Native Fish Monitoring Activities in the Colorado River within Grand Canyon during 2003

Annual Report

Contract # 01WRAG0046

Prepared for

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Prepared by

SWCA Environmental Consultants

July 2004

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1.0 INTRODUCTION

In 2002 the Grand Canyon Monitoring and Research Center (GCMRC) implemented a long-term fisheries monitoring program for a trial period of 5 years. The goal of this program is to develop, refine and implement an effective sampling design for estimating the distribution and relative abundance of native and non-native fish species in the mainstem Colorado River through Grand Canyon. This document reports the second year (2003) of monitoring results for native and non-native species captured with hoop nets, trammel nets and seines in the mainstem Colorado River. This research was conducted by SWCA Environmental Consultants (SWCA), as part of a cooperative effort with GCMRC, Arizona Game and Fish Department (AGFD), and the U.S. Fish and Wildlife Service (FWS). The division of sampling and reporting responsibilities between cooperating agencies in 2003 is a continuation of the division of labor in 2001 and 2002, with AGFD responsible for non-native salmonids in the mainstem, FWS responsible for sampling in the Little Colorado River (LCR), and SWCA responsible for native fishes and warm-water non-native fishes in the mainstem.

1.1 Development of a Long-Term Monitoring Program for Fishes of Grand Canyon

In the early 2000s, fisheries biologists and resource managers determined that a long-term monitoring program was needed to track the status and trends of the fish community in Grand Canyon, particularly the endangered humpback chub and other native species, as well as non-native fishes (Table 1). The development of this program was discussed in a previous annual report by Johnstone et al. (2003). In short, a need was identified for a monitoring program that could detect spatial and temporal trends in river-wide fish distribution and relative abundance. Within the Colorado River in Grand Canyon, adult humpback chub (HBC) exhibit high site fidelity and occur principally in higher concentrations within discrete areas of river known as "aggregations". These aggregations were identified and monitored by Valdez and Ryel (1995) to document the life history and ecology of the HBC in the early 1990s. Other target species such as bluehead sucker, flannelmouth sucker, speckled dace, and invasive non-natives are more commonly distributed in areas outside of HBC aggregations. The monitoring strategy had to account for these differences in distribution to adequately monitor HBC as well as the other target species. Common and scientific names of all fish species referenced in this report are provided in Table 1.

Monitoring the distribution and relative abundance of fish species is essential to assess the effectiveness of management actions. The distribution and abundance of HBC, as well as of other species, may change as a response to management actions or the lack thereof. Management actions related to fisheries in Grand Canyon are generally intended to benefit the endangered HBC by increasing recruitment and population size and expanding their distribution. However, actions intended to benefit native species may also benefit non-native species. Management actions intended to warm the perennially cold water in the Grand Canyon, such as the proposed Temperature Control Device (TCD) and Low Steady Summer Flows of 2001 (Trammel et al. 2003) are likely to increase the distribution and abundance of warm-water non-native fish such as centrarchids, ictalurids, and cyprinids, as well as the native species. Alternatively, management actions (such as the high fluctuating flows in the winter of 2003) may be directed toward disadvantaging non-native species such as the rainbow trout.

The strategy developed by GCMRC for long-term native fish monitoring in Grand Canyon is a combination of stratified-random samples and intensive sampling efforts at known HBC aggregations (i.e., 30-mile, LCR Inflow, Lava Chuar to Hance, Bright Angel Creek Inflow, Shinumo Creek Inflow, Stephen Aisle, Middle Granite Gorge (MGG), Havasu Creek Inflow, and Pumpkin Spring; Valdez and Ryel 1995) (Figure 1). Stratified-random samples were allocated among 11 longitudinal reaches; reaches were designated based on historic catch data (see Figure 2) using a modified version of the sample allocation program *Sample.exe* (Carl Walters 2001, unpublished). The 11 longitudinal reaches determined from the sample allocation program differ from the 11 geomorphic reaches established by Valdez and Ryel (1995).

The number of samples needed in each reach was calculated to achieve a target Coefficient of Variation (CV) of 0.1. This would provide the power to detect a 20% change in relative abundance per year, over a 5-year period. Sampling intensity must account for the amount of variability found in our data. Because HBC, for example, are rare and difficult to capture in the mainstem we must have enough samples so that our % error is not greater than the change (20% change in relative abundance) we are trying to detect.

According to the monitoring program, catch rate statistics will be monitored annually to evaluate the efficacy of using catch-per-effort (CPE) to assess population trends for target species over a period of at least 5 years. Because of CPE variability, Coefficient of Variation (CV=SE/mean), a measure of relative variability, will be used to determine if catch data will support the long-term monitoring model (discussed in section 5.0). In addition to trend monitoring using CPE and CV, river-wide catch information will provide a current baseline for fish distribution.

The sampling design described in the Methods section of this report is intended to evaluate the efficacy of the proposed sampling methods to meet the needs of a long-term monitoring program for native and select non-native species. As these methods are intended and expected to provide long-term data series for monitoring, the basic framework and methodologies should remain consistent from year to year. However, the methods used will continue to be refined, as needed, as is consistent with the Glen Canyon Dam Adaptive Management Program.

The expected ability of this program to monitor the status and trends of native and select non-native fish populations varies by species. CPE variability, and thus CV values, are dependent on the abundance and distribution of each species, and vulnerability to gears. The ability of the model to monitor population change depends on sample size and spatial stratification, which are constrained by logistics. This sampling program will not provide absolute abundance estimates for most species, but is intended to show population trends and changes in relative abundance over 5-year periods. As evidenced by preliminary trend analysis of existing data (Gerrodette 1987, AGFD unpublished data), we do not expect changes in relative abundance (≥20%) to be detectable on time scales of less than 5 years.

1.2 Long-Term Monitoring Program Objectives

The purpose of SWCA's role in GCMRC's long-term monitoring program is to develop, refine, and implement an effective sampling design for estimating the distribution and relative abundance of native fish species,and select warm-water non-native fish species in the Colorado

River ecosystem (CRE). Specific long-term monitoring objectives for each species and category of fish are as follows:

Native Species: Humpback chub, bluehead sucker, flannelmouth sucker, speckled dace

- Determine the status and trends in the distribution and relative abundance of each species in the CRE.
- Estimate annual length distribution of each species in the CRE.

Non-Native Species (including but not limited to): Brown trout, common carp, channel catfish, fathead minnow, plains killifish, rainbow trout, and red shiner.

- Monitor the distribution and relative abundance of the non-native fish community in the CRE.

2.0 MONITORING OF NATIVE AND NON-NATIVE FISHES IN 2003

In accordance with GCMRC's long-term monitoring strategy, SWCA's mainstem monitoring in 2003 included river-wide stratified-random sampling and intensive sampling efforts at known HBC aggregations. Trammel nets and hoop nets were used to obtain catch rate statistics, including sample mean and variance and CPE indices. These two gear types have been used in previous studies in the Grand Canyon and have been shown to sample fish effectively and adequately represent the fish community when used in combination (Valdez and Ryel 1995; AGFD 1996, 2001; Trammell et al. 2003; Trammell and Valdez 2002; Johnstone et al. 2003). Seining was used to sample backwaters and shallow water habitats for smaller fish not typically captured by trammel or hoop netting. Seine samples were not random, but were collected in available habitats.

3.0 METHODS

3.1 Study Area and Methods

The study area was the Colorado River from Lees Ferry (RM 0) to Diamond Creek (RM 226), with river miles (RM) as designated in the Stevens river guide (Stevens 1983). To estimate the relative abundance, distribution, and annual length distribution of selected fish species within the study area, samples were taken with trammel nets, hoop nets, and seines. HBC aggregations were intensively sampled (Figure 1) and river-wide stratified-random samples were allocated within 11 longitudinal reaches (Figure 2). Trammel nets were all the same dimension and mesh size, hoop nets were all the same diameter and mesh size, and seines were all the same dimension and mesh size (net dimensions are described in section 3.5). CPE was calculated for each gear type. Trammel net CPE was reported as number of fish/net set; mean set time was 1.9 hrs (Table 2). Hoop net CPE was reported as number of fish/set; mean set time was 18.6 hrs (Table 2). Seine CPE was reported as number of fish/meter^2; mean seine area was 34.2m^2 (Table 2).

Changes and trends in relative abundance and distribution will be assessed with changes in catch rates over time (CPE index over a 5-year period); significant changes (≥20%) are unlikely to be detected over time intervals of less than 5 years. The slope of mean CPE over time will indicate the direction of trends and the magnitude of the change. The minimum number and distribution of samples needed to detect a significant change (≥20%) in relative abundance over a 5-year period was estimated for each gear type and for each species using the methods described below. Although stratified-random sampling was conducted at randomly chosen river miles within reaches, the habitat sampled was limited to shoreline areas where nets could be effectively set.

Trammel nets were typically set at separation points where eddy current and main current diverge, also known as eddy fences. Hoop nets were set in areas characterized by low velocity shoreline and set at depths of 3 m or less. Seines were used to sample backwaters and shallow near-shore habitats.

3.2 Number of Samples

The number of samples needed to achieve a CV of 0.1, given the historic variance in CPE, was estimated in 2002 using a modified version of the program *Sample.exe* (Table 3). The data used as input for this program were historic catch rates of each species by mile, generated from all sampling conducted in the Colorado River mainstem from 1990 to 2000 (Scott Rogers, AGFD, pers. comm.). *Sample.exe* optimized the number of samples needed by resampling the historic catch data and increasing the number of 'samples' until the estimated CV approached or achieved the target of 0.1, while allocating the samples to the 11 reaches. This exercise was completed for each gear type (i.e., trammel nets, hoop nets, seines) and eight species; i.e., bluehead sucker (BHS), flannelmouth sucker (FMS), humpback chub (HBC), speckled dace (SPD), brown trout (BNT), common carp (CRP), fathead minnow (FHM), and rainbow trout (RBT). Red shiner (RSH), channel catfish (CCF), striped bass (STB), and yellow bullhead (YBH), were combined into one group due to low incidence of capture.

Samples in 2003 were collected during three field sessions (Tables 4, 5, and 6). Numbers and locations of samples collected during each trip are reported in Table 7.

3.3 Selection of Gear Types for Species

Gear types vary in capture efficiency for different species and ages within species. For example, electrofishing (AGFD data) is very efficient at capturing salmonids and CRP, but is ineffective at capturing adult HBC, although young-of-year (YOY) HBC are vulnerable to this gear type. Trammel nets are effective for adult HBC, and hoop nets are very effective at capturing all sizes of HBC (Valdez and Ryel 1995, Trammell et al. 2003). Using the appropriate gear type for the target species allows greater measurement precision, with fewer samples. The relative efficiencies of gear types are reflected in the *Sample.exe* program allocations. For some species/gear combinations, the program calculated a reasonably achievable number of samples; for others, the number of samples calculated was unreasonable to obtain. More samples were required for the less common species. For example, BHS are less frequently captured than most species and therefore require more samples for all gear types. Also, the number of seine samples required for all species was larger than the usual number of available backwater habitats, so the required number cannot be achieved for most species.

