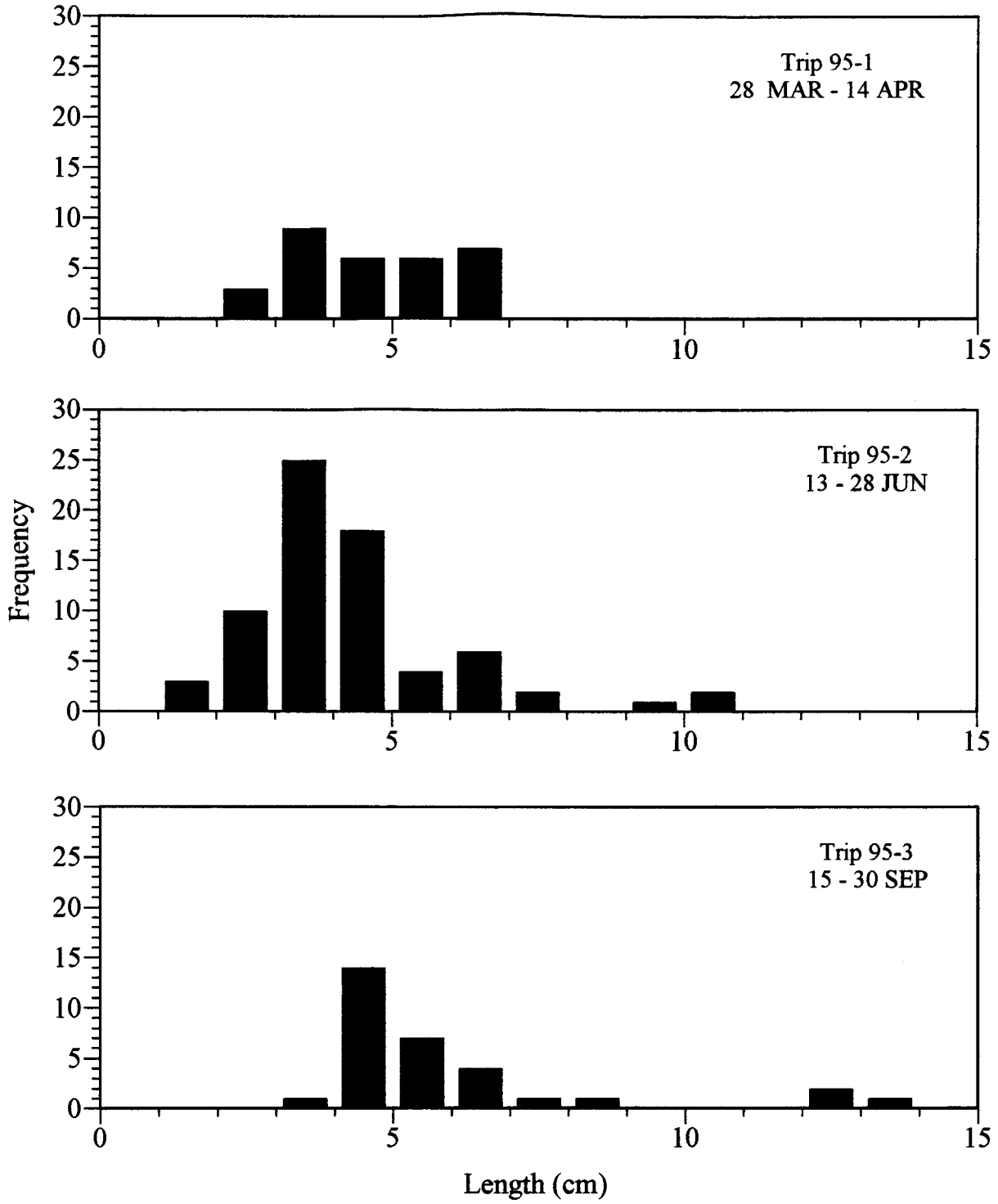

Figure 7. Length frequency of humpback chub caught in the mainstem of the Colorado River, Grand Canyon, during joint AGFD/BioWest monitoring trips, 1995.

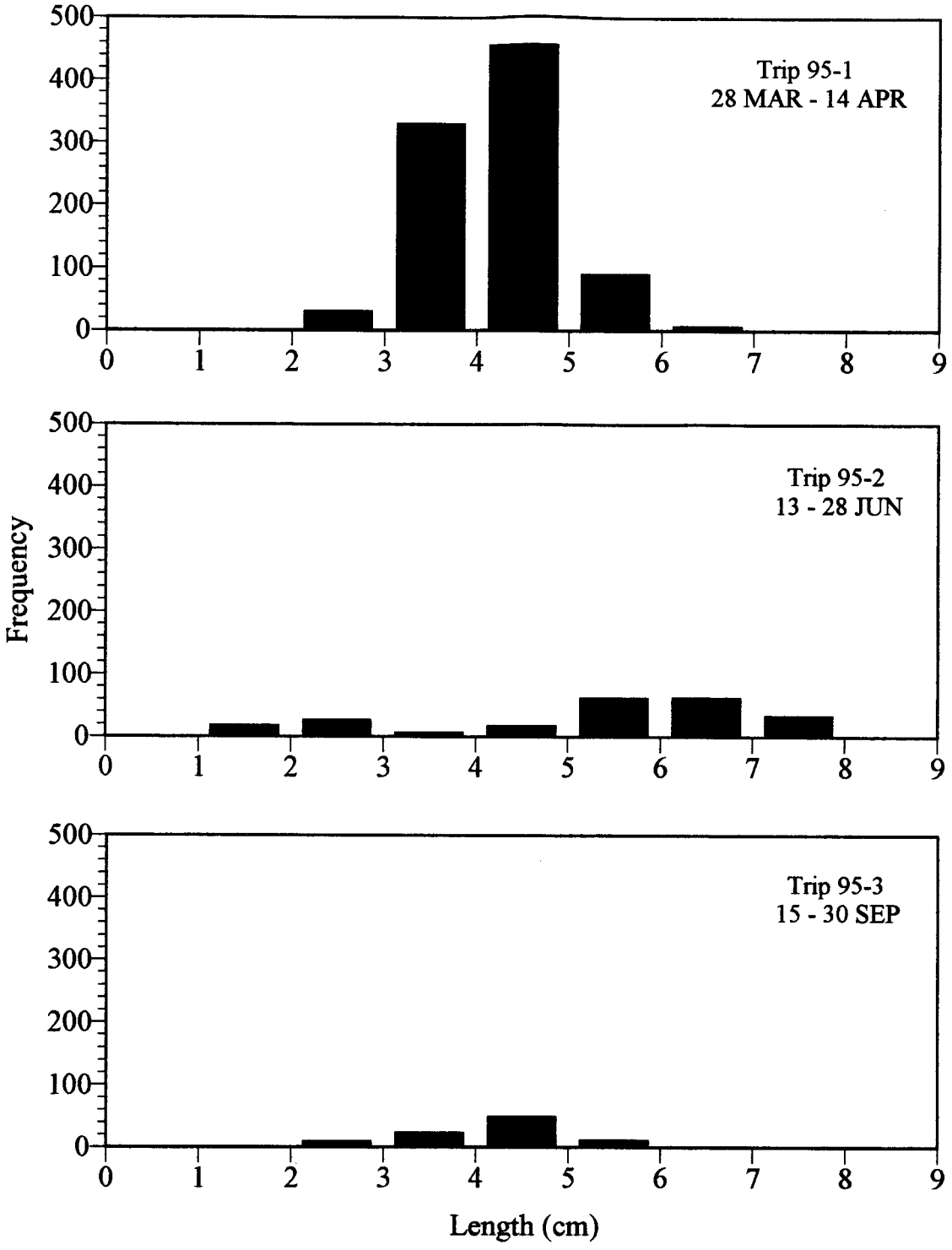

Figure 8. Length frequency of speckled dace caught in the mainstem of the Colorado River, Grand Canyon, during joint AGFD/BioWest monitoring trips, 1995.

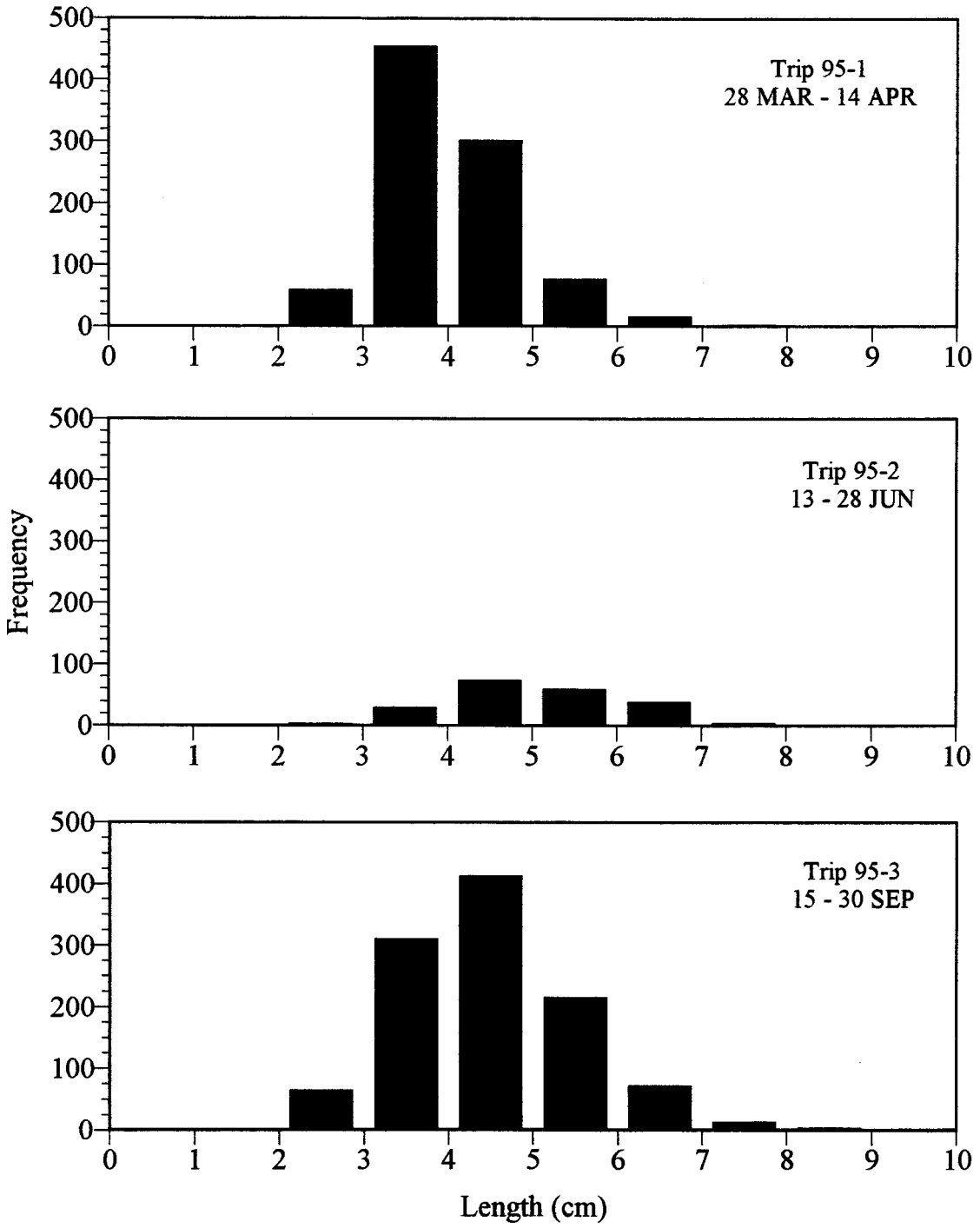

Figure 9. Length frequency of fathead minnow caught in the mainstem of the Colorado River, Grand Canyon, during each trip of joint AGFD/BioWest monitoring trips, 1995.

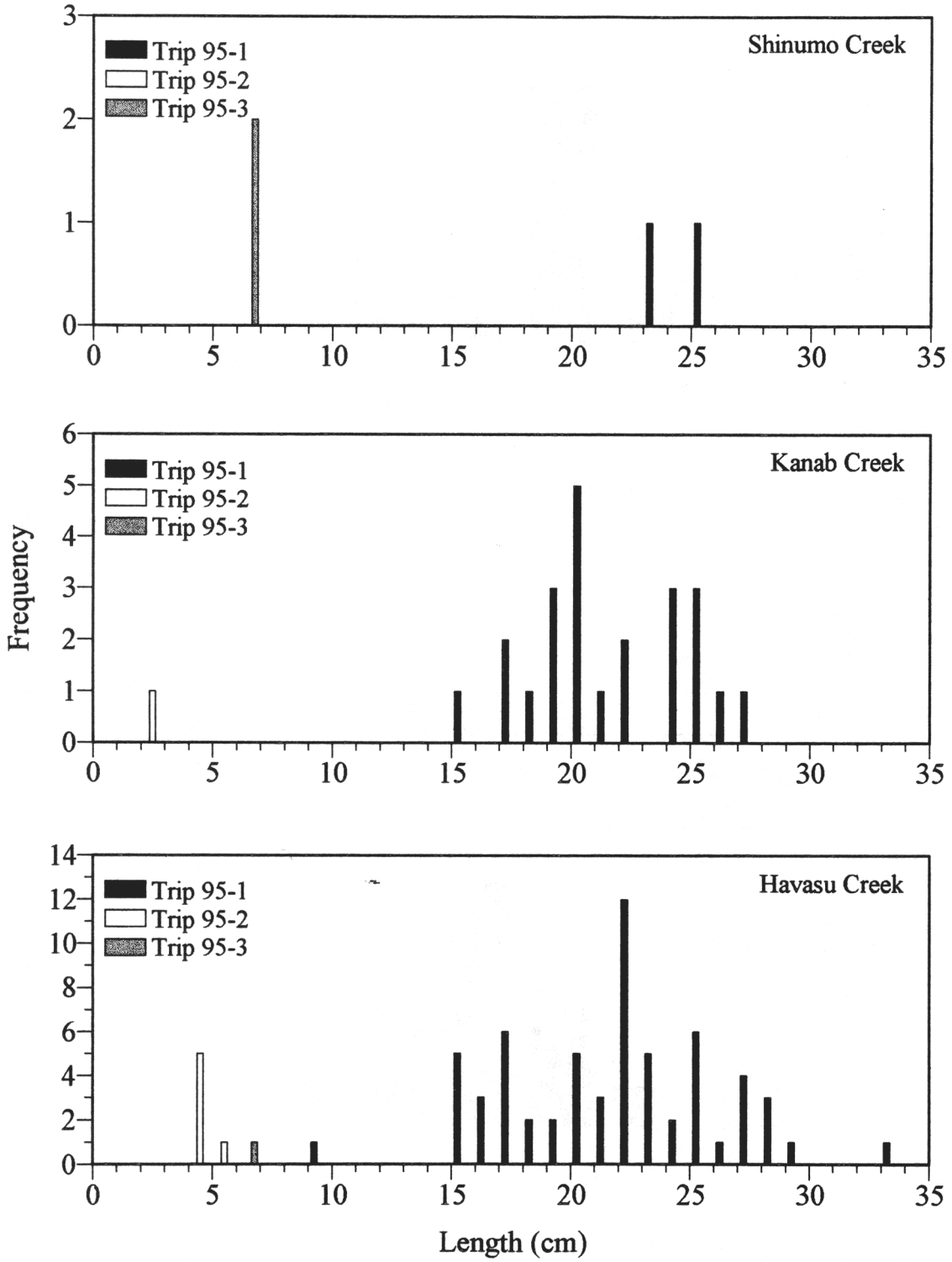

Figure 10. Length frequency of bluehead suckers caught in Shinumo, Kanab, and Havasu Creeks during joint AGFD/BioWest monitoring trips, 1995.

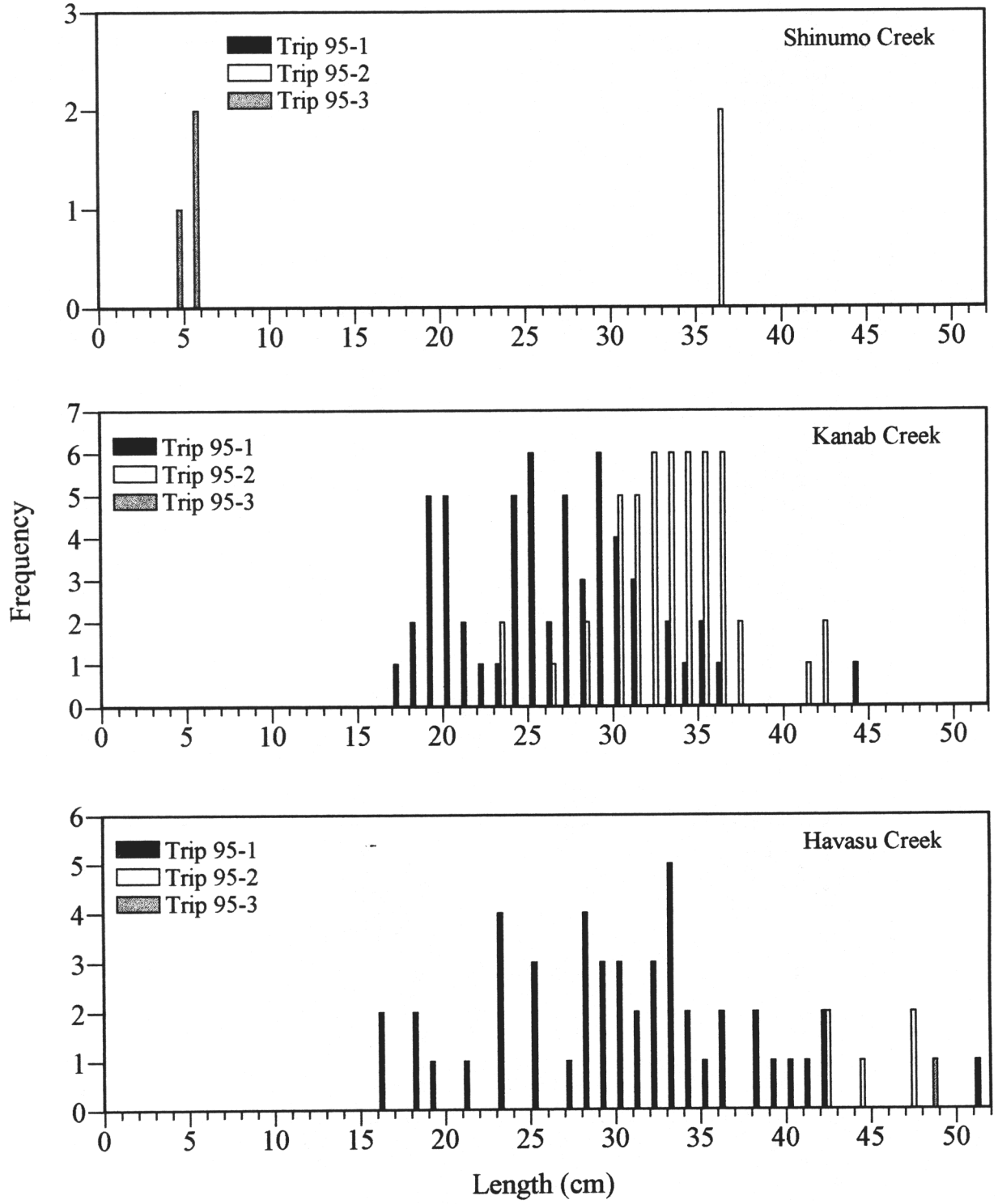

Figure 11. Length frequency of flannelmouth suckers caught in Shinumo, Kanab, and Havasu Creeks during joint AGFD/BioWest monitoring trips, 1995.