The gear, or combination of gear types, that best suited each species was selected. The length distributions of fish captured by each gear type and habitats that can be sampled were not specified in the program but are important to consider (Valdez and Ryel 1995). For example, trammel nets capture large adult fish while hoop nets capture smaller, juvenile fish as well as adults. Seines can be used to sample backwaters and are the best gear type for collecting YOY native fishes and small-bodied non-natives. Thus, all gear types were used to adequately represent the length distribution, as well as the relative abundance of the selected species. Trammel nets were selected for adult BHS, FMS, and HBC; electrofishing (AGFD) was selected for BNT, RBT, and CRP, and possibly FHM and SPD; and hoop nets were selected for smaller HBC. Seining was used for all YOY native fish and SPD, also small-bodied non-natives such as FHM, plains killifish (PKF), and red shiner (RSH).

3.4 Spatial Stratification and Sample Allocation of Gear Types

The *Sample.exe* output was stratified by reach. The final sample allocation is shown in Table 3. In general, the maximum number of samples needed for any species with the appropriate gear type was used to allocate sampling efforts in each reach. However, the *Sample.exe* output allocated a disproportionate number of trammel net and hoop net samples to areas that were historically sampled. In the past, not all fish sampling was random, and was driven by objectives other than population monitoring. Valdez and Ryel (1995) stratified the 226-mile reach of the Colorado River through Grand Canyon into 11 geomorphic reaches and 34 sample strata. Eight to 16 strata were randomly sampled with trammel nets, hoop nets, and electrofishing during each monthly trip. AGFD (1996) sampled only backwaters to assess the importance of these habitats to native fish in Grand Canyon and to monitor effects of Glen Canyon Dam operations. Trammel et al. (2003) sampled throughout Grand Canyon as the initial phase of this monitoring program, and Trammel and Valdez (2002) sampled primarily within select HBC aggregations to generate population estimates for that species. The long-term monitoring program is intended to rectify this sampling inconsistency; therefore, for the final sample allocation, the total number of trammel net and hoop net samples was increased, and the distribution of samples was adjusted for more equitable sampling in less frequently sampled areas. Because the distribution of HBC is clumped in smaller areas within the longitudinal reaches (aggregations), it was feared that random sampling would often fail to capture any HBC. The random sample allocation, therefore, was supplemented by samples at 8 of the 9 known aggregation sites as described by Valdez and Ryel (1995): 30-mile, LCR Creek Inflow, Lava Chuar to Hance (not sampled in 2003), Bright Angel Creek Inflow, Stephen Aisle, Middle Granite Gorge, Shinumo Creek Inflow, and Pumpkin Spring (not sampled in 2003). These data were also analyzed independently of randomly collected data. Thus, the long-term native fish monitoring program is designed to: 1) conduct stratified-random sampling for all reaches of the Colorado River, and 2) monitor the areas that have high concentrations of native fish, especially HBC. The *Sample.exe* allocation, plus adjustments, resulted in a total of 1,015 trammel net samples and 1,244 hoop net samples for 2003, in order to meet the established criteria for sample variability (i.e., CV≤0.10) and level of detection in population change (i.e., ≥20%). The number of seine samples obtained depended on the availability of backwater habitats (determined in the field). A total of 316 seine samples were collected in 2003. The majority of those samples were collected during the September seining trip. More than one backwater was sampled per river mile. This level of seining effort had not been conducted since the mid 1990s by AGFD (1996).

Hoop and trammel net sample sites were randomly chosen using the random number generator in Microsoft® Excel. The total number of samples needed in each reach (Table 3) was divided by the number of samples possible to obtain in one night with two sampling boats (30 trammel net samples, 36 hoop net samples). The area sampled included the selected mile but was limited by navigable river area. The area surrounding each randomly selected mile was examined using the Stevens river guide to estimate navigable area to be sampled (Tables 4 and 5). Within this area, biologists used judgment and experience to place individual hoop and trammel nets. Some sample reaches could not be entirely and effectively sampled because of a narrow, deep, swift channel, or because of the presence of whitewater rapids.

For trammel nets, the *Sample.exe* allocation for BHS was very high and was directed heavily at the LCR inflow reach, which was already well represented for other species by the sampling design. Additional sampling for BHS in the LCR inflow could lead to additional stress on HBC in the reach due to increased probability of multiple capture events for HBC. Therefore, no sampling in addition to that already allocated for FMS and HBC was implemented in the LCR inflow reach. Sample allocation in other reaches satisfied the program allocation for FMS, HBC, and BHS. It is recognized that BHS relative abundance may not be adequately represented by the sampling design. The minimum number of samples taken at each site was 30 (the maximum possible per night), irrespective of *Sample.exe* output (Table 3).

Hoop net sampling prior to 2002 was heavily concentrated near the LCR (AGFD 1996); therefore, the program allocated nearly all the sampling to the LCR inflow reach. For this sampling design, hoop nets were set concurrently with the trammel nets. This satisfied *Sample.exe* allocation requirements and supplemented samples in all other reaches (Table 3). The minimum number of samples taken at each site was 36, irrespective of *Sample.exe* output.

The CV of the historical (1990–2001) seine samples was high for most species, and the *Sample.exe* program estimated that a very large number of samples was needed, often in excess of 1,000. In most years, fewer than 40 backwaters are available to be sampled (AGFD unpublished data), and the number of samples required would be impossible to obtain. Therefore, seining is not likely to be useable in detecting statistically significant trends in the relative abundance of the natives and small-bodied non-natives. It can, however, provide information on the range of those species and on growth of the young native fishes. Seining, therefore, was conducted opportunistically during the June trip depending on availability of backwaters, *en route* between net sample sites. In September almost every backwater as well as several near shore areas were seined. Effort was estimated by measuring the length and width of each seine haul. All fishes were identified to species. In each seine haul, all fish (in small samples) or a sub-sample of up to 30 of each species (in larger samples) were measured to the nearest 1 mm Total Length.

3.5 Definition of Samples

<u>Trammel Nets</u>: One trammel-net sample is one 2-hour net set. Each netting boat set five trammel nets beginning at 1600 hours. Each net was checked every 2 hours, for a total of three sets per night with the final check at 2200 hours. Average set times are reported in Table 2.

Standard net size is 22.86 m long by 1.83 m deep, with 2.54- or 3.81-cm-mesh and 0.30-cm outside walling. CPE is defined as number of fish/2-hour set.

Hoop Nets: One hoop net sample is one net, set overnight. Average set times are reported in Table 2. Each net was baited with small mesh bags containing a handful of Aquamax trout pellets. Each netting boat set 18–20 hoop nets (0.61 m diameter) when camp was reached. Each net was checked and pulled the following morning (approximately 16-hour sets). CPE is defined as number of fish/set.

Seines: One sample is one seine haul. The seine was 3.66 m long by 1.83 m deep with 0.32 cm mesh size. One to three seine hauls were made at different locations in each backwater. Each boat sampled as many backwaters as possible while traveling between camps. Length and width of haul were recorded to determine effort. CPE is defined as number of fish/m^2 (m^2=length × width of seine haul).

3.6 Fish Processing/Data Collection

A standard fish handling protocol was outlined jointly between GCMRC and the cooperating agencies (Ward 2002) and modified further in 2003. A list of the pertinent protocols is given below:

1. Total lengths (TL) were taken on all native and non-native fishes. Forked lengths were taken on all native fishes >150 mm TL.

2. Weights were not taken in an effort to minimize handling stress.

3. All native fish, all brown and rainbow trout with an adipose fin clip, and carp with a dorsal clip were scanned for PIT tags using both new and old PIT tag scanners. Untagged native fish >150 mm were PIT tagged with a "new" 134.2 kHz tag. Brown trout >150 mm were PIT tagged with an "old" 400 kHz tag and given an adipose clip. Carp >150 mm were tagged with a "new" 134.2 kHz tag and given a dorsal spine clip. All PIT tag numbers were recorded on data sheets and stored in the PIT tag readers for later download.

4. A portion of the right pelvic fin of captured HBC (at all sites except LCR inflow reach) was clipped for genetic analysis. Clips were preserved in ethanol with a label indicating date, river mile, and length of fish. Specimens were sent to Dr. Marlis Douglas at Colorado State University for analysis.

5. All native fishes were examined externally for gender, evidence of spawning condition, and external parasites.

6. Global Positioning System (GPS) data were taken at the attachment point of each net, as satellite acquisition allowed.

7. In September all backwaters that were sampled and potential fish-holding shoreline vegetation was mapped on digital aerial imagery (1:3000) provided by GCMRC (see Appendix A).

8. In September all potential trammel net sites within known HBC aggregations were documented on digital aerial imagery (1:3000) provided by GCMRC (see Appendix A).

3.7 Sampling Trip Structure

One SWCA trammel and hoop netting trip was conducted in May and one in June, 2003 (Tables 4 and 5). A third trip, focused on seining and mapping backwaters was conducted in September (Table 6). All trips were 17–20 days long, including one day to rig the boats and equipment, and one day for take-out and de-rig. The purpose of Trip 1 (May 3–21) was to obtain distributional and relative abundance estimates for native fish and to supplement this information for non-natives. The LCR Inflow, Lava Chuar to Hance, and Bright Angel Creek Inflow Aggregations were also sampled on this trip. The primary purpose of Trip 2 (June 14–30) was to sample known HBC aggregations, increase the number of PIT-tagged fish in these areas, and to supplement the estimated number of samples needed in these areas. From 2 to 4 nights were spent at five main aggregations (30-mile, Bright Angel Creek Inflow, Shinumo Creek Inflow, Stephen Aisle, MGG, Havasu Creek Inflow). The second purpose of this trip was to continue the stratified-random sampling initiated on Trip 1. The primary purpose of Trip 3 (September 13–29) was to sample all available backwaters and to record all potential trammel netting sites within HBC aggregations on digital aerial imagery (1:3000). Additionally riparian vegetation that may provide habitat for juvenile and small fish was also recorded. All points were entered into GIS coverage, and summary information is provided in Appendix A.