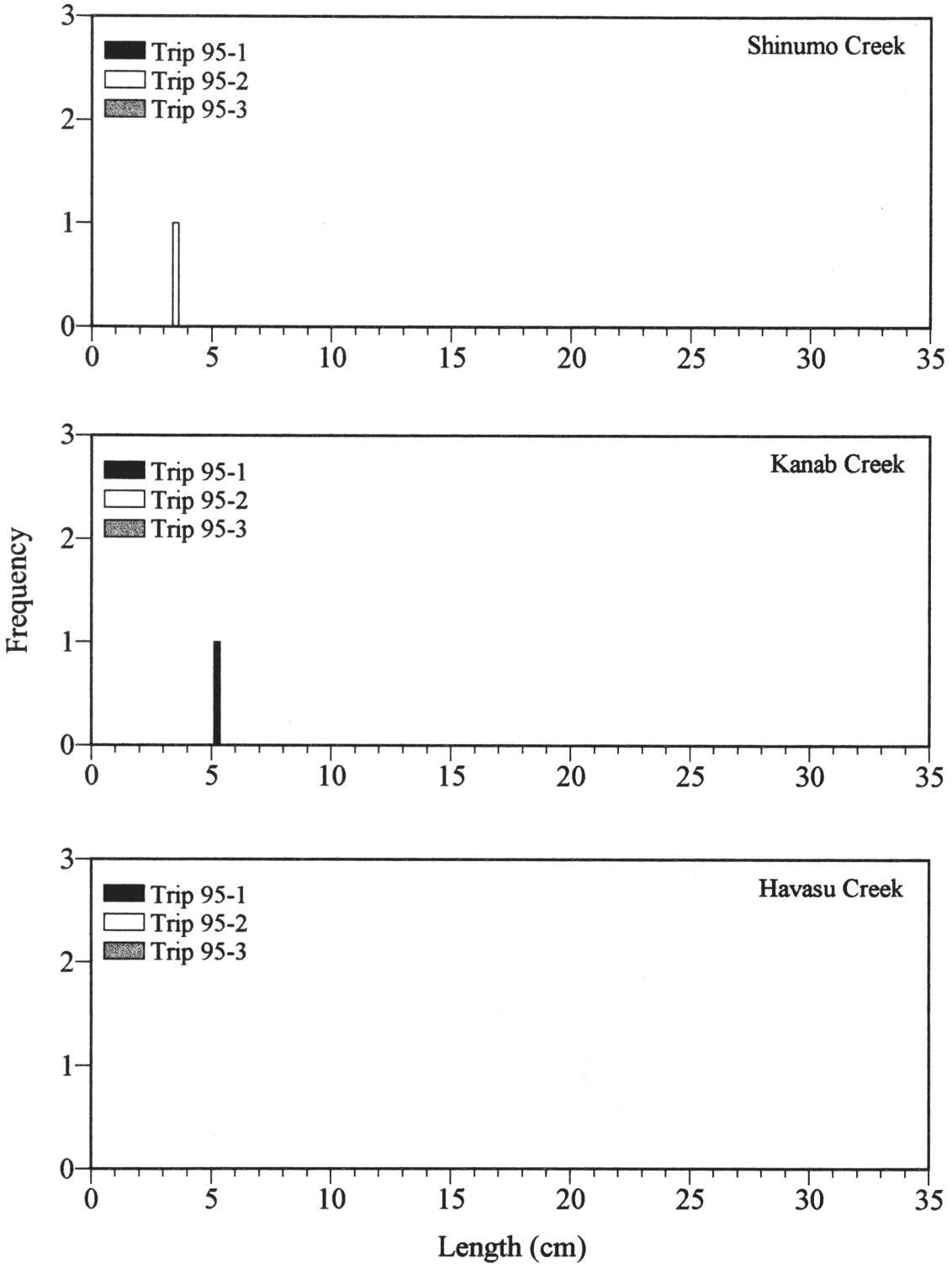

Figure 12. Length frequency of humpback chub caught in Shinumo, Kanab, and Havasu Creeks during joint AGFD/BioWest monitoring trips, 1995.

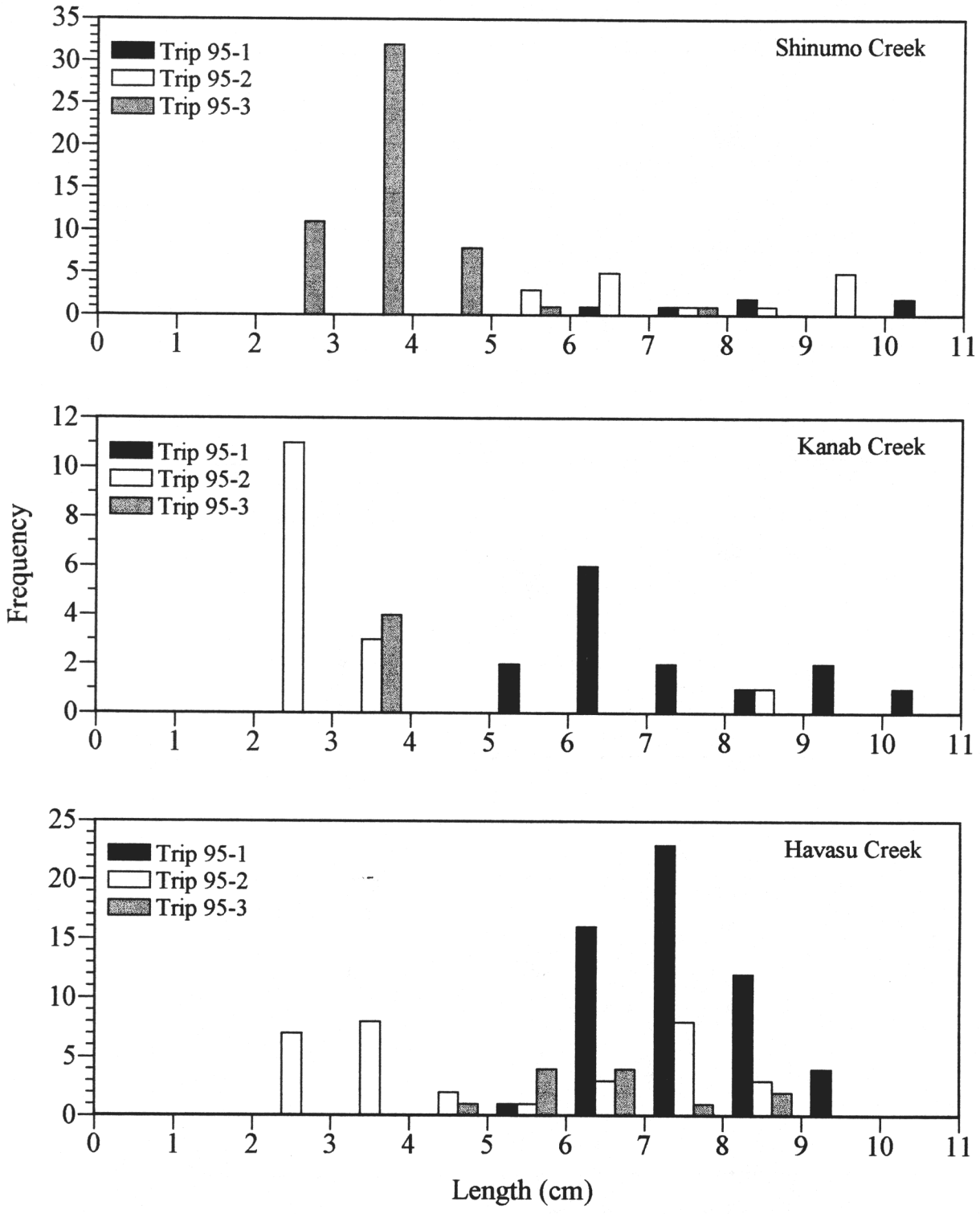

Figure 13. Length frequency of speckled dace caught in Shinumo, Kanab, and Havasu Creeks during joint AGFD/BioWest monitoring trips, 1995.

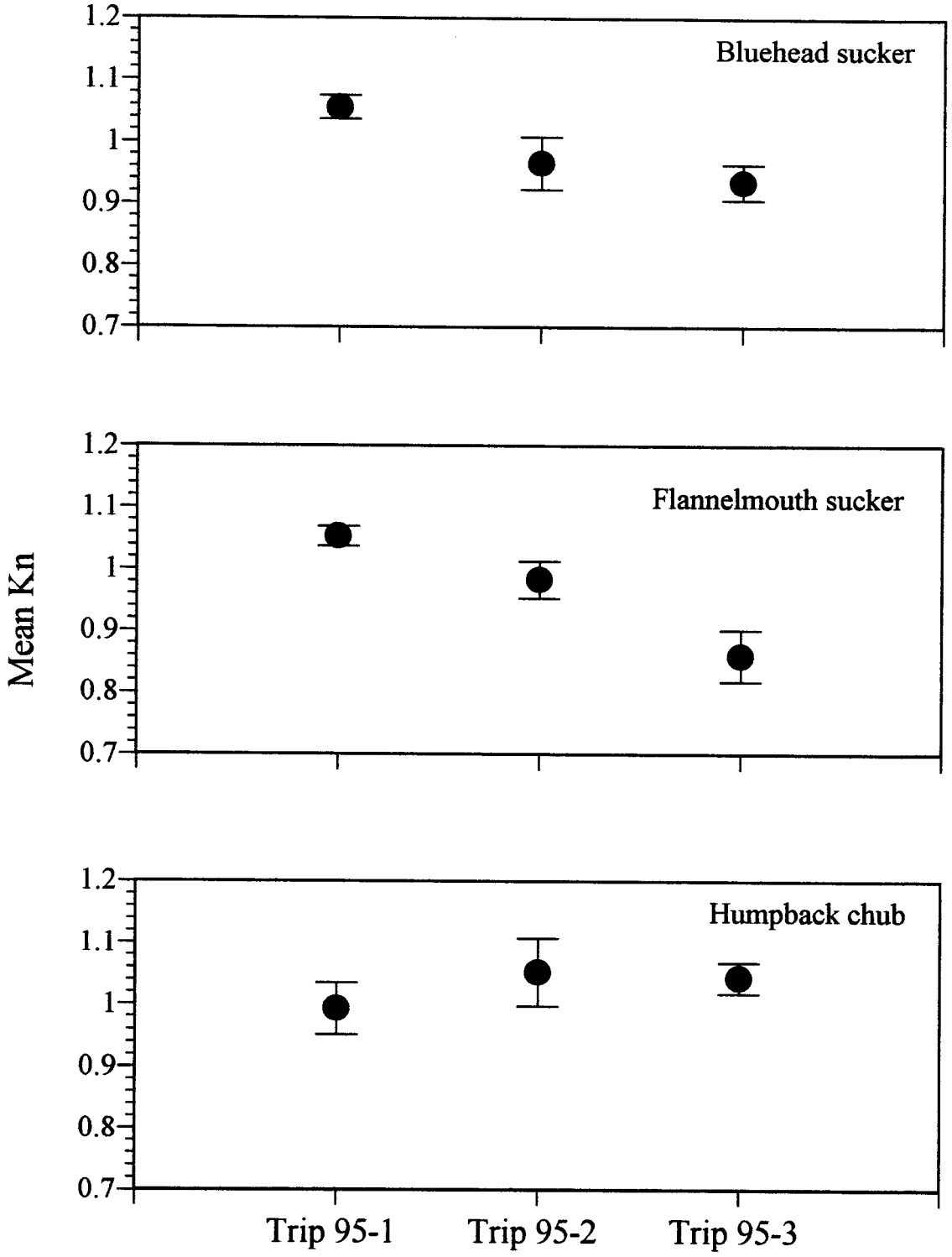

Figure 14. Mean relative condition (Kn) of bluehead sucker, flannelmouth sucker, and humpback chub caught during joint AGFD/BioWest monitoring trips, 1995.

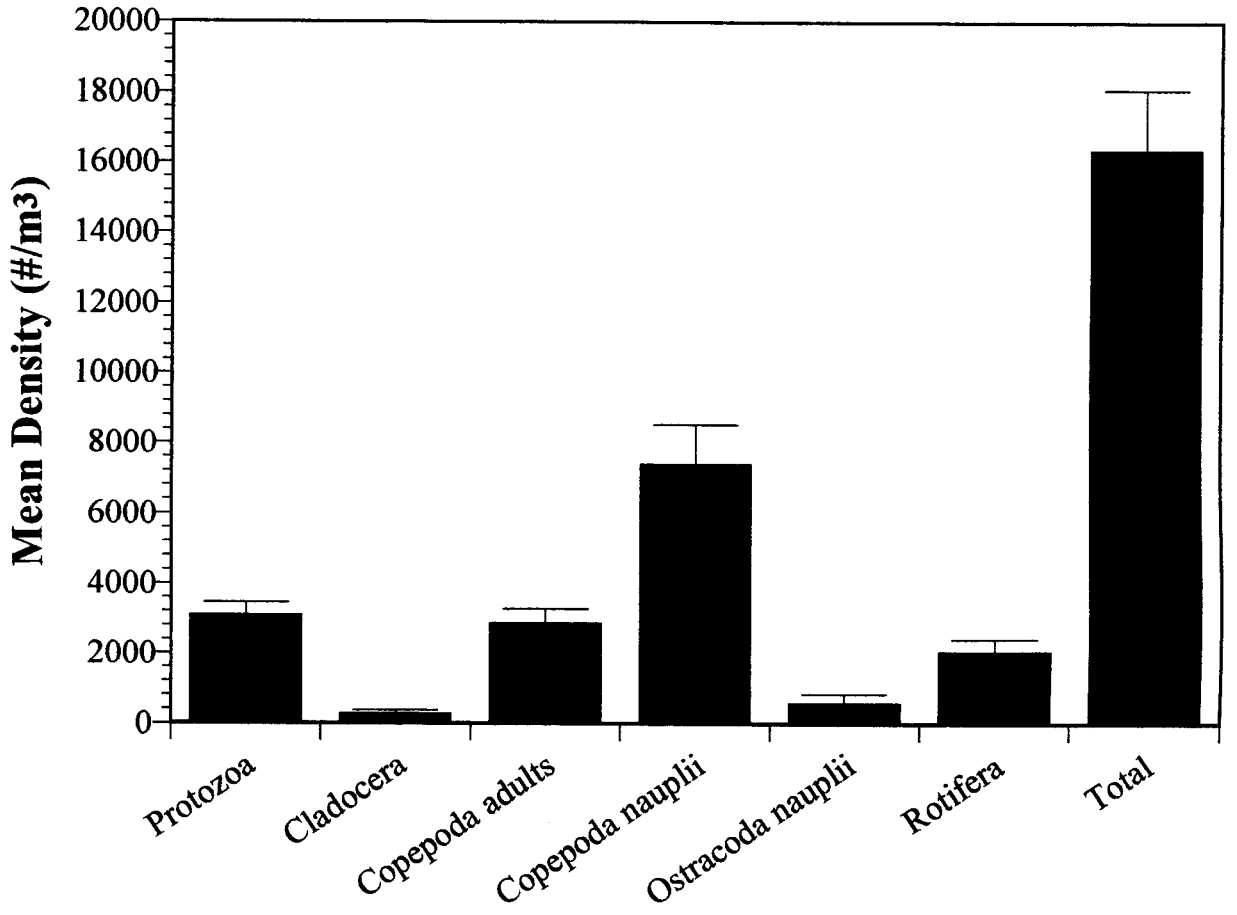

Figure 15. Mean densities of individual zooplankton taxa and total zooplankton collected in the Colorado River, Grand Canyon, during joint AGFD/BioWest monitoring trips, 1995.

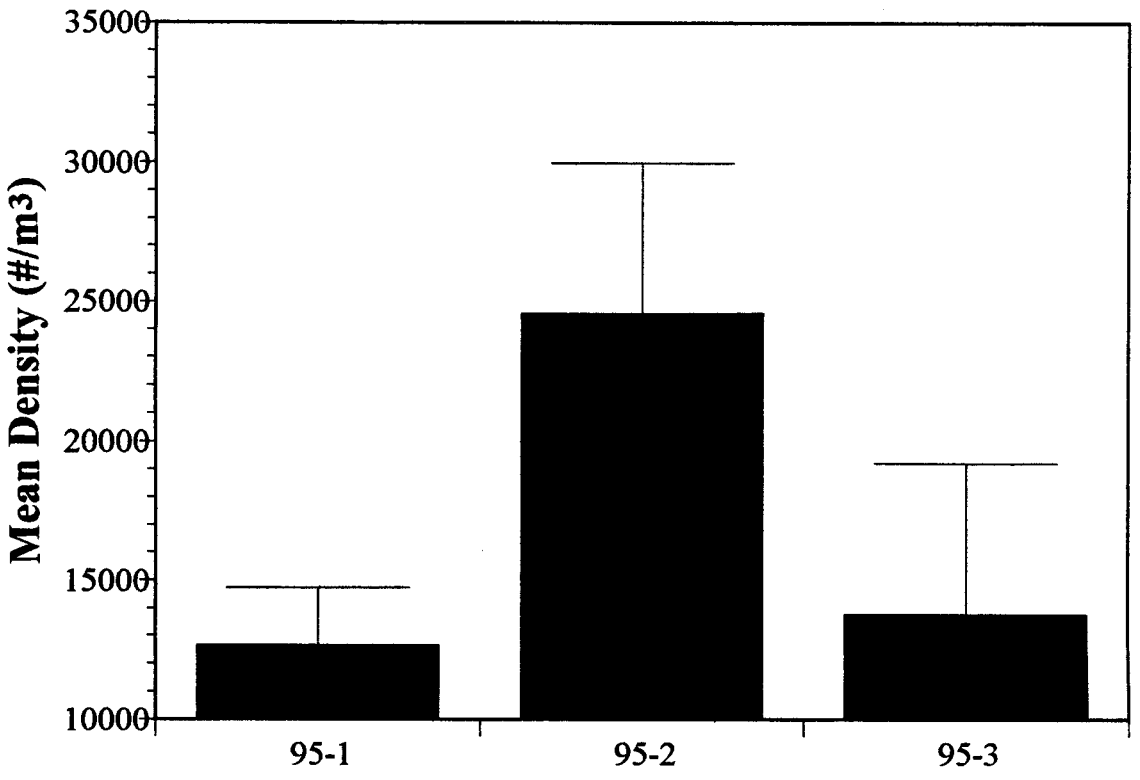

Figure 16. Mean total zooplankton density in samples collected on each sampling trip in the Colorado River, Grand Canyon during joint AGFD/BioWest monitoring trips, 1995.