For Trip 1, a total of seven boats were necessary to support the combined efforts of netting and electrofishing. Two sport boats were used for netting (SWCA biologists) and two for electrofishing (AGFD biologists). One snout boat was used for transporting nets and science equipment. Two S-rigs were used to transport food, duffle, and people (20). Sampling locations and camping sites were moved downriver almost every day. The number of boats and dual objectives (electrofishing and netting) were a logistical constraint on the trip. For Trip 2, two sport boats were used for netting; one snout boat was used for transporting nets and science equipment. One S-rig was used to transport food, duffle and people (14). Multiple nights were spent at aggregation sites. Trip 3 was conducted with four oar boats and eight people. All possible backwaters and near-shore habitats were seined. Oar boats proved to be an effective and efficient tool for seining.

4.0 SAMPLING RESULTS

4.1 Hydrology

Two netting trips and one seining trip were completed as scheduled in May, June, and September. Releases from Glen Canyon Dam followed ROD[1] flows throughout the three

1 Modified Low Fluctuating Flows per the Record of Decision (ROD) for the Operation of Glen Canyon Dam Environmental Impact Statement, 1995.

sampling periods (Figures 3, 4, and 5). Releases fluctuated from approximately 6,690 to 13,961 cubic feet per second (cfs) during Trip 1 (Figure 3), from 9,810 to 18,672 cfs during Trip 2 (Figure 4) and 5,187 to10,418 cfs during Trip 3 (Figure 5). Monsoon storms prior to and during Trip 3 caused flooding in the tributaries, particularly the LCR (Figure 5). This flooding likely influenced catch rates of sub-adult HBC, FHM, and PKF, below the LCR confluence as shown in other studies (Valdez and Ryel 1995; Trammell et al. 2002; Johnstone et al.2003). This topic is further addressed in the discussion. . Information on increased dam discharge temperatures and downstream water quality, is available on the GCMRC website (www. gcmrc.gov). Backwater temperature and fish distribution is addressed in section 4.13.

4.2 Distribution of Effort

Stratified-random and aggregation site trammel-net samples totaled 1,015, and hoop net samples totaled 1,244 for both trips combined (Table 7), as determined from the sample allocation program Sample.exe. A total of 316 seine samples were also taken. The number and distribution of trammel and hoop samples collected for each gear type more than satisfied totals generated by the sample allocation program (Table 3). Trammel and hoop net samples were almost evenly split between random sites and aggregation sites. Approximately half or 55% (559/1,015) of trammel nets and 56% (700/1,244) of hoop nets were fished at or near aggregation sites. During June, seine samples were collected opportunistically as backwaters occurred and schedule permitted. In September, nearly all backwater habitats were seined. Distribution of effort during all trips is shown in Figure 6. The combined efforts of 2002 and 2003 (Figure 7) represent a strong baseline of river-wide samples.

By conducting a separate trip in September primarily for seining, we collected more seine samples than in previous efforts (Table 6). Nearly every backwater as well as several shallow near-shore areas were sampled with a seine from Lees Ferry to Diamond Creek. Additionally, five tributaries were sampled near their confluence with the mainstem: the Paria River, Shinumo Creek, Royal Arch Creek, Deer Creek, and Kanab Creek. A total of 231 seine hauls were collected during Trip 3. Of these, 16 were tributary samples and 215 were backwaters and alcoves. The majority of backwaters occurred upstream of RM 70 and downstream of RM 110, with far fewer in between (Figure 6), which is an area of frequent whitewater rapids and a narrow, deep channel within Upper Granite Gorge.

4.3 Bluehead Sucker

4.3.1 Relative Abundance and Gear Vulnerability

BHS was the least abundant native fish caught in trammel and hoop nets, and the third most abundant native fish caught in seines (Figure 8). Trammel nets were the most effective gear for capturing adult BHS (>100 mm): 35 fish were captured in trammels and 6 in hoop nets (Tables 8a and 8b). Juvenile fish (<100 mm) (n=182) were captured primarily with seine nets in backwaters.

4.3.2 Distribution and catch rate

Of 109 trammel nets in Reach 3 (RM 57–69.9), only four BHS were caught. In Reach 4 (RM 70–79.9) four BHS were caught in 71 trammel nets. This translates to a mean trammel net

CPE for adult BHS of 0.04 fish/net (SE=0.02) and 0.06 fish/net (SE=0.04) in Reaches 3 and 4, respectively (Figure 9). In Reach 5 (RM 80–109.9), CPE decreased further to 0.02 fish/net (SE=0.01). Reaches 6 (RM 110–129.9) and 7 (RM 130–159.9) yielded more adult BHS per trammel net than any other reach (8 BHS/179 nets and 14 BHS/139 nets, respectively). Trammel net CPE for Reach 7 was 0.1 fish/net (SE=0.03). Overall trammel net CPE for BHS was higher in 2002 (0.067, SE=0.01) than in 2003 (0.03, SE=0.0070) (Table 9a); however, river-wide distribution trends (Figure 9) were similar in both years (Johnstone et al. 2003). Only six BHS were captured in hoop nets: one fish in Reach 7 and five fish in Reach 9 (Table 8b). One BHS was captured by hoop netting during 2002.

CPE trends for seine catches (BHS <100 mm) showed the highest catch rates (0.09 fish/m^2 (SE=0.08)) in the LCR inflow region (RM 57.0–79.9), while catch rates from Reach 6 on were much lower (CPE=0.01–0.04). Catch rate did increase downstream through Reach 10 (RM 219.9) (Figure 8). No BHS were captured in seines in Reaches 1 through 6 during 2002. Trammel net CV for BHS (0.193) approached the target CV of 0.10; hoop net CV (0.577) was much higher. Seining CV (0.229) was also much higher then the target value (Tables 9a, 9b, and 9c).

4.3.3 Length Distribution

BHS length distribution is bimodal (Figure 10), with a mode of age-0 fish between 20 and 100 mm, and a substantially smaller mode of age 2+ fish (>180 mm). This shows the reproduction of BHS is occurring in Grand Canyon. Higher catch rate near the LCR inflow suggests that either much of this reproduction is occurring in tributaries or populations are aggregated near warm, productive tributary inflows. Survival of age-0 BHS is unknown and may be limiting recruitment and population size.

4.3.4 Recapture Rate

No BHS were recaptured from previous marking events, and 35 new PIT tags were placed in BHS (>150 mm) (Table 10).

4.4 Flannelmouth Sucker

4.4.1 Relative Abundance and Gear Vulnerability

FMS was the most abundant native fish caught in trammel nets and the second most abundant native fish caught in hoop nets and by seining (Figure 8). Trammel nets were the most effective gear for capturing adult FMS (>200 mm) (Figure 11); 154 fish were captured in trammels and 54 in hoop nets (Table 8a and 8b). Juvenile fish (<200 mm) (n=1377) were primarily captured with seines in backwaters.

4.4.2 Distribution and Catch Rate

FMS were distributed river-wide, with highest CPE values located in Reaches 3, 4, 7, and 8, all of which include or are in close proximity to major tributaries (Figure 2). In Reach 3, 26 FMS were caught out of 109 trammel nets. In Reach 7, 50 FMS were caught out of 139 trammel nets

(Tables 7 and 8a). Mean trammel net CPE for adult FMS was 0.239 fish/net (SE=0.052) in Reach 3 and 0.036 fish/net (SE=0.077) in Reach 7 (Figure 11). Overall trammel net CPE was higher in 2002 (0.064, SE=0.01) than in 2003 (0.043, SE=0.0070) (Table 9a); however, river-wide distribution trends reflected by trammel net catches (Figure 11) were similar in both years (Johnstone et al. 2003). Mean hoop net CPE increased downstream from Reach 5 (0.013, SE=0.01) to Reach 9 (0.167, SE=0.07) (Figure 10). No FMS were captured in hoop nets in the LCR inflow reach (Reach 3 and 4) during 2003 (Figure 11). This compares to a mean hoop net CPE of (0.340, SE= 0.06) for Reach 3 in 2002.

CPE trends for seine catches (FMS <200 mm) showed the highest catch rates (0.30 fish/m^2, SE=0.24) just below the LCR inflow in Reach 4; however, FMS were captured in all reaches and mean CPE values were similar in Reaches 2 through 8. Mean CPE declined in Reaches 9 through 11 (Figure 11). Seining effort is difficult to compare between 2002 and 2003 because of differences in sampling efforts and allocation. However, more FMS were caught in 2003 than in 2002 by seining in the upper reaches (Reaches 1-7) (Table 8c).

Trammel net CV for FMS (0.112) was very close to the target CV of 0.10; hoop net CV (0.241) was much higher. Seining CV (0.171) was also very close to the target value (Tables 9a, 9b, and 9c).

4.4.3 Length Distribution

All lengths of FMS are represented in the catch data (Figure 12). As expected there is a high frequency of age 0 fish in the 20-100 mm range. Far more subtle modes occur in the 220–320 mm and 440–550 mm ranges. As with BHS, these data show that FMS are successfully reproducing in Grand Canyon. Higher catch rate near the LCR inflow suggests that either much of this reproduction is occurring in tributaries or populations are aggregated near warm, productive tributary inflows. Like BHS, survival of age-0 FMS is unknown and may be limiting recruitment and population size.

4.4.4 Recapture Rate

A total of 210 FMS >150 mm were captured; 34 fish were recaptures from previous marking events, and 151 new PIT tags were placed in fish (Table 10).

4.5 Humpback Chub

HBC results are reported in terms of size, longitudinal (river-wide) distribution as well as distribution relative to known aggregations. Three size classes expressed as TL are used in this report: young HBC (0–119 mm), juvenile HBC (120–199 mm), and adult HBC (>200 mm).

4.5.1 Relative Abundance and Gear Vulnerability

HBC were the second most abundant native fish caught in trammel nets, the most abundant native fish caught in hoop nets, and the least abundant native fish caught by seining (Figure 8). In total, 69 fish were captured in trammels and 73 in hoop nets (Tables 8a and 8b). Trammel and hoop nets were equally effective gear for capturing adult HBC (>200 mm) (Figures 13 and 14); hoop nets were the most effective gear for capturing juvenile HBC (120–199 mm). Young HBC (<120 mm) were primarily captured with hoop nets, though a small percentage of fish juvenile HBC (13/235 fish) were captured in seines (Figure 14). Most (112/129 fish) young HBC (<120 mm) were captured in seines.

4.5.2 Distribution and Catch Rate

HBC were captured in most sampling reaches, but catch rates varied considerably. Highest CPEs were in Reaches 3, 4, 5, and 6 (Figure 14). Mean trammel net CPE for adult HBC (>200 mm) was highest in Reach 3 (0.248 fish/net, SE=0.083) followed by Reach 5 (0.056, SE=0.019) and Reach 6 (0.095, SE=0.026) (Figure 14). For fish between 120 and 199 mm, mean CPEs were similar in Reaches 3, 4, 5, and 7 (Figure 14). Mean hoop net CPE for adult HBC (>200 mm) was highest in the LCR inflow reach (0.208, SE=0.083). Mean hoop net CPE for HBC between 120 and 199 mm, was highest in the LCR inflow reach (0.058, SE=0.03) and decreased downstream (Figure 14). CPE values by reach followed similar trends as 2002 (Johnstone et al. 2003). Mean trammel net CPE in 2003 (0.066 fish/net, SE=0.012) was higher than 2002 (0.046 fish/net, SE=0.010) (Table 9a). The CV for HBC caught by trammel nets in 2003 (CV=0.176) was closer to the target of 0.10, compared to 2002 (CV=0.224) (Table 9a). Mean hoop net value in 2003 (0.059 fish/net, SE=0.010) was higher than 2002 (0.020 fish/net, SE=0.010). The overall CV for HBC caught by hoop nets in 2003 (CV=0.176) was closer to the target of 0.10, compared to 2002 (CV=0.224) (Table 9b).

Humpback chub trammel and hoop net CPE and CV analyzed by aggregation are shown in Table 11 and Figure 17. When aggregation data were analyzed separately from reach data, aggregation boundaries were defined based Valdez and Ryel, 1995 (Figure 1). In some cases where HBC were captured outside of these boundaries but within 2-miles of aggregations, these fish were not included in the analysis. Highest aggregation CPE for trammel nets was 0.280 fish/net (SE=0.093) at the LCR Inflow aggregation followed by 0.250 (SE=0.076) at the Shinumo Creek Inflow aggregation. Highest aggregation CPE for hoop nets was 0.324 fish/net (SE=0.101) at the LCR Inflow Aggregation followed by 0.110 (SE=0.030) in the MGG Aggregation. No fish were captured in trammel or hoop nets within the Havasu Creek Inflow Aggregation (Figure 1), however 3 adult HBC were captured between RM 157.1 and 157.4. Compared to overall CPE for HBC (Table 9), CPE analyzed by aggregation (Table 11) was higher. This is to be expected, because HBC are concentrated in these areas. CV for aggregations was higher than when analyzed by reach or overall.

HBC <200 mm were found in most reaches from RM 38 to 217, while adult HBC >200 mm were primarily distributed in close proximity to known aggregations (Figure 15). Twenty-one young HBC (18–49 mm) were captured in backwaters between RM 38.6 and 50.4 (upstream of the LCR). The majority of young and juvenile HBC occurred in the LCR inflow region (Figure 14): 64 HBC between 25 and 116 mm, and 14 HBC between 120 and 194 mm. From RM 70.5 to 76.6, 13 young fish between 26 and 85 mm were caught in hoop and seine nets and 6 fish between 122 and 190 mm were caught in trammel, hoop and seine nets. Several (n=31) young (33–118 mm) and juvenile (n=18) HBC (120–198 mm) were captured downstream of the LCR

(RM 80–217). Six HBC between 40 and 70 mm were caught in June from RM 108.1 to 127.3 primarily in hoop nets.

With the exception of four fish (fish outside of aggregations are notated with an asterisk "*"), most adult HBC (n=92) were distributed in close proximity to known aggregations (Figure 15). CPE for aggregations is shown in Table 11 and Figure 17: LCR Inflow, Shinumo Creek Inflow and the MGG Aggregations had the highest CPEs for adult HBC. Three adult HBC were captured in trammel nets between RM 30.8 and 31.0 (30-mile Aggregation), sizes ranged from 329 to 452 mm. One adult HBC (350 mm) was captured at RM 39.9* (Table 12). Fifty-three HBC (203-461 mm) were captured between RM 59.4 and 68.2 (LCR Inflow Aggregation). Near the confluence of Shinumo Creek (RM 107.9–108.5), 11 adult HBC (211–302 mm) were captured in trammel and hoop nets (Figure 14). At the MGG Aggregation (RM 126.1–129) 20 adult HBC (205–318 mm) were caught in trammel and hoop nets. One HBC (195 mm) was captured at RM 138.6*. Below the confluence of Havasu Creek (RM 157.1 to 157.4), three HBC (223–263 mm) were captured in trammel and hoop nets. Two unmarked HBC (200 and 360 mm) were captured at RM 194.3* in a trammel net. CPE values for aggregations are shown in Table 11 and Figure 17.

4.5.3 Length Distribution

All lengths of HBC are represented in the catch data (Figure 16). As expected there is a high frequency of age 0 fish from 18 to 100 mm. Modes also occur in the range of 100–170 mm, 180–260 mm, and 330–460 mm. Notably several young fish (33 to 118 mm) were captured downstream of the LCR (RM 80–217). The 20 fish (40–118 mm) captured in May and June 2003 likely represent young fish that were flushed out of the LCR during a large-scale flood that occurred in September 2002 (>10,000 cfs). In all 129 HBC <120 mm were captured in 2003; 59 of those were captured in the LCR inflow region. Thirty-eight fish between 120 and 200 mm were captured in 2003.

4.5.4 Recapture Rate

A total of 267 HBC were captured by trammel, hoop, and seine nets. Of those, 121 fish were >150 mm, 64 fish were recaptured from previous marking events and 55 new PIT tags were placed in HBC (Table 10). A list of all recaptured fish with original tag locations are listed in Appendix B. Of those recaptured fish, four were tagged and recaptured on the same trip; one fish was tagged in May 2003 at RM 119.4 and recaptured in June 2003 at RM 108.1. Twenty-five fish were originally tagged in the LCR and recaptured between RM 59.9 and 62.7 (Table 12). Nineteen fish were originally tagged (1991–2001) and recaptured (2003) between RM 58.2 and 62.1. Two fish (402 and 452 mm) were tagged (1993) and recaptured (June 2003) between RM 30.2 and 30.8, one fish (302 mm) was tagged (September 1999) and recaptured (June 2003) at RM 108.3. Four fish (238–318 mm) were tagged (1993–2002) and recaptured (June 2003) between RM 126.1 and 127.4. One recaptured fish (RM 126.8) was tagged in 2001 but no river mile was recorded. One fish (263 mm) was tagged (2002) and recaptured (2003) between RM 157.3 and 157.4. The percent of fish captured (>150 mm) that were previously tagged is reported in Table 12. Of the fish captured in the 30-mile and LCR inflow reaches, 66.67% and 75.86% were previously tagged. However, all other aggregations had a recapture rate of less than 25% (Table 12). Mean TL of fish captured at aggregations was highest at the 30-mile and LCR Inflow Aggregations and was substantially less in downstream aggregations (Figure 18). These data are consistent with values reported by Valdez and Ryel (1995).

4.6 Speckled Dace

SPD were distributed in all reaches (Table 8c). Fish were primarily captured by seining (1,746 fish), 55 fish were captured in hoop nets. Reaches 5 (0.543 fish/m^2, SE=0.278) and 8 (1.062 fish/m^2, SE=0.317) had the highest CPE values (Figure 19). CPE values declined from Reaches 8 thru 11 (0.340 fish/m^2, SE=0.198). SPD lengths ranged between 15 and 96 mm, with most fish occurring between 20 and 50 mm. The CV value for SPD captured by hoop netting was 0.159 and 0.172 for seining (Table 9c).

4.7 Brown Trout

4.7.1 Relative Abundance and Gear Vulnerability

BNT, made up 14.65% of the non-native fish captured by trammel and hoop nets and 7.57% of all fish captured by trammel and hoop nets. Trammel nets were the most effective gear for capturing adult BNT; 67 fish were captured in trammels and 5 in hoop nets (Tables 8a and 8b). Only two BNT were captured by seining (Table 8c).

4.7.2 Distribution and Catch Rate

BNT were distributed between Reaches 2 and 8, with highest CPE values located in Reaches 5 and 6, near the confluence with Bright Angel Creek (Figures 1 and 20). In Reach 5, 36 BNT were caught out of 180 trammel nets. Mean trammel net CPE for adult BNT in Reach 5 was 0.194 fish/net (SE=0.042) and 0.117 fish/net (SE=0.029) for Reach 6 (Figure 19). Overall trammel net CPE was higher in 2002 (0.086, SE=0.018) than in 2003 (0.065, SE=0.010) (Table 9a). However, river-wide distribution trends reflected by trammel net catches (Figure 20) were similar in both years (Johnstone et al. 2003). Trammel net CV for BNT (0.150) was higher than the target CV of 0.10, hoop net CV (0.446) and seining CV (0.446) were much higher than the target value (Tables 9a, 9b, and 9c).

4.7.3 Length Distribution

The majority of BNT captured ranged from 210 to 380 mm (Figure 21). The largest BNT were 653 mm (RM 138.6) and 810 mm (RM 31.6). The smallest BNT were caught in hoop nets; sizes ranged from 60 mm (RM 119.6), 73 mm (RM 108.6), and 80 mm (RM 126.8).

4.7.4 Recapture Rate

Of the 74 BNT captured, three fish were recaptured from previous marking events and 32 new tags were placed in fish (Table 10).

4.8 Rainbow Trout

4.8.1 Relative Abundance and Gear Vulnerability

RBT made up 36.59% of all fish caught and 68.91% of the non-natives captured by trammel and hoop nets. Trammel nets were the most effective gear for capturing adult RBT; 259 fish were captured in trammels and 89 in hoop nets (Tables 8a and 8b). Thirty-five of 43 RBT captured by seining were <100 mm (Table 8c).

4.8.2 Distribution and Catch Rate

RBT were distributed between Reaches 1 and 8, with highest CPE values located in Reaches 2 and 1 (Figure 22). In Reach 2, 40 RBT were caught out of 65 trammel nets. Mean trammel net CPE for adult RBT in Reach 2 was 0.600 fish/net (SE=0.101), and 0.481 fish/net (SE=0.100) for Reach 1 (Figure 21). Trammel net CPE declined steadily downstream (Figure 21). Overall trammel net CPE in 2003 was 0.253 fish/net (SE=0.020) (Table 9a). River-wide distribution trends reflected by trammel net catches (Figure 21) were similar in 2002 and 2003 (Johnstone et al. 2003). Seine CPE was highest in Reaches 4 and 5. Catches in these reaches were 3 fish and 8 fish <150 mm out of 6 and 15 seine hauls respectively (Tables 7 and 8c).

Trammel net CV for RBT (0.079) was below the target CV of 0.10; hoop net CV (0.149) was also very close to the target (Tables 9a and 9b). The CV for seining was (0.249) was much higher than the target value (Table 9c).

4.8.3 Length Distribution

RBT were captured from 30 to 390 mm (Figure 23). The majority of RBT captured were between 190 and 370 mm. The smallest RBT were caught in seine and hoop nets, however RBT of all sizes were captured in hoop nets.