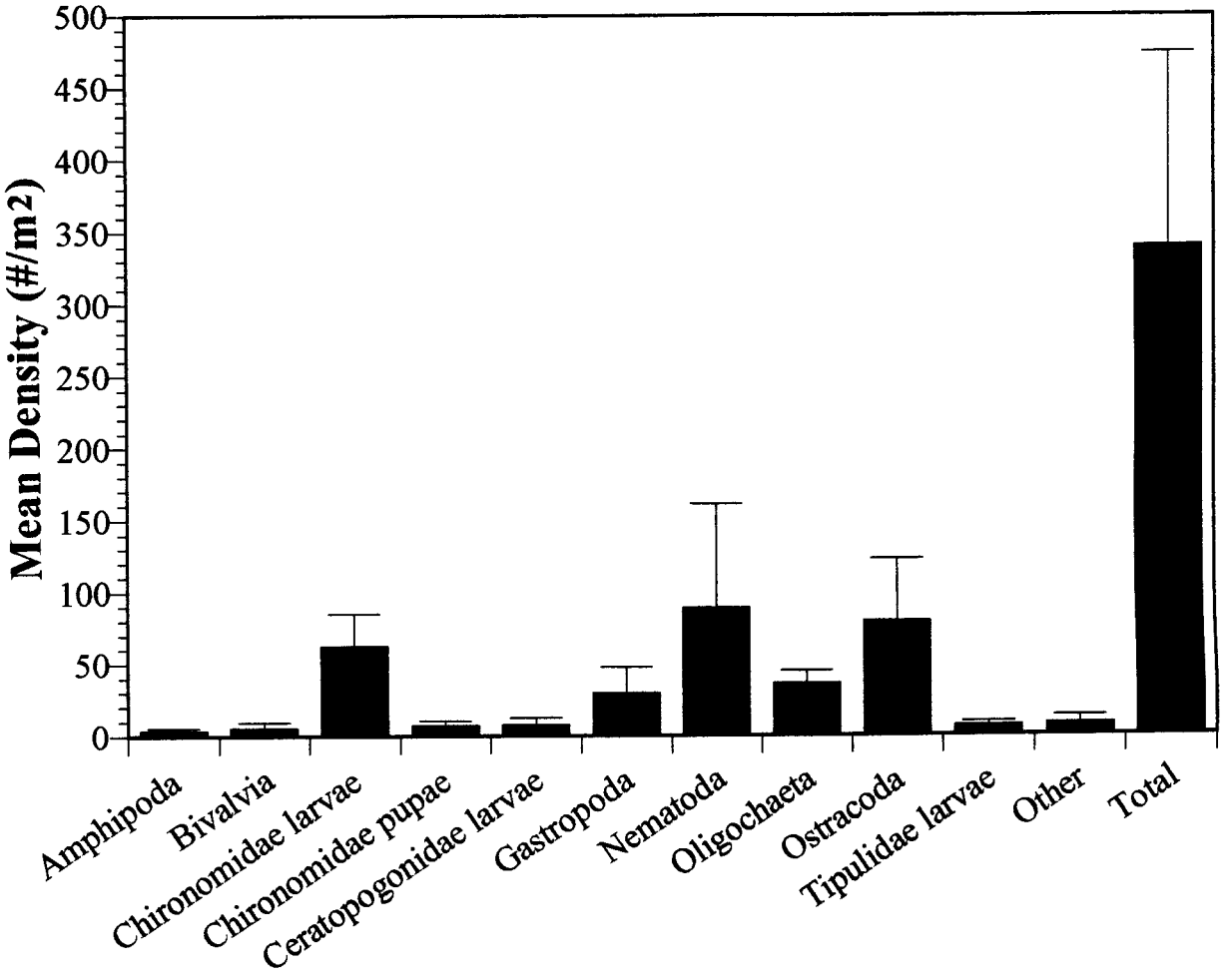

Figure 17. Mean densities of individual benthic invertebrate taxa and total benthic invertebrates collected in the Colorado River, Grand Canyon, during joint AGFD/BioWest monitoring trips, 1995. Other = miscellaneous body parts and unidentified insects.

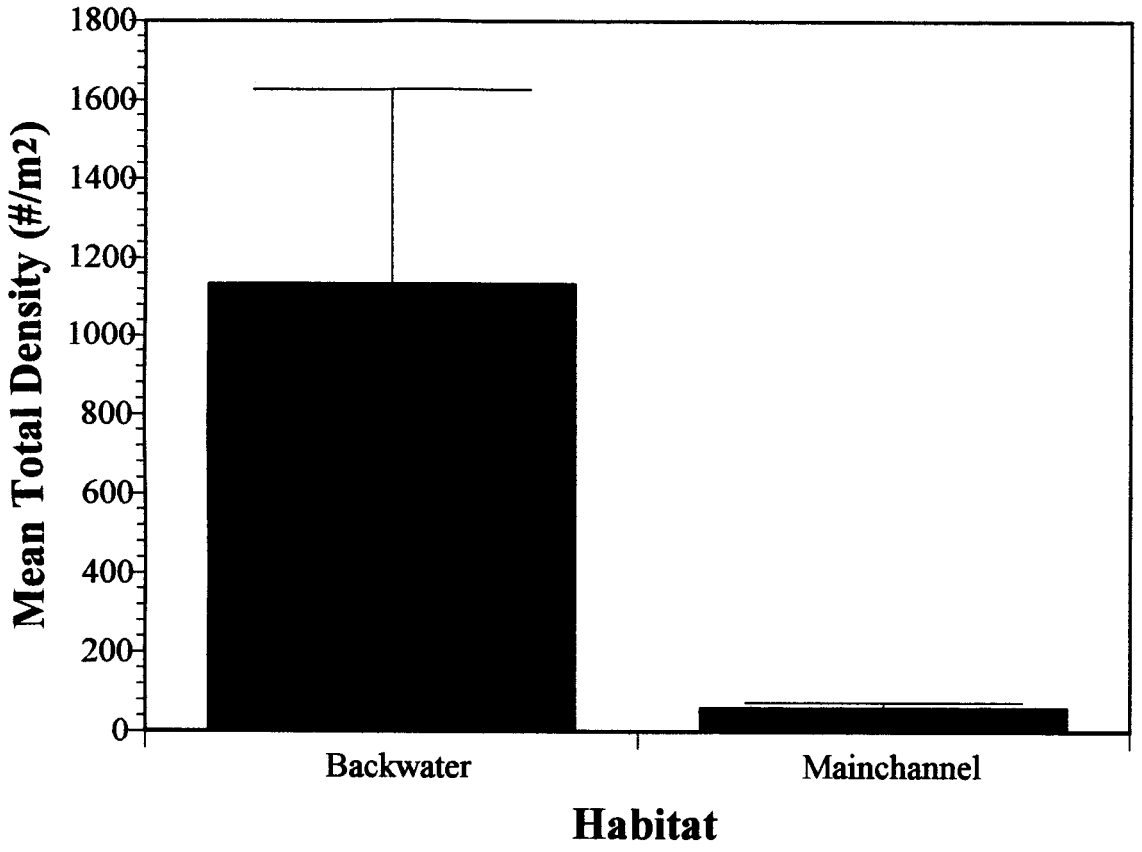

Figure 18. Mean total benthic invertebrate densities in backwater and mainchannel beachface habitats of the Colorado River, Grand Canyon, during joint AGFD/BioWest monitoring trips, 1995.

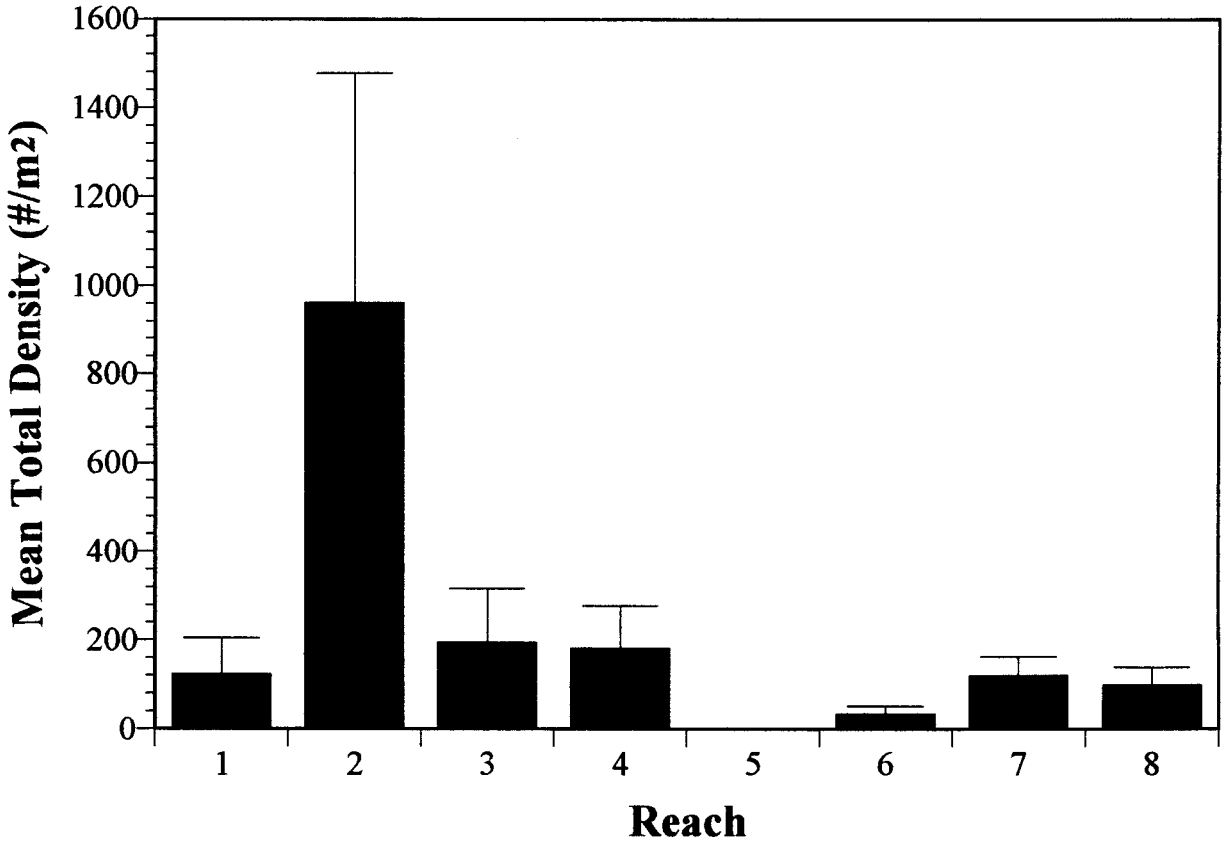

Figure 19. Mean total benthic invertebrate density in each reach of the Colorado River, Grand Canyon, during joint AGFD/BioWest monitoring trips, 1995.

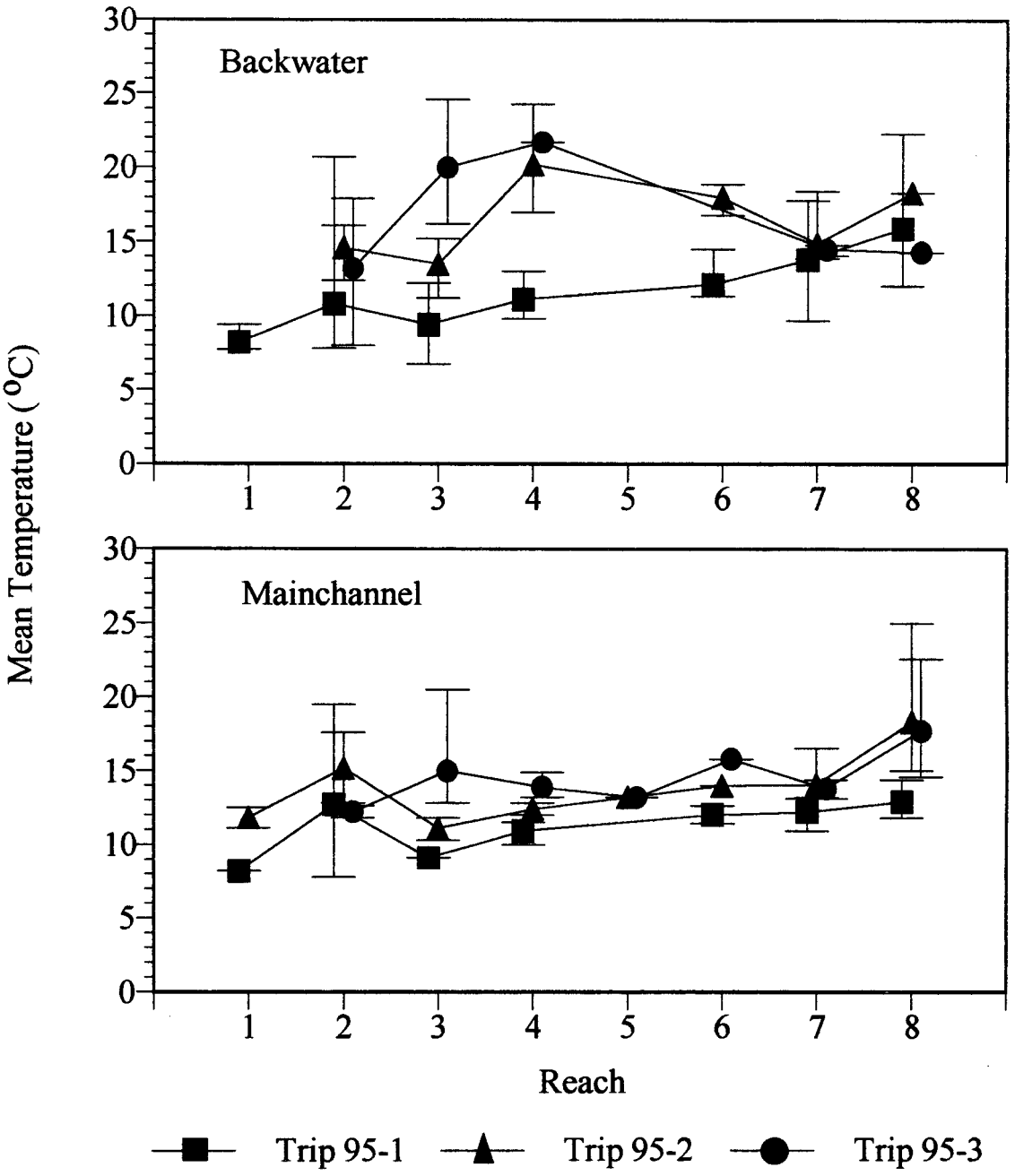

Figure 20. Mean and range of temperature in backwater and mainchannel habitats in each reach of the Colorado River, Grand Canyon, during joint AGFD/BioWest monitoring trips, 1995.

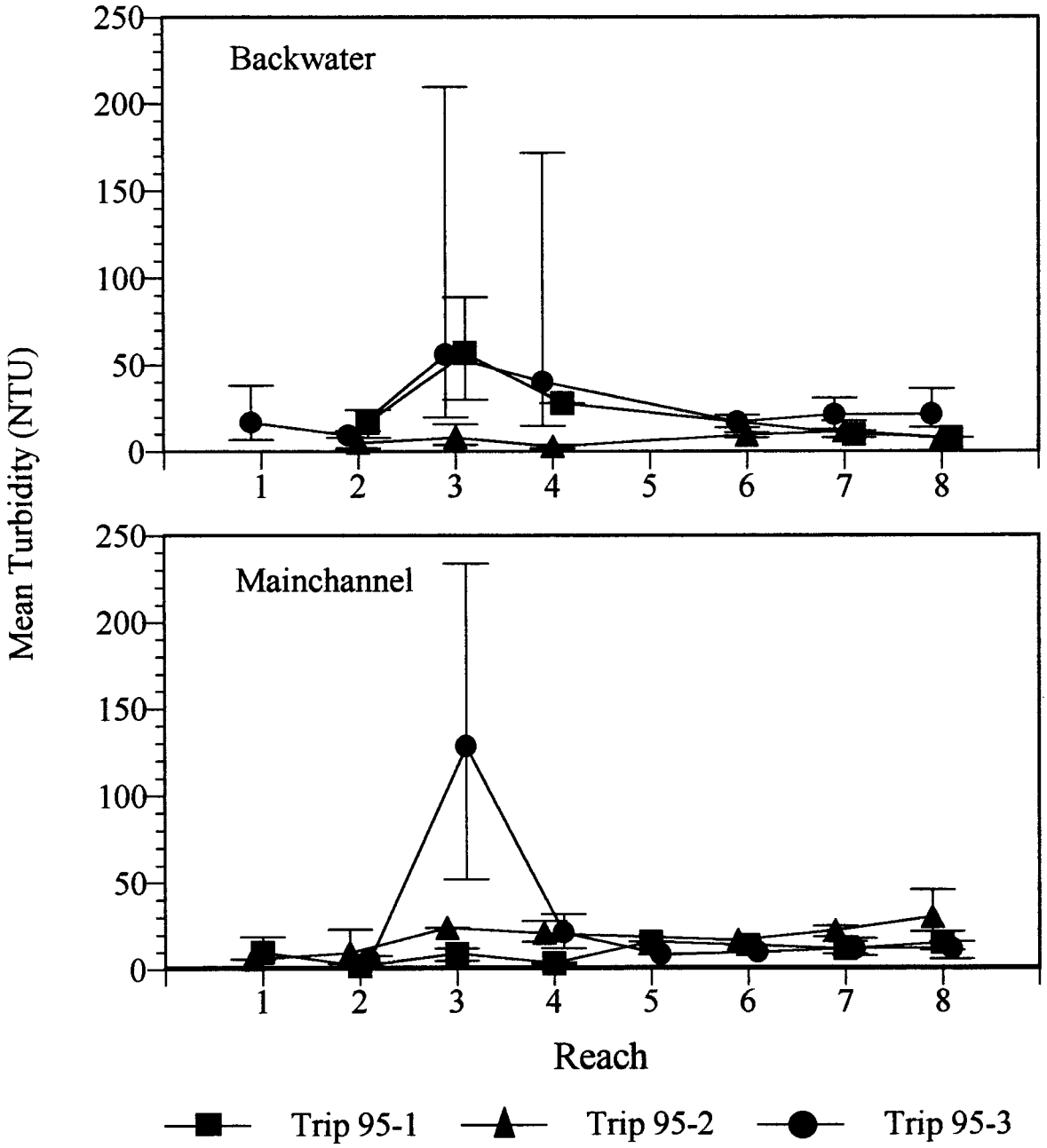

Figure 21. Mean and range of turbidity in backwater and mainchannel habitats in the Colorado River, Grand Canyon, during joint AGFD/BioWest monitoring trips, 1995.