4.9 Carp

4.9.1 Relative Abundance and Gear Vulnerability

CRP made up 4.52% of all fish caught and 8.51% of the non-natives captured by trammel and hoop nets. Trammel nets were the most effective gear for capturing adult CRP; 39 fish were captured in trammels and 4 in hoop nets (Tables 8a and 8b). Twelve CRP were captured by seining (Table 8c).

4.9.2 Distribution and Catch Rate

CRP were distributed between Reaches 1 and 11 with highest CPE values located in Reaches 9 and 11. In Reach 9, 11 CRP were caught out of 90 trammel nets. Mean trammel net CPE for CRP in Reach 9 was 0.122 fish/net (SE=0.035), and 0.125 fish/net (SE=0.064) for Reach 11 (Figure 24). Overall, trammel net CPE was slightly higher in 2002 (0.043, SE=0.008) than in 2003 (0.037, SE=0.006) (Table 9a). However, river-wide distribution trends reflected by trammel net catches (Figure 24) were similar in both years (Johnstone et al. 2003). No fish were caught in hoop nets in 2002; four fish were captured in 2003. Trammel net CV for CRP (0.164) was above the target CV of 0.10, hoop net CV (0.612) and seining CV (0.530) were much higher than the target value (Table 9a, 9b and 9c).

4.9.3 Length Distribution

The majority of CRP captured were 380-620 mm in length (Figure 25). Eleven CRP <190 mm were captured in 2003 compared to seven fish in 2002. Seining captured the smallest CRP.

4.9.4 Recapture Rate

Of the 55 CRP captured 1 fish was recaptured from previous marking events, and 37 new tags were placed in fish (Table 10).

4.10 Fathead Minnow

FHM made up 16.10% of all fish captured by seining and 74.07% of the non-natives captured by seining (Table 8c). Twenty-two FHM were captured in hoop nets. FHM were distributed between Reaches 3 and 11; highest CPE values occurred in Reaches 3, 4, and 8 (Figure 26). In Reach 3, 450 FHM were caught out of 27 seine hauls compared to 23 FHM caught in 2002. CPE was higher in 2003 than 2002; however, river-wide distribution trends were similar between years.

4.11 Plains Killifish

PKF were captured entirely by seining. PKF made up 4.33% of all fish, and 19.92% of the non-natives, captured by seining (Table 8c). CPE was highest in Reaches 3, 4, and 8 (Figure 27). Distribution and abundance was similar in 2003 and 2002; however, CPE values were higher in Reaches 9 and 8 in 2003.

4.12 Other Non-Native Fishes

The following non-native species made up less than 8.00% of the total catch, either due to low abundance or gear biases.

Ten RSH were captured by seining in Reach 6 just above the confluence of Royal Arch Creek (Elves Chasm), 14 were captured in 2002 in Reaches 3, 4, 9, and 10. Seventeen CCF were captured primarily in trammel nets between Reaches 5 and 11 (CPE=0.017, SE=0.005). Twenty-six CCF were captured in 2002 (CPE=0.032, SE=0.008). Highest CPE for CCF in 2003 was in Reach 9 (Table 9a). CCF lengths ranged between 91 and 399 mm. One striped bass (STB), (800 mm) was captured in a trammel net in Reach 9. Stomach contents were examined and the stomach was empty, no STB were captured in 2002. One yellow bullhead (YBH), (202 mm) was captured in a hoop net in Reach 3 (Table 8b).

4.13 Backwater Seining Summary

The majority of seining in 2003 took place during the September seining trip. A total of 316 seine hauls were collected in 2003; 85 were collected in June, and 231 seine hauls were collected in September. Sixteen hauls were tributary inflow samples, the remainder were backwaters and alcoves (Table 6). These hauls produced 3,933 total fish. Backwaters that were 15°C or higher produced a greater average number of fish than those less than 15°C (Figure 28). Relative abundance of fishes captured was approximately 38% SPD, 28% FMS, 19.5% FHM, 5% PKF, 4.5% BHS, 3% HBC, 1% RBT, and less than 1% for BNT, CCF, CRP, and RSH combined (Table 8c). Species composition by river mile is shown in Figure 29. The majority of BHS, FMS, HBC, FHM, and PKF were caught near the confluence of the LCR (Table 8c). The majority of SPD, however, were caught below RM 60 (Table 8c). HBC were captured between RM 38.6 and 216.2 (Table 8c). Twenty-one HBC were captured in backwaters between RM 38.6 and 50.4 and ranged in size from 18 to 49 mm.

The majority of fish captured were less than 100 mm in total length for all species with the exception of BNT (Figure 21). Humpback chub ranged in size from 18–221 mm with only five individuals greater than 150 mm.

4.14 Mapping Results

4.14.1 Shoreline Vegetation Mapping

In addition to seine samples, inundated vegetation was sampled with a dip net (see Appendix A). Most vegetation was not inundated due to low water levels (5,213–10,256 cfs). Seven total dip net samples were taken with a total catch of one FMS and four SPD. At higher flows, (>12,000 cfs), a much larger amount of vegetation may become available as cover for fish. These areas were mapped as potential high water habitat for small fish, on digital aerial imagery (1:3,000) and then entered into GIS coverage (Appendix A). The amount of shoreline vegetation, as measured in meters, that could serve as potential cover for fish at higher water was summarized in Appendix A, Table 2).

4.14.2 Trammel Net Mapping

All potential trammel netting sites within HBC aggregations were recorded on digital aerial imagery (1:3000). All points were entered into GIS coverage (see Appendix A).

5.0 TREND MONITORING

Trammel net CV values for most fishes were lower in 2003 (Table 9a) than in 2002. The decrease in CV can be explained by increased sample numbers and a more even allocation of samples between random sampling and aggregation sites (i.e., 55% of trammels and 56% of hoop nets were fished at or near aggregation sites). This refinement in sampling strategy resulted in an increase in mean CPE values and a decrease in standard deviation for 2003.

The ability to detect trends over a 5-year period based on current CV values is reported in Table 13. Using the program Trends (Gerrodette 1987), the power to detect a change in relative abundance was calculated based on 2003 CV values for each species. Simulations were run based on linear change in relative abundance, for time steps of one year over five years. For example the CV for FMS was 0.11. Given this CV, there is a 95% chance of detecting a 22% change in relative abundance per one year time step (over 5 years) and an 87% overall decline (over 5 years and based on a linear relationship) (Table 13). Power to detect change decreases as CV increases, see Table 13. HBC CV for 2003 was 0.18, that allows a 95% chance of detecting a 53% decline per one year time step and a 213% overall decline over 5 years. At an aggregation level CV values for HBC are higher than overall values (Table 11) and power to detect trends is decreased further. At the LCR Inflow Aggregation trammel net CV for HBC is 0.33. Given this CV, there is a 95% chance of detecting a 76% change in relative abundance per one year time step (over 5 years). However using a one-tailed significance test for negative change, there is a . 95% chance of detecting a 22% decline in relative abundance per one year time step (over 5 years). This is because the CV decreases with a smaller CPE mean.

6.0 DISCUSSION

This monitoring program represents the first distributional survey done with trammel nets and hoop nets since the early 1990s (Valdez and Ryel 1995). For the last decade sampling, particularly with hoop nets, has concentrated on known aggregations of HBC. It had been hypothesized that sampling programs that only targeted known aggregations of humpback chub or other native fishes might not detect changes in distribution of these fishes and might not detect early changes in abundance. This is because catch rates in these areas would remain stable even if the abundance declined or increased in unsampled areas (Carl Walters, pers. comm.). This year's stratified-random sampling design represents the second year of spatial and temporal distributional data for all native and non-native fish species. These data provide important baseline information from which to gauge changes as the result of future management actions (e.g., mechanical removal of salmonids, temperature control device, and experimental flows).

Year two of distributional sampling indicates that the majority of adult HBC captured in the mainstem have not expanded into areas outside of known aggregations. Some fish were captured outside the aggregation RM definitions used by Valdez and Ryel (1995), but most were within 2 miles upstream or downstream. Our distributional data do not vary substantially from those of Valdez and Ryel (1995) and expansion or contraction of HBC distribution in Grand Canyon cannot be asserted at this time. Young and juvenile HBC were found in most reaches sampled (Figure 14). It is not uncommon for young HBC to be captured in downstream reaches following flooding episodes in the LCR (Johnstone et al. 2003, Valdez and Ryel 1995). However, the number of young fish captured in May and June 2003 indicate successful over-wintering of these small fish, possibly because of increased habitat quality in the mainstem. Some factors that could increase available mainstem habitat include: a documented increase in downstream water temperatures due to low water levels in Lake Powell (Hueftle 2003), ongoing mechanical removal of non-native salmonids in the LCR inflow region (Coggins 2003) and spawning BNT removal in Bright Angel Creek (NPS unpublished data). Along with trammel and hoop netting data, the 2003 intensive seining effort will provide a current baseline of information for fish abundance, distribution, length-distribution and habitat area, from which to gauge potential changes in mainstem fish recruitment and habitat availability.

Previous studies (Valdez and Ryel 1995) show that it is difficult to make inferences regarding age, based on total length of HBC in the mainstem Colorado River. Differential growth rates of fishes residing in the warm LCR (>20.0^{o}C) and in the colder mainstem (<10.0^{o}C), and mixing of individuals in both systems, leads to fish of similar age having different lengths (Valdez and Ryel, 1995). It is generally accepted, however, that adult HBC are greater than 200 mm. Young HBC (<120 mm) are either fish that have been displaced from the LCR or are evidence of recruitment from other areas. Juvenile fish (120–199 mm) may represent survival of a young fish that were displaced previously and are residing in the mainstem or have recently been displaced from the LCR. It is also noted that HBC ranging from 18 to 49 mm TL were captured in backwaters between RM 38.6 and 50.4, which is well upstream of the LCR confluence (RM 61.3), and indicates that successful reproduction continues to occur in the mainstem, possibly in warm springs near RM 30 (Valdez and Masslich 1999).

The mean size of HBC was substantially lower at aggregations downstream of the LCR (Figure 18). This suggests either inhibited growth due to lower mainstem temperatures or is evidence of mainstem reproduction and recruitment, or a combination of both. Regardless, the question remains: how important are the mainstem aggregations to the overall population? A total of 121 fish >150 mm were captured in the mainstem during 2003. Less then 25.0% of fish recaptured in aggregations downstream of the LCR were previously marked. This could indicate recruitment to these aggregations, a low mark-rate in the aggregations due to lack of sampling in previous years (1993–2000), or problems with gear saturation. It is unlikely however, that gear saturation occurred during 2003 sampling. The highest catch of HBC at one time in any trammel net was seven fish at RM 60.7, the average number of HBC/trammel net was 1.49 (SE=0.16).