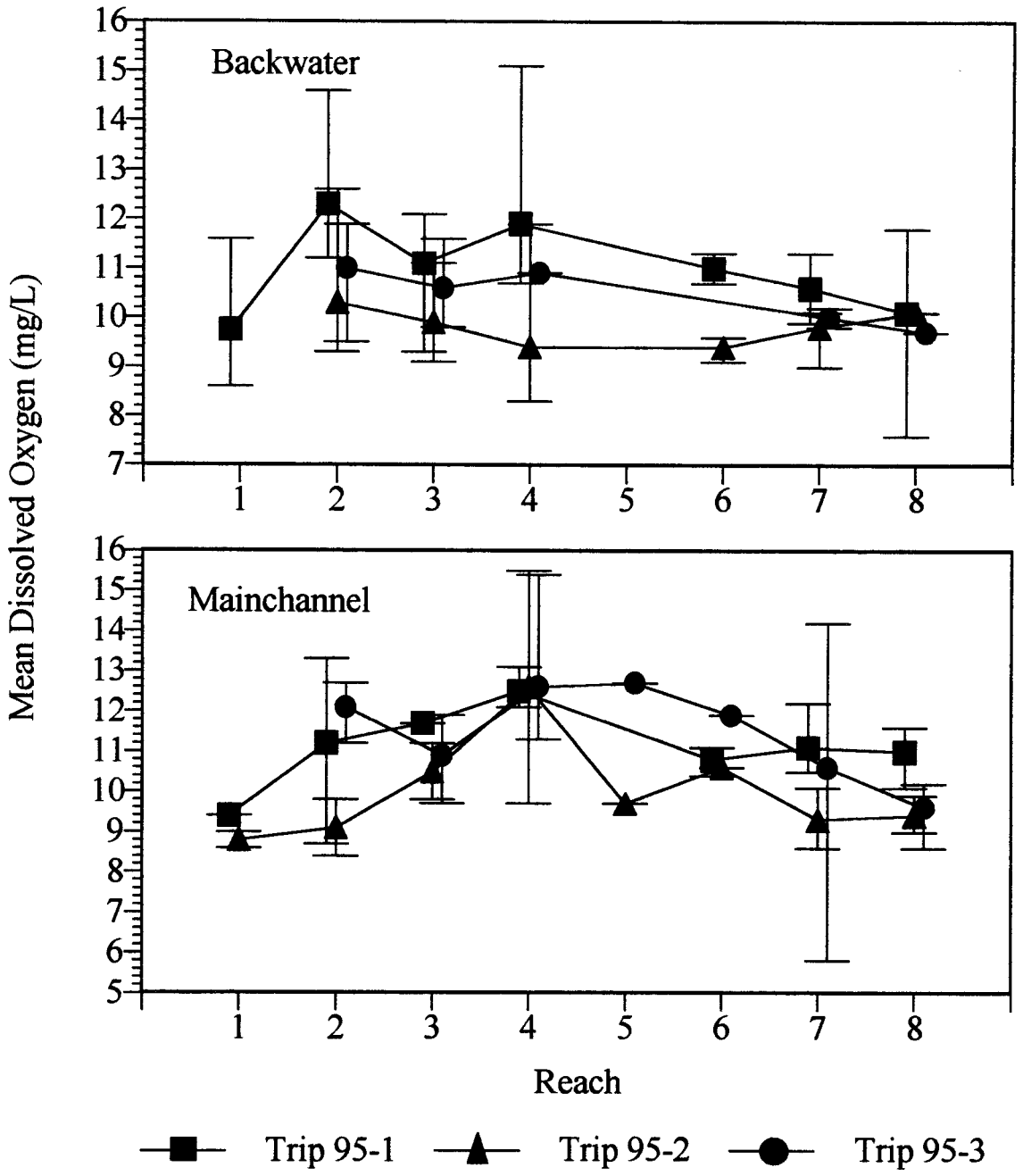

Figure 22. Mean and range of dissolved oxygen (mg/L) in backwater and mainchannel habitats in the Colorado River, Grand Canyon, during joint AGFD/BioWest monitoring trips, 1995.

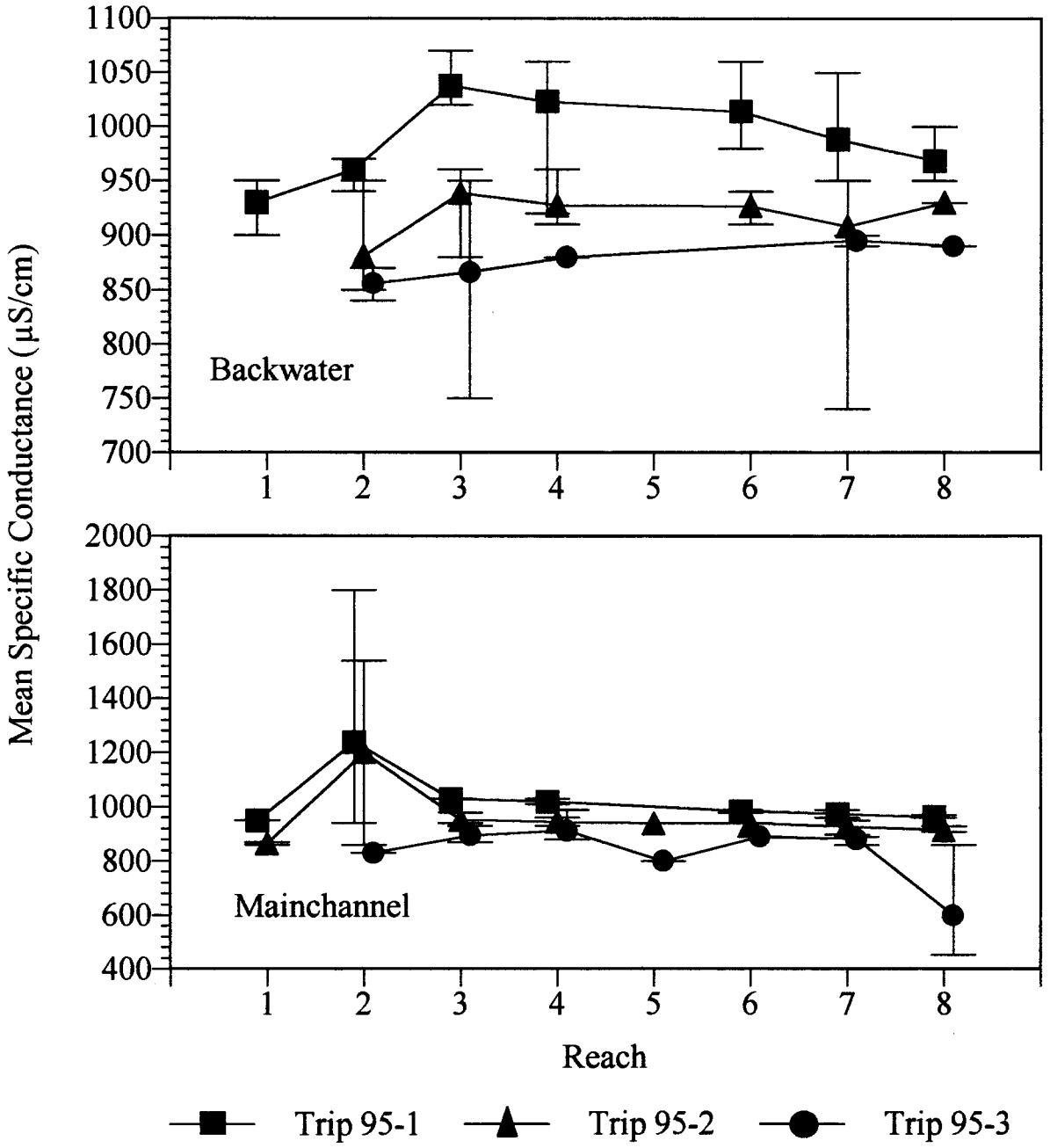

Figure 23. Mean and range of specific conductance in backwater and mainchannel habitats in the Colorado River, Grand Canyon, during joint AGFD/BioWest monitoring trips, 1995.

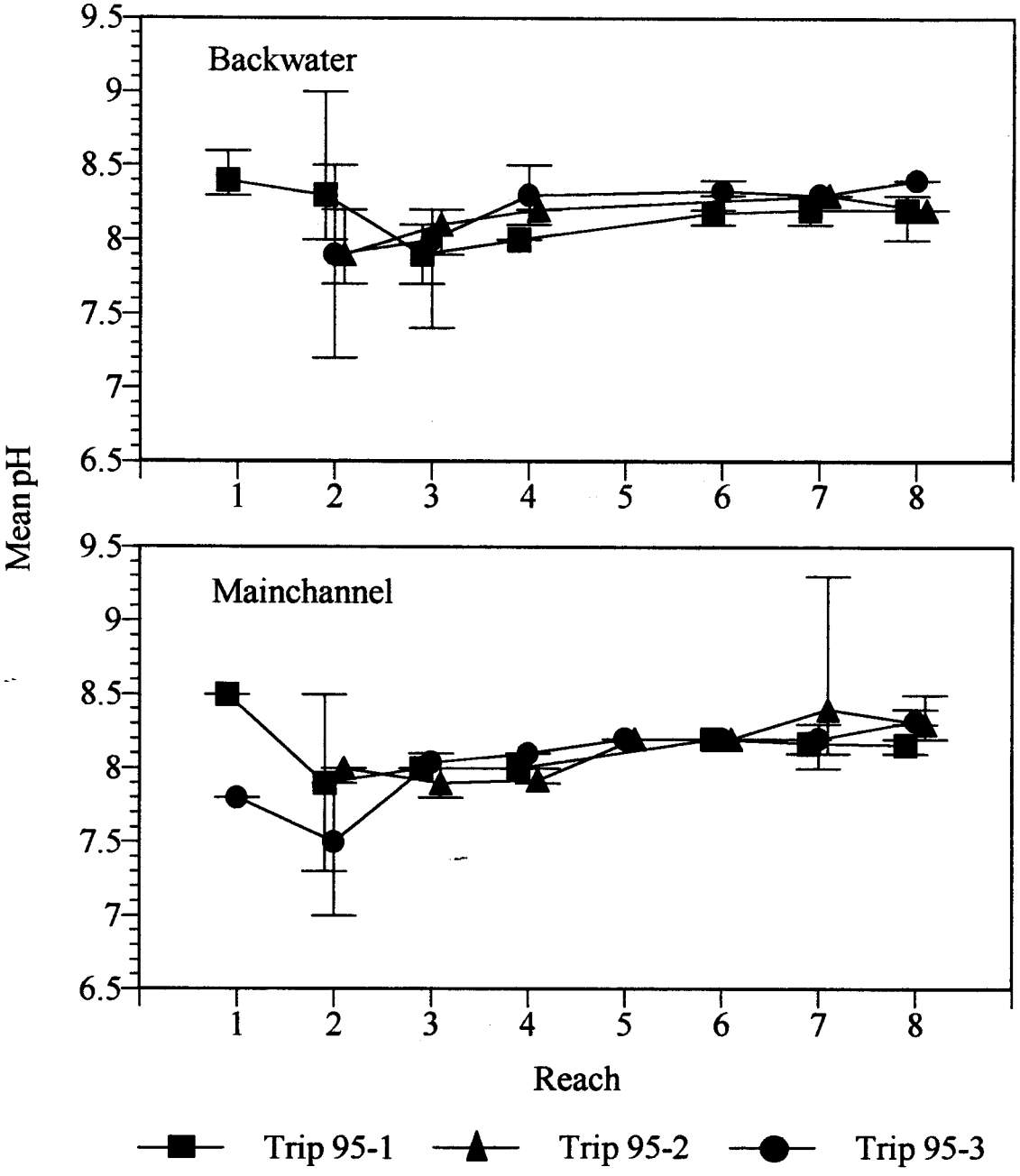

Figure 24. Mean and range of pH in backwater and mainchannel habitats in the Colorado River, Grand Canyon, during joint AGFD/BioWest monitoring trips, 1995.

Appendix 1. List of data codes used by AGFD during joint AGFD/BioWest monitoring trips in 1995.

SAMPLE TYPE

A	Type A
O	Opportunistic
T	Minnow Trap
H	Hoop Net
S	Sonde Set
P	Parasite
L	Larval Sample

REACH CODES

Mainstem

CR1	Lee's Ferry (RM 0) to Shinumo Wash (RM 29.3)
CR2	Shinumo Wash to Little Colorado R.(RM 61.5)
CR3	LCR to Lava Chuar (RM 65.5)
CR4	Lava Chuar to Hance Rapid (RM 76.7)
CR5	Hance Rapid to Elves Chasm (RM 116.5)
CR6	Elves Chasm to Forster Rapid (RM 122.8)
CR7	Forster Rapid to Hell's Hollow (RM 182.5)
CR8	Hell's Hollow to Diamond Creek (RM 225.6)
CR9	Diamond Creek to Lake Mead (~RM 277)

Tributaries

PAR	Paria River (RM 0.9 L)
NKW	Nankoweap Creek (RM 52.2 R)
LCR	Little Colorado River (RM 61.5 L)
CHU	Chuar Cr. (RM 65.3 R)
CLR	Clear Cr. (RM 84.03 R)
BAC	Bright Angel Cr. (RM 87.62 R)
PIP	Pipe Cr. (RM 88.95 L)
HER	Hermit Cr. (RM 95.0 L)
CRY	Crystal Cr.(RM 98.04 R)
SHM	Shinumo Cr.(RM 108.6 R)
ELV	Elves Chasm(RM 116.5 L)
STC	Stone Cr. (RM 131.8 R)
TAP	Tapeats Cr. (RM 133.83 R)
DRC	Deer Cr. (RM 136.25 R)
KAN	Kanab Cr. (RM 143.5 R)
OLO	Olo Canyon (RM 145.5 L)
HAV	Havasu Cr. (RM 156.93 L)
DIA	Diamond Cr. (RM 225.6 L)
TVT	Travertine Cr. (RM 229.0)
SPN	Spencer Cr. (RM 246.0)

FLOW CODES

AC	Ascending
DC	Descending
SH	Stable High
SL	Stable Low

HABITAT and SITE CODES

Connected Backwaters: CB

CB	Connected Backwater
CF	Connected Foot
CC	Connected Center
CM	Connected Mouth
SP	Spring

Isolated Backwater: IB

Mainchannel: MC

MC	Mainchannel
ME	Mainchannel Eddy
BE	Backwater Eddy
CO	Cove
SC	Side Channel
SP	Spring

Tributaries: TM

TM	Tributary Mouth
RU	Run
RI	Riffle
PO	Pool
ED	Eddy
SP	Spring

GEAR CODES

BS	Small Bag Seine 15' x 6' x 1/8" (1/32" bag mesh)
BL	Large Bag Seine 30' x 6' x 1/4" (1/8" bag mesh)
SS	Small Straight Seine
SX	Straight Seine 50' x 6' x 3/16"
KS	Kick Seine 3' x 3' x 1/32"
DN	Dip Net
MH	Mini-Hoop Net 1.5' x 4' x 3/8"
HN	Hoop Net w/o wings 3' x 5 ' x 1/2"
HW	Hoop Net w/wings 4' x 5' x 3/8" x 40' wings
BH	Baited Hoop Net
MT	Minnow Trap
BT	Baited Minnow Trap
TN	Trammel Net
LD	Larval Drift
LL	Larval Light Trap
LT	Larval Trap (acrylic)
AN	Angling
BI	Bi-directional Trapnet (In)
BO	Bi-directional Trapnet (Out)
SD	Sonde

Appendix 1 (cont'd)

SUBSTRATE CODES

CL	Clay
SI	Silt
SA	Sand
GR	Gravel
PE	Pebble
CO	Cobble
BO	Boulder
BD	Bedrock
TR	Travertine

SPECIES CODES

Common

BHS Bluehead Sucker
BNT Brown Trout
CCF Channel Catfish
CRP Common Carp
FMS Flannelmouth Sucker
HBC Humpback Chub
PKF Plains Killifish
RBT Rainbow Trout
SPD Speckled Dace
STB Striped Bass
NFC No fish captured

Uncommon

BBH Black Bullhead
BGS Bluegill
BKT Brook Trout
CUT Cutthroat Trout
GSH Golden Shiner
GSF Green Sunfish
LMB Largemouth Bass
RBS RazorBack Sucker
RSH Red Shiner
SMB Smallmouth Bass
TFS Threadfin Shad
UTC Utah Chub
YBH Yellow Bullhead
SUC Sucker (unidentified)
UID Unidentified

MATURITY CODES

0	Larval, Juvenile
1	Adult, Non-breeding
2	Gravid
3	Ripe
4	Spent
5	Tuberculate
6	Undetermined

FIN CLIPS/PUNCHES

D	Dorsal
UC	Upper Caudal
LC	Lower Caudal
CD	Caudal
RP2	Right Pelvic
LP2	Left Pelvic

SEX

F	Female
M	Male
U	Undetermined

DISPOSITION

RA	Released Alive
MN	Mortality, Not Preserved
MP	Mortality, Preserved
SP	Sacrificed, Preserved
VP	Viscera Preserved
DP	Found Dead, Preserved

Appendix 2. List of AGFD study sites on joint AGFD/BioWest monitoring Trips 95-1, 95-2, and 95-3, in the Colorado River, Grand Canyon, 1995.