The following assumptions were made regarding HBC CPE: trammel net catches accurately represent HBC relative abundance and all potential HBC habitat (between RM 0–225) was included in sample allocation. The combination of trammel nets and hoop nets allowed us to sample many sites that were unsuitable for either gear type used singly.

The overall CV in HBC trammel net catch rates in 2003 was 0.176 compared to 0.222 in 2002. Stratified-random HBC CV values were lower than aggregation CV values. This is due to the high number of zero catches (142 HBC/2,259 hoop and trammel net sets) in the stratified-random samples.

CV values for BHS (CV=0.193) were greater than the target of 0.10. As discussed previously, BHS are difficult to sample effectively due to habitat preferences (riffles), that are difficult to sample with trammel nets. However, we are able to track relative abundance in each reach (Figure 8), as well as distribution and abundance of young BHS (Figure 8 and Figure 29). FMS CV (0.112) was very close to the target of 0.10, which will allow for population trend monitoring in addition to providing distribution and abundance information. Our gear was effective at capturing adult and juvenile FMS and they were fairly well distributed throughout the system (Figure 11).

Trammel net CV values for BNT (CV=0.150) were above the target. Due to gear biases BNT monitoring is better addressed by electrofishing and is therefore the responsibility of the non-native salmonid monitoring program (i.e., AGFD). The low CV value for RBT of 0.079 can be explained by the nearly ubiquitous distribution and gear vulnerability of this species. CRP were more distributed in patches, and the CV of 0.164 yields a low power for trend prediction.

The distribution of species along the Colorado River captured by seining during this study was generally similar to that observed by Johnstone et al. (2003), Trammell et al. (2003), Valdez and Ryel (1995), and AGFD (1996; unpublished data). Outside the LCR inflow reach, catch and CPE of both native and non-native warm-water species increased downstream, while catch of salmonids decreased downstream from Lees Ferry. FHM abundance was much higher in Reaches 3 and 4 in 2003 (550 fish) than in 2002 (44 fish), but comparatively lower in Reaches 8, 9, and 10 during 2003. Distribution and abundance of PKF in 2003 was similar to 2002.

These data represent the second year in what is expected to be a long-term data set. Thus far we have not seen noticeable changes in distribution or relative abundance of any species. Five years of data are needed to adequately determine trends. However high CV values may limit trend-modeling opportunities. We offer some conclusions and recommendations for improving the methods.

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

The native fish of the Colorado River in Grand Canyon exhibit patchy distribution and are difficult to capture. Additionally there are river characteristics which limit placement of trammel and hoop net sets, specifically a river channel with high velocity, deep water, and whitewater rapids. Despite the efforts to minimize the effect of these sampling variables, especially the increase in sample numbers and allocation during 2003, CV for all fish samples (except RBT) was higher than the targeted level of 0.10. CVs for most species however were close, such as FMS (CV=0.112), BNT (0.150), followed by SPD (0.159), CRP (0.164) and HBC (0.176) (Table 9). CV values for these species may prove to be acceptable for long-term monitoring. Doubling sample size would reduce CV to near target levels. However, there are funding and time constraints to consider. Additionally, data from 2002-2003 provide important presence and absence information, catch-rate comparisons, and distribution of species.

Analysis of results for 2002 and 2003 HBC revealed potential problems with the analysis of the current stratified-random design. CV values may provide misleading results for HBC mainstem population trends (due to a high number of zeros). This can be seen in the comparison of overall CV values (Table 9) to aggregation CV values (Table 11). Monitoring results in 2002 and 2003 confirmed high affinity of HBC for certain previously described mainstem sites, as denoted by aggregations. Under current conditions, additional samples outside of these areas will not increase catch rate or reduce variability for HBC, but, would detect changes in distribution.

In order to effectively monitor the mainstem native fish populations it is necessary to use the stratified-random approach as well as HBC aggregation sampling. We suggest separate data analysis for HBC aggregations and stratified-random samples.

In 2003 one stratified-random native fish monitoring trip was conducted in May, an 'aggregation' trip was conducted in June, and a backwater seining trip was conducted in September. This approach worked well and we recommend the same strategy for future monitoring. These conclusions are summarized as follows:

- Target CV values of 0.10 may be unattainable given patchy distribution of fishes and problems with gear vulnerability.

- Doubling sample size could reduce CV to near acceptable levels for FMS, BHS, and HBC in trammel nets if sample variance does not change. Alternatively, target CV could be adjusted.

- Although sample sizes of hoop nets and seines may remain inadequate for trend monitoring, the length frequency distribution and longitudinal distribution of fishes is better represented by including these methods than by trammel nets alone i.e., detect potential recruitment patterns and presence or absence of successful reproduction and possibly recruitment.

- CPE analysis and yearly comparisons may be a valuable tool for determining long-term trends and effects of management actions on native species.

7.2 Recommendations

- Continue long-term monitoring for the planned 5 years to adequately assess the monitoring design.

- Continue to refine methods and sample sizes.
  - Possibly double sample sizes for trammel and hoop nets to reduce CV (which would require additional river days).
  - Continue sampling with hoop nets and seines for longitudinal river distribution and length frequency distribution.
  - Continue use of baited hoop nets to maximize catch rate in mainstem.
  - Vary lengths of trammel nets to maximize fishing opportunities and avoid hyperstability.

- Pursue new technologies that may improve ability to monitor fish.
  - Methods to mark smaller fish.
  - Sonar camera.

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Tables

Table 1. The status and relative abundance of fish species presently occurring in the Colorado River within Grand Canyon from Lees Ferry to Diamond Creek (1990 to present). Adapted from Valdez and Ryel (1995). Status: N=native, NN=non-native, E=endangered. Relative abundance: A=abundant, C=common, LC=locally common, R=rare.

Common name	Abbr.	Scientific Name	Status	Relative Abundance
Bluehead sucker	BHS	*Catostomus discobolus*	N	C
Flannelmouth sucker	FMS	*Catostomus latipinnis*	N	C
Speckled dace	SPD	*Rhinichthys osculus*	N	C
Humpback chub	HBC	*Gila cypha*	N, E	LC
Black bullhead	BBH	*Ictalurus melas*	NN	R
Bluegill sunfish	BGS	*Lepomis macrochirus*	NN	R
Brook trout	BKT	*Salvelinus fontinalis*	NN	R
Brown trout	BNT	*Salmo trutta*	NN	LC
Channel catfish	CCF	*Ictalurus punctatus*	NN	LC
Common carp	CRP	*Cyprinus carpio*	NN	C
Fathead minnow	FHM	*Pimephales promelas*	NN	C
Golden shiner	GSH	*Notemigonus crysoleucas*	NN	R
Green sunfish	GSF	*Lepomis cyanellus*	NN	R
Largemouth bass	LMB	*Micropterus salmoides*	NN	R
Plains Killifish	PKF	*Fundulus zebrinus*	NN	LC
Rainbow trout	RBT	*Oncorhynchus mykiss*	NN	A
Red shiner	RSH	*Cyprinella lutrensis*	NN	LC
Striped bass	STB	*Morone saxatilis*	NN	R
Threadfin shad	TFS	*Dorosoma petenense*	NN	R
Walleye	WAL	*Stizostedion vitreum*	NN	R

Table 2. Mean set times for gears used during the 2003 native fish monitoring field season.

Effort	Hoop	Trammel	Seine
Mean	18.60 Hrs.	1.90 Hrs.	32.40 m^2
Standard Error	0.08 Hrs.	0.01 Hrs.	1.85 m^2
Minimum	12.60 Hrs.	0.70 Hrs.	1.00 m^2
Maximum	25.70 Hrs.	2.80 Hrs.	240.00 m^2

Table 3. Sample.exe output and sample allocation (shaded columns), selected species, for trammel nets and hoop nets. If sample allocation was less than 30 trammel nets or 36 hoop nets, the minimum sample size defaulted to 30 and 36, respectively. Sampling needs for BHS were minimized in Reach 3 in the final sample allocation. Sampling allocation at aggregation sites is included in actual number/year (No./year).

Reach	Start mile	End mile	Trammel Nets					Hoop Nets				
			Number per Year			No./year output	No./year allocated	Number per Year			No./year output	No./year allocated
			BHS	FMS	HBC			BHS	FMS	HBC		
1	0	30	8	4	4	30	60	0	120	19	36	72
2	31	56	47	15	6	47	30	0	431	0	36	36
3	57	69	152	60	38	152	150	569	227	332	332	180
4	70	79	46	6	4	46	60	0	0	0	36	72
5	80	109	26	10	2	30	120	336	43	8	36	144
6	110	129	6	0	1	30	90	39	20	22	36	108
7	130	159	2	0	0	30	90	53	13	0	36	108
8	160	179	20	6	0	30	60	0	0	0	36	72
9	180	199	78	16	1	78	30	0	143	0	36	36
10	200	219	11	4	1	30	60	0	0	0	36	72
11	220	225	11	1	0	30	30	0	0	0	36	36
Total			**407**	**122**	**57**	**533**	**780**	**997**	**997**	**381**	**692**	**936**
Est. N/year CV mean			0.10	0.09	0.07	-	-	0.19	0.32	0.10	-	-

Table 4. Schedule and sample locations for combined SWCA native fish monitoring Trip 1/AGFD sampling trip on the Colorado River, Grand Canyon, May 3–21, 2003.

Day	Date	AGFD Random Start Mile	Sample Area	Number of Samples	
				Trammel	Hoop
0	05/02/2003	Rig	-	-	-
1	05/03/2003	12.3	14.6–16.7	30	36
2	05/04/2003	40.5	39.2–40.7	30	36
3	05/05/2003	56.0	58.1–59.9	30	36
4	05/06/2003	61.0	59.9–61.5	30	36
5	05/07/2003	63.0	62.1–65.4	30	36
6	05/08/2003	69.0	69.4–70.8	30	36
7	05/09/2003	70.4	71.0–72.6	20	36
8	05/10/2003	81.7	83.6–84.1	30	36
9	05/11/2003	87.4	84.8–86.8	30	36
10	05/12/2003	114.0	116.9–117.8	30	36
11	05/13/2003	122.7	118.9–120.5	30	36
12	05/14/2003	134.9	137.7–139.0	30	36
13	05/15/2003	145.3	142.0–143.1	30	36
14	05/16/2003	174.2	171.8–174.1	30	36
15	05/17/2003	176.2	177.8–179.1	30	36
16	05/18/2003	182.5	185.3–187.5	30	36
17	05/19/2003	197.1	195.1–198.6	30	36
18	05/20/2003	218.8	223.6–225.3	20	36
19	05/21/2003	Takeout	225	-	-
Total				**520**	**648**

Table 5. Schedule and sample locations for SWCA native fish monitoring Trip 2 in the Colorado River, Grand Canyon, June 14–July 1, 2003.

Day	Date	Sample area	Number of samples		Miles Traveled
			Trammel	Hoop	
0	06/13/2003	Rig	-	-	-
1	06/14/2003	29.9–31.8	30	36	30
2	06/15/2003	29.9–31.8	30	36	0
3	06/16/2003	75.9–76.6	30	36	43
4	06/17/2003	86.3–87.6	30	36	13
5	06/18/2003	106.1–108.9	30	36	20
6	06/19/2003	106.1–108.9	30	36	0
7	06/20/2003	106.1–108.9	30	36	0
8	06/21/2003	125.7–128.4	30	36	18
9	06/22/2003	125.7–128.4	30	36	0
10	06/23/2003	125.7–128.4	30	36	0
11	06/24/2003	125.7–128.4	29	36	0
12	06/25/2003	156.0–158.8	30	36	30
13	06/26/2003	156.0–158.8	30	36	0
14	06/27/2003	156.0–158.8	19	36	0
15	06/28/2003	166.0–168.0	30	36	10
16	06/29/2003	193.9–195.5	30	36	28
17	06/30/2003	224.0–224.6	20	0	27
18	07/01/2003	Takeout	-	-	-
Total			**488**	**576**	**225**

Table 6. **Seining effort per 10-mile reaches for SWCA native fish monitoring Trip 3 in the Colorado River, Grand Canyon, September 13–29, 2003.**

RM Group/Tributary	# Samples	Total Area Sampled (m^2)	Total Available Habitat Area (m^2)
0.0–9.9	7	222	409
10.0–19.9	5	158	352
20.0–29.9	11	327	790
30.0–39.9	14	371	1,367
40.0–49.9	12	514	1,975
50.0–59.9	14	884	4,836
60.0–69.9	16	583	2,747
70.0–79.9	6	247	1,835
80.0–89.9	1	90	144
90.0–99.9	7	194	3,218
100.0–109.9	2	19	29
110.0–119.9	13	254	1,036
120.0–129.9	9	234	1,078
130.0–139.9	4	101	127
140.0–149.9	3	48	55
150.0–159.9	0	0	0
160.0–169.9	22	359	721
170.0–179.9	10	159	1,323
180.0–189.9	14	429	1,724
190.0–199.9	17	425	2,442
200.0–209.9	12	375	1,658
210.0–219.9	12	412	858
220.0–225.7	4	119	583
Paria River	2	60	NA
Shinumo Creek	5	128	NA
Royal Arch Creek	1	19	NA
Deer Creek	4	115	NA
Kanab Creek	4	200	NA
Totals	**231**	**6,526**	**29,305**

Table 7. Actual number of samples collected during the 2003 native fish monitoring field season.

Reach	RM Group	# Trammel Samples				# Hoop Samples				# Seine Samples			
		Trip 1	Trip 2	Trip 3	Total	Trip 1	Trip 2	Trip 3	Total	Trip 1	Trip 2	Trip 3	Total
1	0–30.9	28	24	0	52	36	57	0	93	0	15	28	43
2	31.0–56.9	30	35	0	65	36	15	0	51	0	12	35	47
3	57.0–69.9	109	0	0	109	120	0	0	120	0	9	18	27
4	70.0–79.9	41	30	0	71	60	36	0	96	0	0	6	6
5	80.0–109.9	60	120	0	180	72	156	0	228	0	0	15	15
6	110.0–129.9	60	119	0	179	72	144	0	216	0	9	23	32
7	130.0–159.9	60	79	0	139	72	116	0	188	0	10	15	25
8	160.0–179.9	60	30	0	90	72	36	0	108	0	13	32	45
9	180.0–199.9	60	30	0	90	72	36	0	108	0	7	31	38
10	200.0–219.9	0	0	0	0	0	0	0	0	0	9	24	33
11	220.0–225.7	20	20	0	40	36	0	0	36	0	1	4	5
ALL	**0–225.7**	**528**	**487**	**0**	**1,015**	**648**	**596**	**0**	**1,244**	**0**	**85**	**231**	**316**

Table 8a. Number of fish captured with trammel nets during the 2003 native fish monitoring field season.

Reach	RM Group	BHS	FMS	HBC	BNT	CCF	CRP	RBT	STB
1	0–30.9	0	5	2	0	0	0	25	0
2	31.0–56.9	0	2	1	1	0	0	40	0
3	57.0–69.9	4	26	30	0	0	1	35	0
4	70.0–79.9	4	7	1	0	0	0	28	0
5	80.0–109.9	3	12	12	36	1	4	56	0
6	110.0–129.9	8	17	17	21	0	6	42	0
7	130.0–159.9	14	50	4	6	2	8	30	0
8	160.0–179.9	0	31	0	3	0	4	2	0
9	180.0–199.9	2	2	2	0	10	11	1	1
10	200.0–219.9	0	0	0	0	0	0	0	0
11	220.0–225.7	0	2	0	0	4	5	0	0
ALL	**0–225.7**	**35**	**154**	**69**	**67**	**17**	**39**	**259**	**1**

BHS=bluehead sucker; FMS=flannelmouth sucker; HBC=humpback chub; BNT=brown trout; CCF=channel catfish; CRP=common carp; RBT=rainbow trout; STB=striped bass

Table 8b. Number of fish captured with hoop nets during the 2003 native fish monitoring field season.

Reach	RM Group	BHS	FMS	HBC	SPD	BNT	CRP	FHM	GSF	RBT	YBH
1	0–30.9	0	0	0	0	0	0	0	0	19	0
2	31.0–56.9	0	0	1	0	0	0	0	0	2	0
3	57.0–69.9	0	0	35	1	0	0	10	1	5	1
4	70.0–79.9	0	0	7	2	0	0	1	0	4	0
5	80.0–109.9	0	3	11	6	2	0	0	0	11	0
6	110.0–129.9	0	6	16	1	3	0	1	0	28	0
7	130.0–159.9	1	15	2	5	0	1	0	0	17	0
8	160.0–179.9	0	10	0	2	0	0	0	0	1	0
9	180.0–199.9	5	18	1	31	0	3	8	0	2	0
10	200.0–219.9	0	0	0	0	0	0	0	0	0	0
11	220.0–225.7	0	2	0	7	0	0	2	0	0	0
ALL	**0–225.7**	**6**	**54**	**73**	**55**	**5**	**4**	**22**	**1**	**89**	**1**

BHS=bluehead sucker; FMS=flannelmouth sucker; HBC=humpback chub; SPD=speckled dace; BNT=brown trout; CRP=common carp; FHM=fathead minnow; GSF=green sunfish; RBT=rainbow trout; YBH=yellow bullhead

Table 8c. Number of fish captured with seine nets during the 2003 native fish monitoring field season.

Reach	RM Group	BHS	FMS	HBC	SPD	SUC	BNT	CRP	CCF	FHM	PKF	RBT	RSH
1	0–30.9	1	71	0	97	0	0	1	0	0	0	8	0
2	31.0–56.9	0	499	21	4	0	0	0	0	0	0	8	0
3	57.0–69.9	45	78	68	2	258	0	2	0	450	106	2	0
4	70.0–79.9	41	128	11	3	1	0	2	0	100	30	3	0
5	80.0–109.9	0	4	5	195	0	1	0	0	2	3	8	0
6	110.0–129.9	7	89	8	30	0	1	0	1	20	17	5	10
7	130.0–159.9	6	84	1	26	2	0	2	0	16	4	8	0
8	160.0–179.9	13	189	2	484	201	0	3	0	167	52	1	0
9	180.0–199.9	29	78	3	430	81	0	0	0	46	12	0	0
10	200.0–219.9	40	148	6	393	106	0	2	0	37	0	0	0
11	220.0–225.7	0	9	0	82	6	0	0	0	2	2	0	0
ALL	**0–225.7**	**182**	**1,377**	**125**	**1,746**	**655**	**2**	**12**	**1**	**840**	**226**	**43**	**10**

BHS=bluehead sucker; FMS=flannelmouth sucker; HBC=humpback chub; SPD=speckled dace; SUC=unidentified sucker; BNT=brown trout; CRP=common carp; CCF=channel catfish; FHM=fathead minnow; PKF=plains killifish; RBT=rainbow trout; RSH=red shiner

Table 9a. Variances for all species captured in trammel nets during the 2003 native fish monitoring field season.

	BHS	FMS	HBC	BNT	CCF	CRP	RBT	STB
# Of Samples	1015	1015	1015	1015	1015	1015	1015	1015
# Of Fish	35	154	69	67	17	39	259	1
Mean CPE (Fish/net)	0.034	0.152	0.066	0.065	0.017	0.037	0.253	0.001
Variance	0.045	0.291	0.137	0.096	0.026	0.038	0.404	0.001
Standard Error	0.007	0.017	0.012	0.010	0.005	0.006	0.020	0.001
Variance/Mean CPE	1.310	1.915	2.070	1.482	1.573	1.016	1.597	1.000
CV (SE/Mean CPE)	0.193	0.112	0.176	0.150	0.304	0.164	0.079	1.000

BHS=bluehead sucker; FMS=flannelmouth sucker; HBC=humpback chub; BNT=brown trout; CCF=channel catfish; CRP=common carp; RBT=rainbow trout; STB=striped bass

Table 9b. Variance for all species captured in hoop nets during the 2003 native fish monitoring field season.

	BHS	FMS	HBC	SPD	BNT	CRP	FHM	GSF	RBT	YBH
# Of Samples	1244	1244	1244	1244	1244	1244	1244	1244	1244	1244
# Of Fish	6	54	73	55	5	4	22	1	89	1
Mean CPE (Fish/net)	0.005	0.043	0.059	0.043	0.004	0.003	0.018	0.001	0.072	0.001
Variance	0.010	0.136	0.136	0.059	0.004	0.005	0.030	0.001	0.140	0.001
Standard Error	0.003	0.010	0.010	0.007	0.002	0.002	0.005	0.001	0.011	0.001
Variance/Mean CPE	1.997	3.144	2.313	1.365	0.997	1.498	1.711	1.000	1.964	1.000
CV (SE/Mean CPE)	0.577	0.241	0.178	0.159	0.446	0.612	0.279	1.000	0.149	1.000

BHS=bluehead sucker; FMS=flannelmouth sucker; HBC=humpback chub; SPD=speckled dace; BNT=brown trout; CRP=common carp; FHM=fathead minnow; GSF=green sunfish; RBT=rainbow trout; YBH=yellow bullhead

Table 9c. Variance for all species captured in seines during the 2003 native fish monitoring field season.