Study	Sample Type	Habitat	Reach	Mile	Side	Flow Stage	Estimated Discharge	Set		Run		Gear Type	Effort
								Date	Time	Date	Time		
Trip 95-1													
3951001	A	Back	CR1	2.41	L	AC	10000	28 MAR 95	10:46			BL	204
3951001	A	Main	CR1	2.41	L	AC	10000	28 MAR 95	10:46			BL	196
3951002	O	Back	CR1	26.27	L	AC	9000	28 MAR 95	16:00			BL	152
3951003	H	Main	CR2	30.47	R	AC	10000	28 MAR 95	18:48	29 MAR 95	6:26	MH	11.6
3951004	A	Back	CR2	44.27	L	DC	11000	29 MAR 95	10:34			BL	556
3951004	A	Main	CR2	44.27	L	DC	11000	29 MAR 95	10:34			BL	280
3951005	A	Back	CR2	58.68	L	DC	12000	30 MAR 95				BL	186
3951005	A	Main	CR2	58.68	L	DC	12000	30 MAR 95				BL	520
3951006	S	Back	CR2	60.85	L	DC	12000	30 MAR 95	10:00	31 MAR 95	12:00	SD	26
3951006	S	Main	CR2	60.85	L	DC	12000	30 MAR 95	10:00	31 MAR 95	12:00	SD	26
3951007	A	Back	CR2	58.23	R	DC	11000	30 MAR 95	13:15			BL	80
3951007	A	Main	CR2	58.23	R	DC	11000	30 MAR 95	13:10			BL	42
3951008	O	Back	CR2	58.24	R	DC	11000	30 MAR 95	14:30			BL	45
3951009	O	Back	CR3	64.12	L	AC	8000	30 MAR 95	20:11			BS	27
3951010	A	Back	CR2	60.85	L	DC	12000	31 MAR 95	11:11			BL	126
3951010	A	Main	CR2	60.85	L	DC	12000	31 MAR 95	11:30			BL	100
3951011	S	Back	CR2	58.68	L	DC	11000	31 MAR 95	11:30	1 APR 95	14:30	SD	27
3951011	S	Main	CR2	58.68	L	DC	11000	31 MAR 95	11:30	1 APR 95	14:30	SD	27
3951012	A	Back	CR3	64.6	R	DC	12000	1 APR 95	8:40			BL	168

Appendix 2 (cont'd).

Study	Sample Type	Habitat	Reach	Mile	Side	Flow Stage	Estimated Discharge	Set Date	Set Time	Run Date	Run Time	Gear Type	Effort
3951012	A	Main	CR3	64.6	R	DC	12000	1 APR 95	8:40			BL	360
3951013	O	Back	CR3	62.1	R	DC	12000	1 APR 95	11:15			BL	152
3951014	O	Back	CR3	64.4	R	AC	9000	1 APR 95	20:22			BL	
3951015	A	Back	CR4	66.85	L	SL	8000	2 APR 95	9:13			BL	88
3951015	A	Main	CR4	66.85	L	SL	8000	2 APR 95	9:13			BL	200
3951016	A	Back	CR4	68.17	L	SL	8000	2 APR 95	13:00			BL	69
3951016	A	Main	CR4	68.17	L	SL	8000	2 APR 95	13:00			BL	160
3951017	O	Back	CR4	68.39	R	AC	8050	2 APR 95	20:15			BS	32
3951018	O	Back	CR4	73.72	L	SL	8000	3 APR 95	10:05			BL	77
3951019	A	Back	CR4	75.25	R	SL	8000	3 APR 95	13:32			BL	100
3951019	A	Main	CR4	75.25	R	SL	8000	3 APR 95	13:25			BL	90
3951020	O	Back	CR4	74.39	R	SL	8000	3 APR 95	20:00			BS	30
3951020	O	Main	CR4	74.39	R	SL	8000	3 APR 95	20:15			BS	44
3951021	T	Trib	SHM	108.6	L	SH		4 APR 95	17:28	5 APR 95	8:18	MT	14.83
3951022	T	Trib	SHM	108.6	R	SH		4 APR 95	17:43	5 APR 95	8:34	MT	14.78
3951023	H	Trib	SHM	108.6	R	SH		4 APR 95	17:45	5 APR 95	8:00	HW	14.25
3951024	O	Back	CR6	117.4	R	AC	9000	5 APR 95	11:25			BS	36
3951025	O	Back	CR6	119.74	R	AC	11000	5 APR 95	13:45			BL	38
3951026	O	Main	CR6	119.9	R	AC	11000	5 APR 95	14:33			BL	24
3951027	A	Back	CR6	120.47	L	AC	8500	6 APR 95	8:53			BL	122.5

Appendix 2 (cont'd).

Study	Sample Type	Habitat	Reach	Mile	Side	Flow Stage	Estimated Discharge	Set		Run		Gear Type	Effort
								Date	Time	Date	Time		
3951027	A	Main	CR6	120.47	L	AC	8500	6 APR 95	8:53			BL	224
3951028	O	Main	CR7	125.78	L	AC	11000	6 APR 95	13:54			BS	46
3951029	T	Trib	KAN	143.5	L	SH	3	7 APR 95	17:49	8 APR 95	8:45	MT	14.94
3951030	T	Trib	KAN	143.5	L	SH	3	7 APR 95	18:06	8 APR 95	8:41	MT	14.85
3951031	H	Trib	KAN	143.5	R	SH	3	7 APR 95	17:50	8 APR 95	8:30	HW	14.67
3951032	T	Trib	HAV	156.93	L	SH	70	8 APR 95	17:08	9 APR 95	8:09	MT	16.01
3951033	T	Trib	HAV	156.93	L	SH	70	8 APR 95	17:32	9 APR 95	9:45	MT	16.21
3951034	H	Trib	HAV	156.93	L	SH	70	8 APR 95	17:30	9 APR 95	8:50	HW	15.33
3951035	A	Back	CR7	165.67	R	DC	9000	9 APR 95	13:34			BS	35
3951035	A	Main	CR7	165.67	R	DC	9000	9 APR 95	13:45			BS	45
3951036	A	Back	CR7	166.86	R	DC	8000	10 APR 95	9:09			BL	155
3951036	A	Main	CR7	166.86	R	DC	8000	10 APR 95	9:09			BL	115
3951037	O	Back	CR7	166.88	R	DC	7800	10 APR 95	11:35			BS	24
3951038	A	Back	CR7	167.83	R	DC	7700	10 APR 95	13:00			BL	72
3951039	O	Back	CR7	171.3	L	DC	7000	10 APR 95	15:15			BL	594
3951040	A	Back	CR8	182.83	R	SL	9000	11 APR 95	9:35			BL	110
3951040	A	Main	CR8	182.83	R	SL	9000	11 APR 95	9:35			BL	259
3951041	A	Back	CR8	186	R	SL	9000	11 APR 95	12:45			BL	156
3951041	A	Main	CR8	186	R	SL	9000	11 APR 95	12:45			BS	42
3951042	O	Back	CR8	187.53	R	DC	9000	11 APR 95	14:30			BL	357

Appendix 2 (cont'd).

Study	Sample Type	Habitat	Reach	Mile	Side	Flow Stage	Estimated Discharge	Set Date	Set Time	Run Date	Run Time	Gear Type	Effort
3951043	S	Back	CR8	195.95	R	SH	12500	12 APR 95	10:11	13 APR 95	9:30	SD	23.32
3951043	S	Main	CR8	195.95	R	SH	12500	12 APR 95	10:26	13 APR 95	9:20	SD	22.9
3951044	A	Back	CR8	194.13	L	DC	10000	12 APR 95	15:20			BL	78
3951044	A	Main	CR8	194.13	L	DC	10000	12 APR 95	15:43			BL	138
3951045	O	Back	CR8	201.06	R	DC	11000	13 APR 95	10:08			BL	45
3951046	P	Trib	LCR	61.5	L			1 APR 95				SS	
3951047	P	Trib	BAC	87.62	R			4 APR 95				SS	
3951048	P	Trib	KAN	143.5	L			7 APR 95				SS	
3951049	P	Trib	SHM	108.6	R			5 APR 95				DN	
							Trip 95-2						
3952001	O	Main	CR1	2.41	L	AC	16500	13 JUN 95	11:20			BL	100
3952002	O	Main	CR1	5.7	R	AC	17000	13 JUN 95	13:43			SS	48
3952003	L	Main	CR2	30.47	R	SH	19000	13 JUN 95	21:20	14 JUN 95	6:10	LL	8.83
3952007	P	Trib	NKW	52.2	R			15 JUN 95	11:00			SS	
3952008	O	Back	CR2	60.85	L	DC	19000	15 JUN 95	14:20			BL	37.5
3952009	O	Back	CR2	58.68	L	DC	18000	15 JUN 95	20:35			BL	32
3952010	S	Back/Main	CR2	60.48	L	DC	20000	16 JUN 95	9:39	18 JUN 95	7:00	SD	45.5
3952011	A	Back/Main	CR3	63.18	L	DC	19000	16 JUN 95	12:36			BL	76
3952012	O	Back	CR3	63.08	L	DC	17000	16 JUN 95	16:00			BL	152
3952013	O	Back	CR3	64.35	L	DC	17000	16 JUN 95	8:45			BL	16

Appendix 2 (cont'd).

Study	Sample Type	Habitat	Reach	Mile	Side	Flow Stage	Estimated Discharge	Set		Run		Gear Type	Effort
								Date	Time	Date	Time		
3952014	O	Main	CR3	64.6	R	DC	19000	17 JUN 95	9:13			BL	156
3952015	O	Main	CR3	61.92	L	DC	19000	17 JUN 95	10:00			BL	258
3952016	O	Back	CR3	62.73	R	DC	19000	17 JUN 95	13:30			BS	16
3952017	O	Main	CR3	62.7	R	DC	19000	17 JUN 95	14:00			BL	90
3952018	O	Main	CR3	62.75	L	DC	17000	17 JUN 95	15:22			BL	145
3952019	O	Back	CR3	65.25	L	SH	20000	18 JUN 95	9:29			BL	104
3952020	A	Back	CR4	68.38	R	DC	18000	18 JUN 95	16:50			BL	299
3952021	O	Back	CR4	68.38	R	DC	17000	18 JUN 95	20:38			BL	210
3952022	O	Main	CR4	75.25	R	DC	17000	19 JUN 95	20:20			BL	160
3952023	T	Trib	SHM	108.6	R		9	20 JUN 95	18:13	21 JUN 95	8:34	MT	14.35
3952024	T	Trib	SHM	108.6	R		9	20 JUN 95	17:53	21 JUN 95	9:27	MT	15.57
3952025	T	Trib	SHM	108.6	R		9	20 JUN 95	18:53	21 JUN 95	8:49	MT	13.94
3952026	H	Trib	SHM	108.6	R		9	20 JUN 95	17:40	21 JUN 95	8:30	HW	14.83
3952030	O	Main	CR7	125.67	R	AC	16000	22 JUN 95	9:35			BS	80
3952031	O	Main	CR7	125.68	R	AC	16000	22 JUN 95	9:50			BS	63
3952032	O	Main	CR7	126.91	R	DC	15000	23 JUN 95	9:00			BS	25
3952033	O	Main	CR7	126.93	R	DC	15000	23 JUN 95	9:11			BS	15
3952034	T	Trib	KAN	143.5	R		1	23 JUN 95	17:36	24 JUN 95	8:11	MT	14.58
3952035	T	Trib	KAN	143.5	R		1	23 JUN 95	18:03	24 JUN 95	8:21	MT	14.3
3952036	T	Trib	KAN	143.5	R		1	23 JUN 95	18:13	24 JUN 95	8:38	MT	14.42
3952037	H	Trib	KAN	143.5	R		1	23 JUN 95	17:45	24 JUN 95	7:30	HW	13.75

Appendix 2 (cont'd).

Study	Sample Type	Habitat	Reach	Mile	Side	Flow Stage	Estimated Discharge	Set Date	Set Time	Run Date	Run Time	Gear Type	Effort
3952038	T	Trib	HAV	156.93	L		44	24 JUN 95	17.:28	25 JUN 95	6:32	MT	12.55
3952039	T	Trib	HAV	156.93	L		44	24 JUN 95	18:16	25 JUN 95	7:03	MT	12.78
3952040	H	Trib	HAV	156.93	L		44	24 JUN 95	18:06	25 JUN 95	6:11	HW	12.08
3952041	O	Back	CR7	160.26	R	AC	16000	25 JUN 95	10:41			BS	16
3952042	O	Back	CR7	160.75	L	AC	16000	25 JUN 95	11:40			BS	6
3952043	O	Main	CR7	165	L	SL	16000	25 JUN 95	14:00			BL	54
3952044	O	Main	CR7	165.11	R	AC	16000	25 JUN 95	14:15			BL	240
3952045	O	Back	CR7	165.11	R	AC	16000	25 JUN 95	14:15			BS	32
3952046	A	Back	CR7	168.72	L	DC	19000	26 JUN 95	8:19			BS	47
3952047	O	Main	CR8	182.27	L	AC	16000	26 JUN 95	14:25			BS	69
3952048	O	Back	CR8	191.15	L	AC	17000	26 JUN 95	16:10			BS	30
3952049	O	Main	CR8	198.55	R	AC	17000	27 JUN 95	8:50			BS	80
							Trip 95-3						
3953002	O	Back	CR2	32.76	R	SL	18000	16 SEP 95	910			BS	39
3953003	O	Main	CR2	36.71	R	SL	18000	16 SEP 95	1000			BL	88
3953004	A	Back/Main	CR2	44.27	L	SL	18000	16 SEP 95	1141			BL	220
3953005	A	Back/Main	CR3	62.1	R	DC	18500	17 SEP 95	1245			BL	97.5
3953006	S	Back/Main	CR3	62.1	R			18 SEP 95	930	20 SEP 95	1000	SD	
3953007	O	Main	CR3	61.95	L	DC	18000	18 SEP 95	1100			BS	159.5
3953008	O	Main	CR3	62.73	R	DC	18000	18 SEP 95	1328			BS	130
3953009	O	Back	CR3	61.95	L	DC	18000	18 SEP 95	1148			BS	92
3953010	O	Back	CR2	61.5	L	DC	19500	19 SEP 95	920			BL	174

Appendix 2 (cont'd).

Study	Sample Type	Habitat	Reach	Mile	Side	Flow Stage	Estimated Discharge	Set		Run		Gear Type	Effort
								Date	Time	Date	Time		
3953011	A	Back	CR3	63.18	L	AC	18000	19 SEP 95	1415			BL	
3953012	O	Main	CR4	66.85	L	DC	18500	20 SEP 95	1330			BS	
3953013	O	Main	CR4	68.39	R	DC	18000	20 SEP 95	1546			BL	
3953014	O	Main	CR4	68.39	R	DC	18000	20 SEP 95	1605			BL	132
3953015	O	Back	CR4	72.3	L	DC	19000	21 SEP 95	1120			BL	155
3953016	O	Main	CR4	75.25	R	DC	18500	21 SEP 95	1340			BS	93
3953017	T	Trib	SHM	108.6	R		8	22 SEP 95	1735	23 SEP 95	704	MT	13.47
3953018	T	Trib	SHM	108.6	R		8	22 SEP 95	1742	23 SEP 95	717	MT	13.33
3953019	T	Trib	SHM	106.8	L		8	22 SEP 95	1803	23 SEP 95	732	MT	13.49
3953023	T	Trib	KAN	143.5	R		4	25 SEP 95	1714	26 SEP 95	801	MT	14.79
3953027	H	Trib	HAV	156.93	L		68	26 SEP95	910	27 SEP 95	635	HW	12.25
3953028	T	Trib	HAV	156.93	L		68	26 SEP95	1737	27 SEP 95	634	MT	12.96
3953029	T	Trib	HAV	156.93	L		68	26 SEP95	1746	27 SEP 95	647	MT	13.02
3953030	O	Back	CR7	161	L	AC	18000	27 SEP95	931			BS	24
3953031	O	Main	CR7	165	L	AC	18000	27 SEP95	1015			BL	150
3953032	O	Main	CR7	165.47	L	AC	18000	27 SEP95	1038			BS	45
3953033	O	Main	CR7	168.72	L	AC	18000	27 SEP95	1116			BS	28
3953034	O	Back	CR7	176.62	L	AC	18500	27 SEP95	1223			BS	
3953035	O	Main	CR8	182.83	L	AC	18000	28 SEP95	1151			BS	48
3953036	O	Main	CR8	183.25	R	AC	18000	28 SEP95	1245			BS	16
3953037	O	Main	CR8	194.13	L	AC	18000	28 SEP95				BL	90

Appendix 3a. Amount of collection effort expended by AGFD and number of sites () in each reach and tributary with each gear type in the Colorado River, Grand Canyon, during joint AGFD/BioWest monitoring Trip 95-1, 28 March - 14 April 1995.

	Seine (m^2)			Hoop Net (hr)		Minnow Trap (hr/4 traps)	Dip Net
Reach/Tributary	Backwater	Mainchannel	Tributary	Mainchannel	Tributary	Tributary	Tributary
Reach 1	356 (2)	196 (1)					
Reach 2	948 (4)	942 (4)		23.2 (2)			
Little Colorado River			P				
Reach 3	347 (3)	360 (1)					
Reach 4	396 (6)	494 (4)					
Reach 5		No Collections Attempted					
Bright Angel Creek			P				
Shinumo Creek					14.25 (1)	29.6 (2)	P
Reach 6	196.5 (3)	248 (2)					
Reach 7	880 (5)	260 (3)					
Tapeats Creek			P				
Deer Creek							P
Kanab Creek					14.67 (1)	29.78 (2)	
Havasu Creek					15.33 (1)	32.22 (2)	
Reach 8	746 (6)	439 (4)					

Appendix 3b. Amount of collection effort expended by AGFD and number of sites () in each reach and tributary with each gear type in the Colorado River, Grand Canyon, during joint AGFD/BioWest monitoring Trip 95-2, 13 - 28 June 1995.

	Seine (m^2)			Minnow Traps (hr / 4 traps)	Hoop Net (hr)	Larval Light Trap (hr)		Sonde (hr)	
Reach/Tributary	Back	Main	Trib	Trib	Trib	Back	Main	Back	Main
Reach 1		148 (2)							
Reach 2	387.5 (4)	225 (1)				21.70 (3)	8.83 (1)	45.2 (1)	45.5 (1)
Nankoweap Creek			P						
Reach 3	376 (5)	713 (5)							
Reach 4	360 (2)	608 (2)							
Reach 5		45 (1)							
Bright Angel Creek			P						
Shinumo Creek				43.87 (3)	14.83 (1)				
Reach 6	384 (1)	64 (1)							
Reach 7	126 (4)	553 (9)							
Kanab Creek				43.31 (3)	13.75 (1)				
Havasu Creek				25.34 (2)	12.08 (1)				
Reach 8	30 (1)	202 (3)							

Appendix 3c. Amount of collection effort expended by AGFD and number of sites () in each reach and tributary with each gear type in the Colorado River, Grand Canyon, during joint AGFD/BioWest monitoring Trip 95-3, 15-30 September 1995.

	Seine (m^2)			Minnow Trap (hr)	Hoop Net (hr)	Sonde (hr)	
Reach/Tributary	Back	Main	Trib	Trib	Trib	Back	Main
Reach 1							
Reach 2	485 (3)	412 (3)					
Nankoweap Creek			P				
Little Colorado River			P				
Reach 3	528 (4)	829 (4)				24 (1)	24 (1)
Reach 4	155 (1)	348 (4)					
Reach 5							
Shinumo Creek			P	40.28 (3)	12.75 (1)		
Reach 6		230 (1)					
Reach 7	24 (1)	241 (4)					
Kanab Creek			P	44.91 (3)	14.2 (1)		
Havasu Creek			P	25.98 (2)	12.25 (1)		
Reach 8	12 (1)	154 (3)					

Appendix 4a. Number and composition of catch in AGFD samples from backwater and mainchannel habitats in each reach and from tributary mouths of the Colorado River, Grand Canyon, during AGFD/BioWest monitoring Trip 95-1, 28 March - 14 April 1995.

	Backwater		Mainchannel		Tributary	
Reach/Species	N	%	N	%	N	%
Reach 1						
Rainbow Trout	1	100				
Total	1	100				
Reach 2						
Flannelmouth Sucker	13	12				
Humpback Chub	7	6				
Speckled Dace	2	2				
Fathead Minnow	81	72				
Plains Killifish	4	4				
Rainbow Trout	5	4				
Total	112	100				
Little Colorado River						
Speckled Dace					5	63
Fathead Minnow					3	37
Total					8	100
Reach 3						
Bluehead Sucker		0	2	1		
Flannelmouth Sucker		0	4	1		
Humpback Chub	3	1	10	3		
Speckled Dace	1	<1	7	2		
Fathead Minnow	306	98	337	92		
Plains Killifish	1	<1	5	1		
Rainbow Trout	1	<1	___	0		
Total	312	100	365	100		
Reach 4						
Bluehead Sucker	2	1				
Flannelmouth Sucker	4	1				
Humpback Chub	10	3	2	100		
Speckled Dace	7	2				
Fathead Minnow	337	92				
Plains Killifish	5	1	_			
Total	365	100	2	100		

Appendix 4a (cont'd).

	Backwater		Mainchannel		Tributary	
Reach/Species	N	%	N	%	N	%
Reach 5	No Collections Attempted					
Bright Angel Creek						
Speckled Dace					1	100
Total					1	
Shinumo Creek						
Bluehead Sucker					2	20
Speckled Dace					6	60
Rainbow Trout					2	20
Total					10	100
Reach 6						
Bluehead Sucker	6	8	1	12		
Speckled Dace	10	14				
Fathead Minnow	52	72	7	88		
Plains Killifish	4	6	–			
Total	72	100	8	100		
Reach 7						
Bluehead Sucker	35	13				
Flannelmouth Sucker	16	6	2	33		
Humpback Chub	5	2				
Speckled Dace	71	26	1	17		
Common Carp	1	0				
Fathead Minnow	130	48	2	33		
Plains Killifish	9	3	1	17		
Rainbow Trout	3	1	–			
Total	270	100	6	100		
Kanab Creek						
Bluehead Sucker					23	17
Flannelmouth Sucker					58	42
Humpback Chub					1	1
Speckled Dace					14	10
Fathead Minnow					40	29
Green Sunfish					1	1
Total					137	100

Appendix 4a (cont'd).

	Backwater		Mainchannel		Tributary	
Reach/Species	N	%	N	%	N	%
Havasu Creek						
Bluehead Sucker					62	38
Flannelmouth Sucker					47	28
Speckled Dace					56	34
Total					165	100
Reach 8						
Bluehead Sucker	98	7				
Flannelmouth Sucker	127	9	1	50		
Humpback Chub	4	0				
Speckled Dace	827	58	1	50		
Common Carp	1	0				
Fathead Minnow	359	25				
Plains Killifish	16	1				

Appendix 4b. Number and composition of catch in AGFD samples from backwater and mainchannel habitats in each reach and from tributaries of the Colorado River, Grand Canyon, during joint AGFD/BioWest monitoring Trip 95-2, 13 - 28 June 1995.

	Backwater		Mainchannel		Tributary	
Reach/Species	N	%	N	%	N	%
Reach 1						
Rainbow Trout			1	100		
Total			1			
Reach 2						
Flannelmouth Sucker	1	14				
Humpback Chub	1	14				
Rainbow Trout	5	72				
Total	7	100				
Nankoweap Creek						
Speckled Dace					6	100
Total					6	100
Reach 3						
Bluehead Sucker	2	2				
Flannelmouth Sucker	10	12	1	100		
Humpback Chub	35	41				
Speckled Dace	22	26				
Common Carp	1	1				
Fathead Minnow	12	14				
Rainbow Trout	3	4	—			
Total	85	100	1			
Reach 4						
Bluehead Sucker	8	3	1	4		
Flannelmouth Sucker	7	2				
Humpback Chub	23	8	4	15		
Speckled Dace	109	37	2	8		
Fathead Minnow	144	49	19	73		
Plains Killifish	4	1	—	—		
Total	295	100	26	100		
Reach 5						
Common Carp			1	100		
Total			1			
Reach 6						
Humpback Chub	1	20				
Fathead Minnow	3	60				
Rainbow Trout	1	20				
Total	5	100				

Appendix 4b (cont'd).

	Backwater		Mainchannel		Tributary	
Reach/Species	N	%	N	%	N	%
Reach 7						
Bluehead Sucker	36	21	9	26		
Flannelmouth Sucker	44	24	8	24		
Humpback Chub	4	2	2	6		
Speckled Dace	64	35	4	12		
Unidentified Sucker	4	2				
Common Carp			3	9		
Fathead Minnow	31	17	6	17		
Rainbow Trout	—	—	2	6		
Total	183	100	34	100		
Kanab Creek						
Bluehead Sucker					1	2
Flannelmouth Sucker					52	76
Speckled Dace					13	19
Common Carp					2	3
Total					68	100
Havasu Creek						
Bluehead Sucker					6	14
Flannelmouth Sucker					6	14
Speckled Dace					32	72
Total					44	100
Reach 8						
Bluehead Sucker	2	11	9	17		
Flannelmouth Sucker	11	61	11	21		
Humpback Chub	1	6				
Speckled Dace	4	22	33	62		
Total	18	100	53	100		

Appendix 4c. Number and composition of catch in AGFD samples from backwater and mainchannel habitats in each reach and from tributaries of the Colorado River, Grand Canyon, during joint AGFD/BioWest monitoring Trip 95-3, 15-30 September 1995.

	Backwater		Mainchannel		Tributary	
Reach/Species	N	%	N	%	N	%
Reach 1			No collections attempted			
Reach 2						
Flannelmouth Sucker	1	1				
Humpback Chub	1	1				
Speckled Dace	8	8				
Fathead Minnow	79	82				
Rainbow Trout	7	8				
Total	96	100				
Reach 3						
Bluehead Sucker	35	9	4	1		
Flannelmouth Sucker	15	4	1	<1		
Humpback Chub	14	4	12	2		
Speckled Dace	29	8	39	7		
Common Carp	2	1				
Fathead Minnow	251	68	445	86		
Plains Killifish	21	6	15	3		
Rainbow Trout	3	1	2	<1		
Total	370	100	518	100		
Reach 4						
Bluehead Sucker	1	2	3	5		
Flannelmouth Sucker			1	1		
Humpback Chub			2	2		
Speckled Dace	2	5	6	7		
Fathead Minnow	36	90	70	82		
Plains Killifish	2	5	1	1		
Rainbow Trout	—	—	2	2		
Total	41	100	85	100		
Reach 5			No collections attempted			
Shinumo Creek						
Flannelmouth Sucker					3	5
Speckled Dace					53	75
Brown Trout					1	2
Fathead Minnow					7	10
Rainbow Trout					5	8
Total					71	100

Appendix 4c (cont'd).

	Backwater		Mainchannel		Tributary	
Reach/Species	N	%	N	%	N	%
Reach 6						
Bluehead Sucker			5	23		
Fathead Minnow			17	77		
Total			22	100		
Reach 7						
Bluehead Sucker	3	23	2	20		
Humpback Chub	1	8	1	10		
Speckled Dace			3	30		
Fathead Minnow	9	69	4	40		
Total	13	100	10	100		
Kanab Creek						
Speckled Dace					2	100
Total					2	
Havasu Creek						
Bluehead Sucker					1	8
Flannelmouth Sucker					1	8
Speckled Dace					10	84
Total					12	100
Reach 8						
Bluehead Sucker	1	8	2	25		
Flannelmouth Sucker	3	25				
Speckled Dace	8	67	5	63		
Fathead Minnow	—	—	1	12		
Total	12	100	8	100		

Appendix 5a. Mean, minimum and maximum total length, standard length and weight for each species caught in each reach and tributary of the Colorado River, Grand Canyon, during AGFD/BioWest monitoring trip 95-1, 28 March - 14 April 1995.

	Total Length			Standard Length			Weight		
Species	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Reach 1									
Rainbow Trout	26.0	26	26						
Reach 2									
Fathead Minnow	54.3	34	86				1.90	0.3	8.3
Flannelmouth Sucker	82.9	36	109				6.15	0.2	11.4
Humpback Chub	36.0	27	52	29.4	22	41	0.37	0.1	1.0
Plains Killifish	41.0	38	45				0.58	0.4	0.7
Rainbow Trout	90.8	30	311				38.32	0.2	190.0
Speckled Dace	41.0	35	48				0.70	0.4	1.0
Reach 3									
Fathead Minnow	45.0	26	84				0.83	0.1	3.5
Humpback Chub	49.0	41	56	39.3	35	42	0.77	0.5	1.1
Plains Killifish	51.0	51	51				1.20	1.2	1.2
Rainbow Trout	389.0	389	389				396.00	396.0	396.0
Speckled Dace	36.0	36	36				0.30	0.3	0.3
Reach 4									
Bluehead Sucker	71.5	61	82				3.30	1.7	4.9
Fathead Minnow	42.3	24	78				0.73	0.1	3.4
Flannelmouth Sucker	74.3	60	89				3.30	1.7	5.4
Humpback Chub	58.0	28	69	46.2	20	57	1.40	0.1	2.4
Plains Killifish	48.0	35	55				1.00	0.4	1.5
Speckled Dace	52.1	41	62				1.10	0.5	1.9
Reach 5	No Collections Attempted								
Reach 6									
Bluehead Sucker	61.1	55	69				1.70	1.2	2.2
Fathead Minnow	39.0	23	61				0.61	0.1	2.0
Plains Killifish	35.3	32	40				0.40	0.3	0.6
Speckled Dace	40.8	28	58				0.56	0.1	1.3
Reach 7	53.2	34	75				1.44	0.3	3.5
Bluehead Sucker		50	50				1.60	1.6	1.6
Common Carp		23	71				0.79	0.1	4.0
Fathead Minnow	54.6	31	80				1.59	0.1	4.2
Flannelmouth Sucker	33.2	30	39	27.2	24	32	0.22	0.1	0.4
Humpback Chub	50.0								
Plains Killifish	41.8	31	52				0.61	0.2	1.2
Rainbow Trout	33.3	29	36				0.33	0.2	0.5
Speckled Dace	42.1	25	65				0.69	0.1	2.3

Appendix 5a (cont'd).

	Length			Standard Length			Weight		
Species	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Reach 8									
Bluehead Sucker	51.0	28	97				1.30	0.1	8.1
Common Carp	511.0	511	511				1682.00	1682.0	1682.0
Fathead Minnow	38.3	22	65				0.61	0.1	2.6
Flannelmouth Sucker	57.8	27	137				2.04	0.1	29.0
Humpback Chub	42.8	38	45	34.3	31	36	0.60	0.4	0.7
Plains Killifish	37.6	26	51				0.50	0.2	1.1
Speckled Dace	42.2	22	79				0.71	0.1	4.0
Little Colorado River									
Fathead Minnow	51.7	42	60						
Speckled Dace	75.4	51	102						
Bright Angel Creek									
Speckled Dace	66.0	66	66						
Shinumo Creek									
Bluehead Sucker	246.5	234	259				159.00	135.0	183.0
Rainbow Trout	212.5	174	251				90.00	43.0	137.0
Speckled Dace	84.2	65	104				5.60	2.3	10.5
Kanab Creek									
Bluehead Sucker	216.7	158	271				97.48	45.0	180.0
Fathead Minnow	59.5	41	80				2.16	0.6	5.3
Flannelmouth Sucker	265.4	174	446				211.19	53.0	973.0
Green Sunfish	55.0	55	55				2.50	2.5	2.5
Humpback Chub	56.0	56	56	42.0	42	42			
Speckled Dace	72.3	53	105				4.44	1.6	12.6
Havasu Creek									
Bluehead Sucker	217.2	95	330				105.70	3.5	330.0
Flannelmouth Sucker	306.4	160	511				331.09	48.0	1210.0
Speckled Dace	75.1	51	94				3.82	1.0	8.0

Appendix 5b. Mean, minimum, and maximum total length, standard length and weight for each species caught in each reach and tributary of the Colorado River, Grand Canyon, during joint AGFD/BioWest monitoring Trip 95-2, 13 - 28 June 1995.

	Total Length (mm)			Standard Length (mm)			Weight (g)		
Reach/Species	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.
Reach 1									
Rainbow Trout	27.0	27	27						
Reach 2									
Flannelmouth Sucker	240.0	240	240				121.0	121	121
Humpback Chub	52.0	52	52	42.0	42	42	1.3	1	1
Rainbow Trout	294.8	74	380				246.9	4	380
Nankoweap Creek									
Speckled Dace	84.7	60	132						
Reach 3									
Bluehead Sucker	41.0	35	47				0.6	0	1
Flannelmouth Sucker	38.8	19	103				1.4	0	8
Humpback Chub	40.3	18	100	32.6	14	77	0.8	0	8
Speckled Dace	41.1	23	74				1.0	0	3
Common Carp	328.0	328	328				453.0	453	453
Fathead Minnow	49.9	35	65				1.4	0	3
Rainbow Trout	32.3	28	37				0.3	0	0
Reach 4									
Bluehead Sucker	31.9	25	43				0.3	0	0
Flannelmouth Sucker	48.1	18	110						
Humpback Chub	43.8	25	78	35.4	21	63	1.5	0	3
Speckled Dace	61.3	20	80				0.8	1	1
Fathead Minnow	51.1	25	86				1.5	0	6
Plains Killifish	45.0	39	52				1.0	1	1
Shinumo Creek									
Flannelmouth Sucker	361.0	361	361				577.0	577	577
Humpback Chub	33.0	33	33	27.0	27	27	0.2	0	0
Speckled Dace	69.3	52	97				3.4	1	9
Reach 5									
Common Carp	568.0	568	568				2234.0	2234	2234
Reach 6									
Humpback Chub	106.0	100	112	84.0	80	88	9.2	7	11
Fathead Minnow	64.3	60	68				3.3	3	4
Rainbow Trout	90.0	90	90				5.9	6	6

Appendix 5b (cont'd).

	Total Length (mm)			Standard Length (mm)			Weight (g)		
Reach/Species	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.
Reach 7									
Bluehead Sucker	26.8	12	80				1.9	0	4
Flannelmouth Sucker	27.0	11	147				7.9	0	29
Humpback Chub	49.6	18	95	40.2	16	75	3.2	1	7
Speckled Dace	40.9	12	72				1.4	0	3
Unidentified Suckers	12.3	7	17						
Common Carp	437.3	409	455				1124.0	817	1410
Fathead Minnow	42.7	18	65				1.0	0	3
Rainbow Trout	86.5	48	125				10.5	1	20
Kanab Creek									
Bluehead Sucker	27.0	27	27						
Flannelmouth Sucker	334.9	234	423				350.5	101	668
Speckled Dace	31.0	22	85				1.3	0	4
Common Carp	426.0	404	448				938.0	838	1038
Havasu Creek									
Bluehead Sucker	46.5	43	54				0.8	1	1
Flannelmouth Sucker	448.4	424	478				895.0	718	1195
Speckled Dace	52.3	22	89				2.3	0	6
Reach 8									
Bluehead Sucker	23.4	15	37				0.3	0	0
Flannelmouth Sucker	25.9	16	47				0.4	0	1
Humpback Chub	30.0	24	36	24.0	20	28			
Speckled Dace	50.8	18	76				1.6	1	4

Appendix 5c. Mean, minimum, and maximum total length, standard length and weight for each species caught in each reach and tributary of the Colorado River, Grand Canyon, during AGFD/BioWest monitoring Trip 95-3, 15 - 30 September 1995.

	Total Length (mm)			Standard Length (mm)			Weight (g)		
Reach/Species	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.
Reach 1									
Reach 2									
Flannelmouth Sucker	149.0	149	149				31.30	31.3	31.3
Humpback Chub	123.0	123	123	123	96.0	96.0	14.10	14.1	14.1
Speckled Dace	39.8	22	46				0.59	0.4	0.9
Fathead Minnow	40.2	20	53				0.60	0.1	1.4
Rainbow Trout	265.4	98	362				181.33	9.3	304.0
Reach 3									
Bluehead Sucker	53.2	36	73				1.14	0.3	2.9
Flannelmouth Sucker	77.9	42	123				3.95	0.3	13.4
Humpback Chub	57.6	40	135	46.2	31	110	2.41	0.4	19.4
Speckled Dace	42.6	22	66				0.70	0.1	1.9
Common Carp	126.0	92	160				38.80	12.0	65.6
Fathead Minnow	39.3	19	70				0.74	0.1	4.8
Plains Killifish	40.5	27	52				0.68	0.2	1.3
Rainbow Trout	297.0	114	361				260.76	13.8	414.0
Reach 4									
Bluehead Sucker	45.3	39	55				0.70	0.5	0.9
Flannelmouth Sucker	84.0	84	84				4.20	4.2	4.2
Humpback Chub	60.0	54	66				1.70	1.2	2.2
Speckled Dace	39.9	32	47				0.44	0.1	0.6
Fathead Minnow	37.5	21	60				0.48	0.1	1.7
Plains Killifish	42.3	36	46				0.63	0.4	1.1
Rainbow Trout	366.5	322	411				357.50	256.0	459.0
Reach 5				No Collections Attempted					
Shinumo Creek									
Brown Trout	310.0	310	310				273.00	273.0	273.0
Fathead Minnow	41.6	32	55				0.67	0.1	1.3
Flannelmouth Sucker	51.0	45	56				0.93	0.6	1.1
Rainbow Trout	277.0	225	370				221.40	84.0	530.0
Speckled Dace	34.9	22	70				0.42	0.1	2.8
Reach 6									
Bluehead Sucker	49.8	28	65				1.42	0.1	3.1
Fathead Minnow	58.6	42	71				2.41	0.3	4.3

Appendix 5c (cont'd).

	Total Length (mm)			Standard Length (mm)			Weight (g)		
Reach/Species	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.
Reach 7									
Bluehead Sucker	38.2	20	48				0.68	0.2	1.1
Humpback Chub	40.5	39	42	31.5	30	35	0.45	0.4	0.5
Speckled Dace	30.7	18	42				0.40	0.2	0.6
Fathead Minnow	37.5	18	55				0.90	0.2	1.6
Kanab Creek									
Speckled Dace	35.5	35	36				0.50	0.3	0.7
Havasu Creek									
Bluehead Sucker	68.0	68	68				2.20	2.2	2.2
Flannelmouth Sucker	480.0	480	480				993.00	993.0	993.0
Speckled Dace	63.8	43	89				2.29	0.7	4.6
Reach 8									
Bluehead Sucker	43.7	35	50				0.60	0.3	0.8
Flannelmouth Sucker	74.0	51	89				3.47	1.0	5.1
Speckled Dace	34.6	21	74				0.61	0.1	3.1
Fathead Minnow	27.0	27	27				0.20	0.2	0.2

Appendix 6. Location of capture, and length, weight, and sex of fish implanted with a PIT-tag in the Colorado River and its tributaries, Grand Canyon, during joint AGFD/BioWest monitoring trips, 1995. Note: SHM = Shinumo Creek, KAN = Kanab Creek, and HAV = Havasu Creek.

Study	Capture Location Mile	Total Length	Weight	Sex	PIT-Tag Number
Bluehead Sucker					
3951023	SHM	259	183	F	1F3E64003F
3951023	SHM	234	135	F	7F7B190D51
3951031	KAN	223	123	U	1F3E64251A
3951031	KAN	271	180	M	7F7D7F3C7D
3951031	KAN	260	142	M	7F7B190E1B
3951031	KAN	211	90	M	7F7D7F3749
3951031	KAN	241	132	M	1F3E5D390D
3951031	KAN	205	72	M	7F7D7F3756
3951031	KAN	254	131	M	1F3E57715B
3951031	KAN	252	128	M	7F7D7F4474
3951031	KAN	158	144	M	1F3E623D04
3951031	KAN	249	146	M	7F7B183711
3951031	KAN	207	70	M	7F7A121720
3951031	KAN	185	45	M	1F3E664578
3951031	KAN	190	59	F	7F7B182C4E
3951031	KAN	242	123	M	7F7B196F5D
3951031	KAN	226	109	M	7F7B1A0C4F
3951031	KAN	209	76	F	7F7B072B12
3951031	KAN	196	62	M	7F7A121B39
3951031	KAN	200	73	F	1F3C122B68
3951031	KAN	253	128	M	1F3C1A0209
3951031	KAN	173	46	F	7F7B073D6C
3951031	KAN	203	60	M	1F3C1E3C4B
3951031	KAN	178	47	M	1F3C132171
3951031	KAN	199	56	M	7F7B184A54
3951034	HAV	330	330	M	1F7A796707
3951034	HAV	271	208	F	1F781F1436
3951034	HAV	240	125	F	1F7B672956
3951034	HAV	273	210	F	1F78020B5C
3951034	HAV	225	90	M	1F7825182C
3951034	HAV	224	150	M	1F781C1B32
3951034	HAV	236	134	M	1F7A213115
3951034	HAV	256	110	M	1F7A270E32
3951034	HAV	185	38	M	1F7A773B35
3951034	HAV	200	63	M	1F78303D7C
3951034	HAV	222	97	M	1F7B096479
3951034	HAV	247	139	F	1F7B672E51
3951034	HAV	295	256	F	1F7B5E2F59

Appendix 6 (cont'd).

Study	Capture Location	Total Length	Weight	Sex	PIT-Tag Number
3951034	HAV	211	81	M	1F7B07510E
3951034	HAV	231	82	M	1F78276C56
3951034	HAV	273	223	M	1F7B160E42
3951034	HAV	284	232	M	1F7B094815
3951034	HAV	192	70	M	1F7A7F7870
3951034	HAV	250	148	M	1F7A735123
3951034	HAV	267	190	M	1F7B574F40
3951034	HAV	173	58	F	1F2051630D
3951034	HAV	251	123	M	1F2052747B
3951034	HAV	225	91	M	1F78163C17
3951034	HAV	227	103	M	1F783D6844
3951034	HAV	233	108	M	1F78321324
3951034	HAV	276	189	F	1F7A2E7A3F
3951034	HAV	253	129	M	1F203F4240
3951034	HAV	201	85	M	1F1F65607D
3951034	HAV	150	29	M	1F20481762
3951034	HAV	280	212	F	1F200A1522
3951034	HAV	220	94	M	1F7A370C24
3951034	HAV	225	101	M	1F7812490E
3951034	HAV	231	118	M	1F781C0E3F
3951034	HAV	230	90	M	1F780F5B7F
3951034	HAV	220	80	M	1F78427136
3951034	HAV	205	71	F	1F781B7856
3951034	HAV	226	102	M	1F780D3D1F
3951034	HAV	224	103	M	1F78341C19
3951034	HAV	211	106	M	1F7A34347F
3951034	HAV	224	111	M	1F7B03491A
3951034	HAV	215	72	M	1F7A3D4D5D
3951034	HAV	250	153	M	1F7A250A38
3951034	HAV	250	140	F	1F781B5F6F
3951034	HAV	160	40	F	1F7B596B22
3951034	HAV	157	45	F	1F777D3439
3951034	HAV	192	65	M	1F7B52662E
3951034	HAV	205	79	M	1F7B637013
3951034	HAV	175	58	F	1F78260B38
3951034	HAV	220	101	F	1F77727B7D
3951034	HAV	185	66	F	1F781D2527
3951034	HAV	172	50	M	1F77763440
3951034	HAV	150	30	M	1F7B545C36
3951034	HAV	171	39	M	1F7A2A112C
3951034	HAV	178	49	M	1F78207059
3951034	HAV	200	83	F	1F77782E44

Appendix 6 (cont'd).

Study	Capture Location	Total Length	Weight	Sex	PIT-Tag Number
3951034	HAV	159	36	M	1F7A274878
3951034	HAV	160	38	M	1F77767103
3951034	HAV	160	39	M	1F7B520E06
3951034	HAV	159	39	M	1F5B557938
Flannelmouth Sucker					
3951031	KAN	365	523	U	7F7B183210
3951031	KAN	312	322	F	1F3C264C33
3951031	KAN	310	322	F	7F7B19165B
3951031	KAN	446	973	M	7F7B072C06
3951031	KAN	248	143	U	7F7B07294D
3951031	KAN	264	182	M	1F3E60261D
3951031	KAN	342	460	F	7F7D7F4D08
3951031	KAN	249	137	M	7F7D7F3368
3951031	KAN	303	288	F	1F3E61132F
3951031	KAN	314	307	F	7F7B183240
3951031	KAN	299	273	F	7F7B1A0260
3951031	KAN	309	271	F	7F7B073964
3951031	KAN	256	160	M	7F7D7F5573
3951031	KAN	297	243	F	7F7A13567C
3951031	KAN	331	341	M	7F7B197D43
3951031	KAN	256	154	F	7F7B197723
3951031	KAN	258	175	F	7F7B181877
3951031	KAN	287	244	F	1F3E594802
3951031	KAN	247	154	M	7F7B196D25
3951031	KAN	299	255	F	7F7A123D3D
3951031	KAN	277	196	F	7F7D7F452C
3951031	KAN	277	194	M	7F7B191345
3951031	KAN	294	260	F	1F3E596268
3951031	KAN	249	147	M	7F7B197247
3951031	KAN	207	71	M	7F7A123D59
3951031	KAN	275	199	F	7F7D7F3D67
3951031	KAN	236	122	F	7F7D7F456B
3951031	KAN	212	95	F	1F3E5D6066
3951031	KAN	201	84	F	7F7F787A71
3951031	KAN	296	241	F	7F7B183979
3951031	KAN	278	220	F	7F7B18281F
3951031	KAN	201	82	M	7F7B1A0933
3951031	KAN	240	131	F	7F7B197D23
3951031	KAN	252	149	M	7F7B1A0B5F
3951031	KAN	196	78	M	1F3C1C7F0A
3951031	KAN	221	115	M	1F3C18434A
3951031	KAN	266	167	M	7F7B196930

Appendix 6 (cont'd).

Study	Capture Location	Total Length	Weight	Sex	PIT-Tag Number
3951031	KAN	185	53	M	7F7A12270B
3951031	KAN	195	78	M	7F7B182A49
3951031	KAN	256	144	M	7F7B1A055B
3951031	KAN	197	81	F	1F3C16622D
3951031	KAN	190	67	F	7F7D7F4950
3951031	KAN	200	78	F	7F7B073A13
3951031	KAN	210	76	M	7F7B181037
3951034	HAV	386	525	M	7F7B197008
3951034	HAV	366	499	F	7F7A121C00
3951034	HAV	511	1210	M	1F3E62073A
3951034	HAV	422	705	F	7F7B073B7C
3951034	HAV	389	514	F	7F7A165375
3951034	HAV	390	566	M	1F3C214044
3951034	HAV	336	408	F	7F7B196E33
3951034	HAV	320	299	M	7F7A165F05
3951034	HAV	401	684	M	7F7B182C16
3951034	HAV	416	640	M	7F7D445A3C
3951034	HAV	362	495	F	7F7B067A27
3951034	HAV	332	363	F	1F3E60675C
3951034	HAV	336	437	F	7F7B067566
3951034	HAV	356	351	F	7F7A16597C
3951034	HAV	325	336	M	7F7B073909
3951034	HAV	307	287	M	7F7A166408
3951034	HAV	280	218	F	7F7A123C5B
3951034	HAV	343	413	F	1F7B5B6823
3951034	HAV	-339	400	F	1F7A242D16
3951034	HAV	317	307	F	1F7826794A
3951034	HAV	288	223	M	1F7B19202D
3951034	HAV	280	231	F	1F7A3C6A41
3951034	HAV	298	216	F	1F7A7C7B70
3951034	HAV	180	52	M	1F7B6B304B
3951034	HAV	339	392	M	1F5E60190A
3951034	HAV	298	261	M	1F7B18410D
3951034	HAV	318	342	M	1F7A771E52
3951034	HAV	276	188	M	1F7B181A34
3951034	HAV	321	352	F	1F777E7745
3951034	HAV	302	254	F	1F7A7F2C3C
3951034	HAV	257	160	F	1F200B7046
3951034	HAV	298	267	M	1F204C7B7A
3951034	HAV	287	230	M	1F7A1C7B50
3951034	HAV	239	133	F	1F1F602141

Appendix 6 (cont'd).

Study	Capture Location	Total Length	Weight	Sex	PIT-Tag Number
3951034	HAV	231	130	F	1F782F7F3B
3951034	HAV	211	108	F	1F7B052B36
3951034	HAV	254	150	F	1F7775294C
3951034	HAV	180	55	F	1F7A2C2219
3951034	HAV	233	119	F	1F7A212125
3951034	HAV	250	128	F	1F782C0637
3951034	HAV	196	75	F	1F7B06134D
3951034	HAV	160	48	F	1F7B691A63
3951034	HAV	168	52	F	1F7A23576D
3952037	KAN	235	324	F	1F7A7D1159
3952037	KAN	234	101	F	1F7B12666E
3952037	KAN	265	169	M	1F7B503C5A
3952037	KAN	285	197	M	1F7A1D4E7C
3952037	KAN	309	310	M	1F78380A27
3952037	KAN	307	253	M	1F77717009
3952037	KAN	309	282	M	1F3E695B5F
3952037	KAN	303	229	F	1F78396B45
3952037	KAN	312	242	F	1F7B0A716B
3952037	KAN	318	314	F	1F78332E08
3952037	KAN	317	294	F	1F777B412E
3952037	KAN	325	324	F	1F7A285E61
3952037	KAN	320	313	M	1F7B5F5C2B
3952037	KAN	324	286	F	1F782B5F5F
3952037	KAN	324	289	F	1F78112731
3952037	KAN	325	308	F	1F78422502
3952037	KAN	323	291	U	1F7B6B4437
3952037	KAN	334	338	M	1F782B300E
3952037	KAN	332	347	M	1F7A7B313B
3952037	KAN	335	327	F	1F7A272020
3952037	KAN	335	315	M	1F78130056
3952037	KAN	332	318	M	1F7A36052C
3952037	KAN	330	296	M	1F7B5F7F08
3952037	KAN	345	326	F	1F78221532
3952037	KAN	344	362	M	1F7A1C410A
3952037	KAN	348	419	M	1F782B2C12
3952037	KAN	356	425	M	1F7A2A1020
3952037	KAN	355	390	M	1F7B52771D
3952037	KAN	353	357	M	1F7A1E5D6C
3952037	KAN	357	370	M	1F78016503
3952037	KAN	359	416	U	1F780F2832
3952037	KAN	362	375	F	1F7A29546A

Appendix 6 (cont'd).

Study	Capture Location	Total Length	Weight	Sex	PIT-Tag Number
3952037	KAN	368	408	M	1F7A727D78
3952037	KAN	360	479	M	1F7B600600
3952037	KAN	365	426	F	1F783E1E0D
3952037	KAN	360	431	U	1F78200C3D
3952037	KAN	362	398	F	1F7A2D7A40
3952037	KAN	377	467	M	1F783E1219
3952037	KAN	375	528	F	1F7A265F62
3952037	KAN	415	668	F	1F7B131A39
3952040	HAV	424	772	F	1F7B56325E
3952040	HAV	424	718	M	1F7B4A7B21
3952040	HAV	445	827	U	1F7A25350D
3952040	HAV	478	1195	F	1F7B67740B
3953027	HAV	480	993	U	1F7B4F2A6D

Appendix 7a. Mean and range of temperature, turbidity, light penetration, dissolved oxygen, specific conductance, pH, depth at sampling point, and maximum site depth of habitats in each reach of the Colorado River and tributaries, Grand Canyon, sampled by AGFD during joint AGFD/BioWest monitoring Trip 95-1, 28 March - 14 April 1995.

		Temperature (°C)			Turbidity (NTU)			Light Penetration (mE)		
Reach/Tributary	Habitat	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.
Reach 1	Backwater	8.17	7.6	9.4	17.0	7.0	38.0	476.5	333	641
	Mainchannel	8.03	8.0	8.0	6.0	6.0	6.0	2365.0	2365	2365
Reach 2	Backwater	10.73	7.8	20.7	9.5	8.0	11.0	1622.3	116	2326
	Mainchannel	12.48	7.8	19.4	10.7	2.1	23.0	1601.0	139	2201
	Isolated Pool	18.30	18.3	18.3	4.1	4.1	4.1	1633.0	1633	1633
Reach 3	Backwater	9.33	6.6	12.2	56.0	20.0	210.0	527.5	152	1589
	Mainchannel	9.10	9.1	9.1	24.0	24.0	24.0	214.0	214	214
Reach 4	Backwater	11.13	9.8	12.7	40.2	15.0	172.0	1307.3	213	2456
	Mainchannel	10.85	9.9	11.6	21.0	16.0	28.0	1643.3	356	2533
Shinumo Creek	Tributary	12.80	12.8	12.8	16.5	16.5	16.5			
Reach 6	Backwater	12.10	11.3	14.5	17.2	14.0	21.0	1142.8	222	2391
	Mainchannel	12.00	11.4	12.6	17.0	17.0	17.0	840.5	126	1555
Reach 7	Backwater	13.85	9.7	17.3	21.4	13.0	31.0	1760.7	137	2562
	Mainchannel	12.18	11.0	13.1	22.5	19.0	25.0	1455.3	147	2537
Kanab Creek	Tributary	16.50	16.5	16.5	11.5	11.5	11.5			
Havasu Creek	Tributary	16.65	16.7	16.7	10.4	6.4	42.7			
Reach 8	Backwater	15.87	12.0	22.3	21.7	14.0	36.0	1906.4	1451	2323
	Mainchannel	12.73	11.7	14.1	30.3	22.0	46.0	2005.0	1664	2306

Appendix 7a (cont'd).

		Dissolved Oxygen (%)			Dissolved Oxygen (mg/L)			Specific conductance (µS/cm)		
Reach/Tributary	Habitat	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.
Reach 1	Backwater	83.73	73.5	101.8	9.75	8.6	11.6	930.0	900	950
	Mainchannel	80.40	80.4	80.4	9.40	9.4	9.4	950.0	950	950
Reach 2	Backwater	111.55	100.7	126.7	12.29	11.2	14.6	960.0	940	970
	Mainchannel	108.82	103.9	117.0	11.57	9.9	13.3	1246.7	940	1825
	Isolated Pool	114.00	114.0	114.0	10.80	10.8	10.8	940.0	940	940
Reach 3	Backwater	98.50	88.8	112.6	11.14	9.3	12.1	1038.0	1020	1070
	Mainchannel	102.50	102.5	102.5	11.70	11.7	11.7	1030.0	1030	1030
Reach 4	Backwater	108.75	97.9	137.0	11.94	10.7	15.1	1023.3	920	1060
	Mainchannel	113.40	110.6	119.0	12.50	12.1	13.1	1020.0	1010	1030
Shinumo Creek	Tributary	107.27	107.0	107.3	11.25	11.3	11.3	300.0	300	300
Reach 6	Backwater	103.32	100.5	105.3	11.02	10.7	11.3	1014.0	980	1060
	Mainchannel	100.90	96.0	105.8	10.75	10.4	11.1	985.0	980	990
Reach 7	Backwater	103.11	98.3	114.2	10.60	9.9	11.3	988.2	950	1050
	Mainchannel	104.55	98.9	116.8	11.14	10.5	12.2	975.0	960	990
Kanab Creek	Tributary	99.85	99.9	99.9	9.65	9.7	9.7	1270.0	1270	1270
Havasu Creek	Tributary	98.12	95.9	98.4	9.11	9.1	9.2	741.7	740	755
Reach 8	Backwater	102.42	86.9	115.3	10.10	7.6	11.8	968.2	950	1000
	Mainchannel	105.87	101.6	110.3	11.00	10.1	11.6	963.3	960	970

Appendix 7a (cont'd).

		pH			Depth (cm)			Maximum Depth (cm)		
Reach/Tributary	Habitat	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.
Reach 1	Backwater	8.40	8.3	8.6	35.9	13	70	84.0	84	84
	Mainchannel	8.50	8.5	8.5	47.7	48	48	100.0	100	100
Reach 2	Backwater	8.25	8.0	9.0	46.0	19	86	93.2	81	100
	Mainchannel	7.87	7.2	8.5	65.6	29	136	67.0	45	95
	Isolated Pool	8.20	8.2	8.2	52.0	52	52			
Reach 3	Backwater	7.96	7.7	8.1	23.7	13	38	50.0	50	50
	Mainchannel	8.00	8.0	8.0	56.3	56	56			
Reach 4	Backwater	8.00	8.0	8.0	50.4	14	99	100.0	50	125
	Mainchannel	8.00	8.0	8.0	48.9	26	75	59.0	33	100
Shinumo Creek	Tributary	8.46	8.5	8.5	37.1	24	56			
Reach 6	Backwater	8.18	8.1	8.2	86.9	25	158	122.0	122	122
	Mainchannel	8.20	8.2	8.2	32.0	22	42			
Reach 7	Backwater	8.20	8.1	8.3	33.8	15	82	83.5	31	136
	Mainchannel	8.18	8.1	8.2	40.0	26	58			
Kanab Creek	Tributary	8.20	8.2	8.2	35.0	19	64			
Havasu Creek	Tributary	8.21	8.2	8.3	62.1	48	75			
	Mainchannel	8.17	8.1	8.2	40.1	22	53	81.3	32	130

Appendix 7b. Mean and range of temperature, turbidity, specific conductance, dissolved oxygen, pH, redox potential, light penetration, and depth at sampling point of backwater, mainchannel and tributary mouth habitats in each reach of the Colorado River and tributaries, Grand Canyon, sampled by AGFD during joint AGFD/BioWest monitoring Trip 95-2, 13 - 28 June 1995.

		Temperature (°C)			Turbidity (NTU)			Specific Conductance (µS/cm)		
Reach/Tributary	Habitat	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.
Reach 1	Mainchannel	11.80	11.1	12.5	10.00	1.0	19.0	865.0	860	870
Reach 2	Backwater	14.36	11.9	17.7	4.79	2.0	11.0	937.3	860	1535
	Mainchannel	15.87	12.4	19.3	2.05	1.1	3.0	1280.0	860	1700
Reach 3	Backwater	13.40	11.2	15.2	8.29	4.0	16.0	938.6	880	960
	Mainchannel	10.93	10.3	11.6	9.20	5.0	12.0	952.0	940	980
Reach 4	Backwater	19.98	16.6	24.2	3.00	2.0	4.0	927.5	910	960
	Mainchannel	12.35	11.9	12.8	3.50	3.0	4.0	945.0	930	960
Shinumo Creek	Tributary	16.65	16.1	16.8	2.14	2.0	3.0	325.0	320	355
Reach 5	Mainchannel	13.20	13.2	13.2	16.00	16.0	16.0	940.0	940	940
Reach 6	Backwater	17.42	16.8	18.0	9.67	8.0	11.0	926.7	910	940
	Mainchannel	13.63	13.6	13.6	14.00	14.0	14.0	940.0	940	940
Reach 7	Backwater	14.84	13.9	18.4	11.83	8.0	18.0	908.3	740	950
	Mainchannel	14.47	13.2	17.3	11.78	9.0	16.0	928.9	900	950
Kanab Creek	Tributary	19.35	19.4	19.4	6.92	4.0	42.0	1136.4	1135	1137
Havasu Creek	Tributary	20.95	16.6	21.5	3.00	2.5	7.0	736.1	720	865
Reach 8	Backwater	18.30	18.3	18.3	8.00	8.0	8.0	930.0	930	930
	Mainchannel	18.67	15.0	25.0	16.33	11.0	22.0	910.0	910	910

Appendix 7b (cont'd).

		Dissolved Oxygen (%)			Dissolved Oxygen (mg/L)			pH		
Reach/Tributary	Habitat	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.
Reach 1	Mainchannel	82.05	78.7	85.4	8.80	8.6	9.0	7.80	7.8	7.8
Reach 2	Backwater	100.05	91.3	129.8	10.24	9.3	12.6	7.94	7.0	8.5
	Mainchannel	92.58	89.2	96.0	8.68	7.6	9.8	7.38	6.9	7.9
Reach 3	Backwater	97.16	87.6	107.4	9.95	9.1	11.1	8.00	7.4	8.2
	Mainchannel	96.56	88.3	103.2	10.46	9.8	11.2	8.04	8.0	8.1
Reach 4	Backwater	107.95	89.5	153.7	9.40	8.3	11.9	8.30	8.1	8.5
	Mainchannel	119.95	92.7	147.2	12.60	9.7	15.5	8.10	8.1	8.1
Shinumo Creek	Tributary	93.21	92.8	96.0	13.37	9.4	14.0	8.54	8.5	8.6
Reach 5	Mainchannel	94.40	94.4	94.4	9.70	9.7	9.7	8.20	8.2	8.2
Reach 6	Backwater	100.77	94.9	104.9	9.40	9.1	9.6	8.33	8.3	8.4
	Mainchannel	104.20	104.2	104.2	10.60	10.6	10.6	8.20	8.2	8.2
Reach 7	Backwater	96.18	94.4	97.7	9.77	9.0	10.1	8.30	8.3	8.3
	Mainchannel	92.00	83.0	96.9	9.33	8.6	10.1	8.23	8.0	8.3
Kanab Creek	Tributary	97.40	97.4	97.4	9.01	9.0	9.0	8.30	8.3	8.3
Havasu Creek	Tributary	99.33	97.6	99.6	8.81	8.7	9.5	8.49	8.4	8.5
Reach 8	Backwater	105.30	105.3	105.3	10.10	10.1	10.1	8.40	8.4	8.4
	Mainchannel	98.30	94.0	106.1	9.47	9.0	9.9	8.33	8.3	8.4

Appendix 7b (cont'd).

		Redox potential (mV)			Velocity (cm/S)			Light penetration (mE)		
Reach/Tributary	Habitat	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.
Reach 1	Mainchannel	297.0	295	299	3.0	0	6	959.0	15	1903
Reach 2	Backwater	320.9	295	342	1.3	0	5	1296.2	685	1729
	Mainchannel	329.3	320	339	12.3	0	25	741.0	0	1482
Reach 3	Backwater	323.3	275	353	3.5	2	6	808.7	356	1736
	Mainchannel	327.6	317	337	14.4	10	24	1161.8	331	2372
Reach 4	Backwater	312.0	284	328	3.8	2	6	1350.7	1335	1378
	Mainchannel	334.5	311	358	26.3	26	26	1318.0	1318	1318
Shinumo Creek	Tributary	309.3	309	314	4.5	1	10			
Reach 5	Mainchannel	327.0	327	327	0.0	0	0	17.0	17	17
Reach 6	Backwater	317.7	317	318	7.0	3	13	71.3	6	118
	Mainchannel	329.0	329	329	19.0	19	19	2479.0	2479	2479
Reach 7	Backwater	355.3	332	374	1.8	0	4	6084.0	1044	8830
	Mainchannel	344.9	323	371	17.6	6	42	2451.4	1610	6738
Kanab Creek	Tributary	335.5	336	336	0.8	0	3			
Havasu Creek	Tributary	330.5	331	331	6.2	1	15			
Reach 8	Backwater	401.0	401	401				1675.0	1675	1675
	Mainchannel	374.7	361	394	22.0	13	40	3094.5	2040	4149

Appendix 7b continued.

		Depth (cm)		
Reach/Tributary	Habitat	Mean	Min.	Max.
Reach 1	Mainchannel	74.5	44	105
Reach 2	Backwater	70.5	37	108
	Mainchannel	46.5	43	50
Reach 3	Backwater	39.2	18	76
	Mainchannel	42.9	29	55
Reach 4	Backwater	25.6	11	36
	Mainchannel	30.7	29	32
Shinumo Creek	Tributary	71.4	36	109
Reach 5	Mainchannel	74.0	74	74
Reach 6	Backwater	36.3	20	50
	Mainchannel	20.7	21	21
Reach 7	Backwater	50.5	19	73
	Mainchannel	48.7	30	78
Kanab Creek	Tributary	67.9	47	93
Havasu Creek	Tributary	62.4	45	152
Reach 8	Backwater	46.0	46	46
	Mainchannel	20.3	12	36

Appendix 7c. Mean and range of temperature, turbidity, specific conductance, dissolved oxygen, pH, redox potential, light penetration, and depth at sampling point of backwater, mainchannel and tributary mouth habitats in each reach of the Colorado River and tributaries, Grand Canyon, sampled by AGFD during joint AGFD/BioWest monitoring Trip 95-3, 15-30 September 1995.

		Temperature (°C)			Turbidity (NTU)			Specific Conductance (µS/cm)		
Reach/Tributary	Habitat	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.
Reach 1					No Samples					
Reach 2	Backwater	12.89	8.0	17.9	16.8	8	24	856.0	840	870
	Mainchannel	12.19	11.8	12.6	5.4	4	8	830.0	830	830
Reach 3	Backwater	19.65	15.6	24.4	57.0	30	89	866.3	750	950
	Mainchannel	14.88	12.7	20.5	128.5	52	234	895.0	870	930
Reach 4	Backwater	21.70	21.7	21.7	28.0	28	28	880.0	880	880
	Mainchannel	13.85	13.2	14.9	21.3	12	32	912.5	880	990
Shinumo Creek	Tributary	15.58	11.5	16.5	7.5	6	10	393.9	390	400
Reach 5	Mainchannel	13.00	13.0	13.0	7.9	8	8	845.0	845	845
Reach 6	Mainchannel	15.80	15.8	15.8	10.0	10	10	890.0	890	890
Reach 7	Backwater	14.45	14.1	14.8	10.0	8	12	895.0	890	900
	Mainchannel	13.58	13.1	13.9	13.5	10	18	887.5	880	890
Kanab Creek	Tributary	15.59	13.7	19.9	7.5	4	9	1009.6	885	1290
Havasu Creek	Tributary	19.44	19.4	19.5	7.1	4	8	725.0	725	725
Reach 8	Backwater	14.30	14.3	14.3	8.0	8	8	890.0	890	890
	Mainchannel	17.73	14.6	22.6	12.0	6	16	599.3	88	860

Appendix 7c (cont'd).

Reach/Tributary	Habitat	Dissolved Oxygen (%)			Dissolved Oxygen (mg/L)			pH		
		Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.
Reach 1					No Samples					
Reach 2	Backwater	107.70	100.8	114.1	11.04	9.5	11.9	7.90	7.7	8.2
	Mainchannel	113.00	105.0	119.7	12.07	11.2	12.7	8.00	8.0	8.0
Reach 3	Backwater	117.96	104.2	133.8	10.62	9.8	11.6	8.05	7.9	8.2
	Mainchannel	106.00	94.6	112.5	10.88	9.7	11.9	7.90	7.8	8.0
Reach 4	Backwater	126.50	126.5	126.5	10.90	10.9	10.9	8.20	8.2	8.2
	Mainchannel	122.85	108.9	148.9	12.62	11.3	15.4	7.93	7.9	8.0
Shinumo Creek	Tributary	114.08	114.0	114.2	11.34	11.3	11.4	8.55	8.6	8.6
Reach 5	Mainchannel	116.20	116.2	116.2	12.50	12.5	12.5	8.25	8.3	8.3
Reach 6	Mainchannel	119.20	119.2	119.2	11.90	11.9	11.9	8.20	8.2	8.2
Reach 7	Backwater	96.20	94.8	97.6	10.03	9.9	10.2	8.30	8.3	8.3
	Mainchannel	85.40	54.5	96.6	9.09	5.8	10.3	8.53	8.2	9.3
Kanab Creek	Tributary	124.43	120.0	126.4	11.92	11.1	12.3	8.18	8.1	8.4
Havasu Creek	Tributary	110.73	107.4	111.2	10.33	10.1	10.4	8.34	8.3	8.4
Reach 8	Backwater	93.20	93.2	93.2	9.71	9.7	9.7	8.20	8.2	8.2
	Mainchannel	98.07	96.1	100.8	9.61	8.6	10.2	8.30	8.2	8.5

Appendix 7c (cont'd).

Reach/Tributary	Habitat	Velocity (cm/s)			Maximum Depth (cm)		
		Mean	Min.	Max.	Mean	Min.	Max.
Reach 1		No Samples					
Reach 2	Backwater	2.3	1	5	93.7	64	128
	Mainchannel	12.8	2	20	62.0	25	110
Reach 3	Backwater	8.0	2	21	41.5	20	62
	Mainchannel	19.5	5	31	47.0	33	66
Reach 4	Backwater	1.0	1	1	14.0	14	14
	Mainchannel	8.0	1	21	76.5	36	112
Shinumo Creek	Tributary	4.0	2	8			
Reach 5	Mainchannel						
Reach 6	Mainchannel	1.0	1	1	111.0	111	111
Reach 7	Backwater	5.0	5	5	82.0	56	108
	Mainchannel	5.5	3	10	124.3	53	247
Kanab Creek	Tributary	5.3	2	9			
Havasu Creek	Tributary	9.3	2	21			
Reach 8	Backwater	0.0	0	0	50.0	50	50
	Mainchannel	9.7	1	26	71.3	17	156

Appendix 8. List of all participating personnel during joint AGFD/BioWest monitoring trips, 1995.

Trip 95-1; 28 March - April 14

Personnel	Agency	Comments
Bill Persons	AGFD	Hiked out Phantom Ranch
Tim Hoffnagle	AGFD	
Mark Brouder	AGFD	
Martin Tuegel	AGFD	
Kirsten Tinning	AGFD	
Debbie McGuinn-Robbins	AGFD	Hiked in Phantom Ranch
Rich Valdez	Bio/West, Inc.	Hiked out Tanner
Bryan Cowdell	Bio/West, Inc.	Hiked out Tanner
Bill Masslich	Bio/West, Inc.	
Leslie Brown	Bio/West, Inc.	Hiked in Tanner
Paul Abate	Bio/West, Inc.	
Teresa Yates	Bio/West, Inc.	
Mike Yard	GCES	
Larry Crist	BoR	Hiked out Phantom Ranch
Leo Lentsch	Utah DNR	Hiked in Tanner, out Phantom Ranch
Steve Bledsoe	OARS	
Greg Williams	OARS	
Bob Grusy	OARS	
Melissa Richmond	OARS	

Trip 95-2; June 13 - 28

Personnel	Agency	Comments
Martin Tuegel	AGFD	
Mark Brouder	AGFD	
Kirsten Tinning	AGFD	
Debbie McGuinn-Robbins	AGFD	
John Nagy	GCES/ATA	
Rich Valdez	Bio/West, Inc.	Hiked out Tanner

Appendix 8 (cont'd).

Personnel	Agency	Comments
Bryan Cowdell	Bio/West, Inc.	
Erika Pratz	Bio/West, Inc.	
Yvette Converse	Bio/West, Inc.	Hiked out Phantom Ranch
Peter Weiss	Bio/West, Inc.	
Ted Mellis	USGS	Hiked out Tanner
Mike Douglas	ASU	Hiked out Phantom Ranch
Marlis Douglas	ASU	Hiked out Phantom Ranch
Steve Bledsoe	OARS	
Greg Williams	OARS	
Butch Schimp	OARS	
Andy Vaork	OARS	

Trip 95-3; September 15 - 30

Personnel	Agency	Comments
Martin Tuegel	AGFD	
Tim Hoffnagle	AGFD	Hiked out Phantom Ranch
Mark Brouder	AGFD	
Kirstin Tinning	AGFD	
Quin Olsen	AGFD	Hiked out Phantom Ranch
Scott Rogers	AGFD	Hiked in Phantom Ranch
Jeff Sorenson	AGFD	Hiked in Phantom Ranch
John Nagy	GCES/ATA	
Bryan Cowdell	Bio/West, Inc.	
Erika Pratz	Bio/West, Inc.	Hiked out Phantom Ranch
Yvette Converse	Bio/West, Inc.	
Peter Weiss	Bio/West, Inc.	
Paula Trader	Bio/West, Inc.	Hiked in Tanner
Stuart Reeder	OARS	
Greg Williams	OARS	

Appendix 9. Location of campsites during joint AGFD/BioWest, monitoring trips, 1995.

Trip 95-1; 28 March - 14 April

Date	Campsite	River Mile/Side
28 March	South Canyon	30.45 R
29 March	Lava-Chuar	65.25 L
30 March	Lava-Chuar	65.25 L
31 March	Lava-Chuar	65.25 L
1 April	Lava-Chuar	65.25 L
2 April	Tanner	68.39 L
3 April	Rattlesnake	74.39 R
4 April	Upper Bass	107.90 R
5 April	above Blacktail	119.72 L
6 April	above Randy's Rock	126.37 R
7 April	Kanab Creek	143.30 L
8 April	above Havasu Cr.	155.95 R
9 April	National Canyon	166.30 L
10 April	Prospect Canyon	179.00 L
11 April	194 mile	194.00 L
12 April	194 mile	194.00 L
13 April	above Diamond Creek	224.50 L
14 April	Take Out	

Trip 95-2; June 13 - 28

Date	Campsite	River Mile/Side
13 June	South Canyon	30.29 R
14 June	Eminence	44.27 L
15 June	LCR point camp	61.15 R
16 June	Carbon Creek	64.55 R
17 June	Carbon Creek	64.55 R
18 June	Tanner	68.39 L
19 June	Rattlesnake	74.72 R
20 June	Upper Bass	107.90 R

Appendix 9. (cont'd).

Date	Campsite	River Mile/Side
21 June	below Randy's Rock	126.48 R
22 June	below Randy's Rock	126.48 R
23 June	Kanab Creek	143.31 L
24 June	above Havasu Cr.	155.95 R
25 June	Fern Glen	168.00 L
26 June	194 mile	194.00 L
27June	above Diamond Creek	224.50 L
28 June	Take Out	

Trip 95-3; September 15 - 30

Date	Campsite	River Mile/Side
15 September	South Canyon	30.29 R
16 September	Eminence	44.27 L
17 September	Carbon Creek	64.55 R
18 September	Carbon Creek	64.55 R
19 September	Carbon Creek	64.55 R
20 September	Tanner	68.39 L
21 September	lower Rattlesnake	74.72 R
22 September	upper Bass	107.90 R
23 September	below Randy's Rock	126.48 R
24 September	below Randy's Rock	126.48 R
25 September	Kanab Creek	143.31 L
26 September	above Havasu	155.95 R
27 September	Prospect Wash	179.00 L
28 September	Parashant Wash	198.00 R
29 September	above Diamond Creek	224.50 L
30 September	Take Out	