	BHS	FMS	HBC	SPD	BNT	CCF	CRP	FHM	PKF	RBT	RSH
# Of Samples	308	308	308	308	308	308	308	308	308	308	308
# Of Fish	182	1377	125	1746	2	12	1	840	226	43	10
Mean CPE (Fish/m^2)	0.023	0.141	0.017	0.317	0.0003	0.0001	0.003	0.154	0.048	0.006	0.002
Variance	0.008	0.181	0.006	0.918	0.0000	0.0000	0.001	0.756	0.145	0.001	0.000
Standard Error	0.005	0.024	0.004	0.055	0.0002	0.0001	0.001	0.050	0.022	0.002	0.001
Variance/Mean CPE	0.370	1.278	0.361	2.894	0.056	0.033	0.236	4.899	3.034	0.121	0.133
CV (SE/Mean CPE)	0.229	0.171	0.265	0.172	0.738	1.000	0.530	0.321	0.455	0.249	0.466

BHS=bluehead sucker; FMS=flannelmouth sucker; HBC=humpback chub; SPD=speckled dace; SUC=unidentified sucker; BNT=brown trout; CRP=common carp; CCF=channel catfish; FHM=fathead minnow; PKF=plains killifish; RBT=rainbow trout; RSH=red shiner

Table 10. PIT tag recapture and tagging information for the 2003 native fish monitoring field season.

Species	Data	Total
BHS	Count of RECAPTURES	0
	Count of NEW PIT TAGS	35
BNT	Count of RECAPTURES	3
	Count of NEW PIT TAGS	32
CRP	Count of RECAPTURES	1
	Count of NEW PIT TAGS	37
FMS	Count of RECAPTURES	34
	Count of NEW PIT TAGS	151
HBC	Count of RECAPTURES	64
	Count of NEW PIT TAGS	55
Total Count of RECAPTURES		102
Total Count of NEW PIT TAGS		310

BHS=bluehead sucker; BNT=brown trout; CRP=common carp; FMS=flannelmouth sucker; HBC=humpback chub

Table 11. Variance for humpback chub captured within aggregations, captured with trammel and hoop nets during the 2003 native fish monitoring field season.

	30-mile	LCR Inflow	Lava Chuar-Hance	Bright Angel Ck Inflow	Shinumo Ck Inflow	Stephen Aisle	Middle Granite Gorge	Havasu Ck Inflow	Pumpkin Spring
Trammel Net									
# Of Samples	32	100	62	69	48	57	104	24	0
# Of Fish	3	28	1	0	12	2	15	0	0
Mean CPE	0.094	0.280	0.016	0	0.250	0.035	0.144	0	N/A
Standard Error	0.052	0.093	0.016	0	0.076	0.025	0.042	0	N/A
CV (SE/Mean CPE)	0.558	0.333	1	-	0.30	0.700	0.290	-	N/A
Hoop Net									
# Of Samples	66	108	99	87	78	63	126	30	N/A
# Of Fish	0	35	5	3	7	2	14	0	0
Mean CPE	0.00	0.324	0.051	0.034	0.090	0.032	0.110	0	N/A
Standard Error	0.00	0.101	0.026	0.02	0.033	0.032	0.030	0	N/A
CV (SE/Mean CPE)	0.00	0.311	0.522	0.570	0.363	1.00	0.272	-	N/A

Table 12. Number of taggable (>150 mm) HBC captured at aggregation sites and percent of previously tagged fish (recaptures) captured during the 2003 native fish monitoring field season.

Location	# HBC > 150 mm	# Of recaps	% Recaps
30-MILE	3	2	66.67
RM 39.9	1	0	0.00
LCR INFLOW	58	44	75.86
RM 65.7-76.3	4	0	0.00
BAC INFLOW	4	0	0.00
SHINUMO CREEK INFLOW	15	1	6.67
STEPHEN AISLE	5	0	0.00
MGG	24	4	16.67
RM 138.6	1	0	0.00
RM 194.3	2	0	0.00
HAVASU CREEK INFLOW	0	0	0.00
RM 157.1-157.4	4	1	25.00

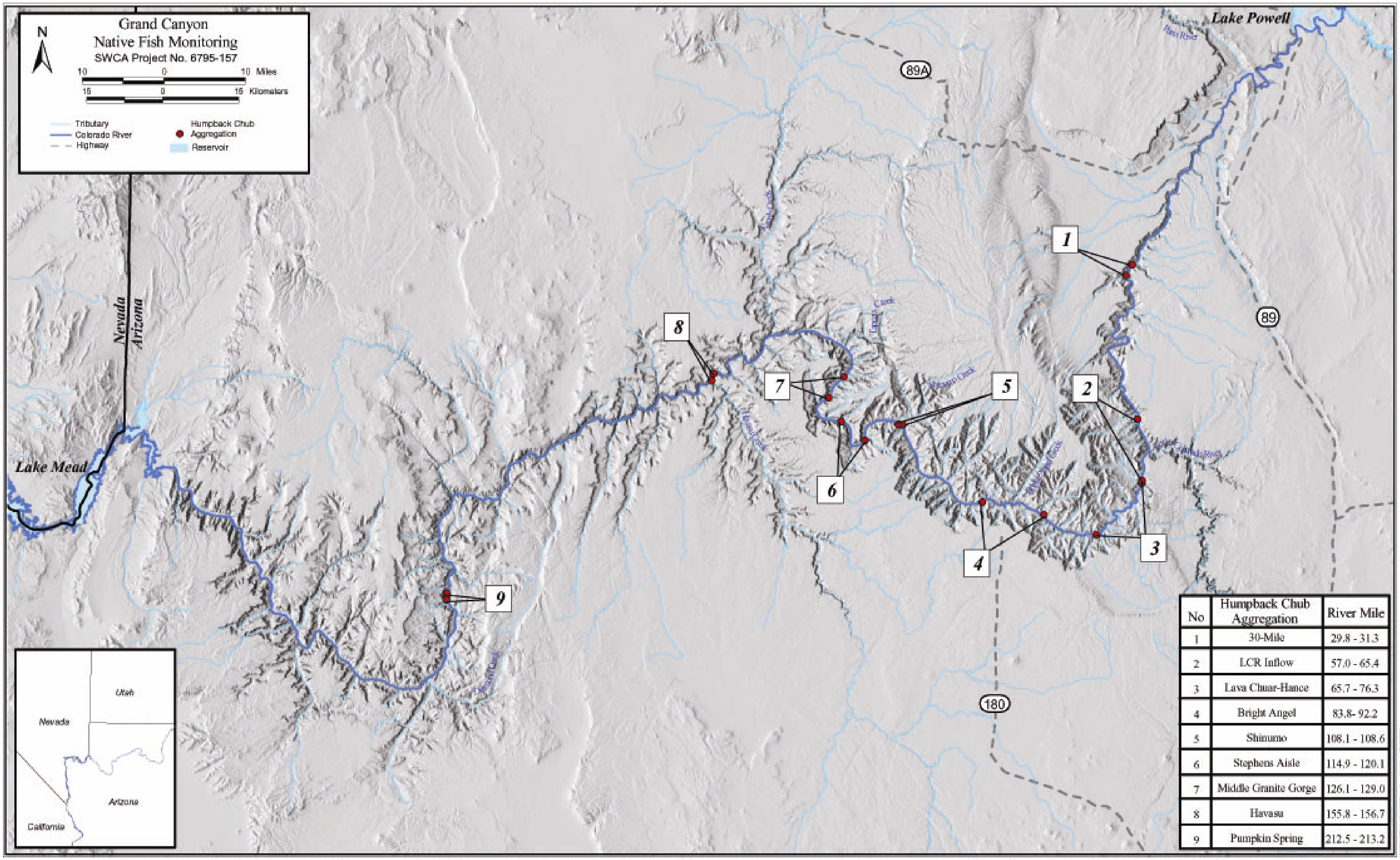
Aggregations and RM sampled, 30-mile (RM 29.8–31.3), LCR (RM 57–65.4), Lava Chuar to Hance (RM 65.7–76.3), Bright Angel Creek Inflow (BAC) (RM 83.8–92.2), Shinumo Creek Inflow (RM 108.1–108.6), Stephen Aisle (RM 114.9–120.1), Middle Granite Gorge (MGG)(RM 126.1–129), Havasu (RM 155.8–156.7).

Table 13. Estimates of detectable rate of change using the coefficient of variation (CV) calculated from 2003 sampling CPE for trammel nets. Estimates were calculated using the program *TRENDS* (Gerrodette 1987). Assumptions in *TRENDS* input include: significance value (α) = 0.05, (β) = 0.20, power = 80% (1-β), change is linear, CV remains constant with abundance, and duration of study = 5 years. Species are in order of CV (lowest to highest). Minimum detectable rate of change, indicates rate of change per one year time step. Minimum detectable overall change indicates change over 5-year study. Both 2-tailed and 1-tailed tests were run for comparison. The 2-tailed test can detect positive or negative changes; the 1-tailed test for negative rate of change is more sensitive.

Trends Input		2-Tailed Significance Test		1-Tailed Significance Test, Negative Rate of Change	
Species	CV known	Minimum Detectable Rate of Change	Minimum Detectable Overall Change for Duration of Study	Minimum Detectable Rate of Change	Minimum Detectable Overall Change for Duration of Study
RBT	0.08	14%	56%	-7%	-29%
FMS	0.11	22%	87%	-9%	-38%
BNT	0.15	36%	146%	-12%	-49%
CRP	0.16	41%	165%	-13%	-51%
HBC	0.18	53%	213%	-14%	-56%
BHS	0.19	61%	243%	-15%	-58%

RBT=rainbow trout; FMS=flannelmouth sucker; BNT=brown trout; CRP=common carp; HBC=humpback chub; BHS=bluehead sucker

Figures



No	Humpback Chub Aggregation	River Mile
1	30-Mile	29.8 - 31.3
2	LCR Inflow	57.0 - 65.4
3	Lava Chuar-Hance	65.7 - 76.3
4	Bright Angel	83.8- 92.2
5	Shinumo	108.1 - 108.6
6	Stephens Aisle	114.9 - 120.1
7	Middle Granite Gorge	126.1 - 129.0
8	Havasu	155.8 - 156.7
9	Pumpkin Spring	212.5 - 213.2

Figure 1. Map of the Colorado River as it flows through the Grand Canyon. River miles are based on the Stevens river guide (1983). The long-term native fish monitoring program utilizes river-wide stratified-random sampling, and targeted sampling at known humpback chub aggregations (30-mile, LCR inflow, Lava Chuar to Hance, Bright Angel, Shinumo, Stephen Aisle, Middle Granite Gorge, Havasu, and Pumpkin Spring). These aggregations were identified and monitored by Valdez and Ryel (1995) to document the life history and ecology of humpback chub in the early 1990s.

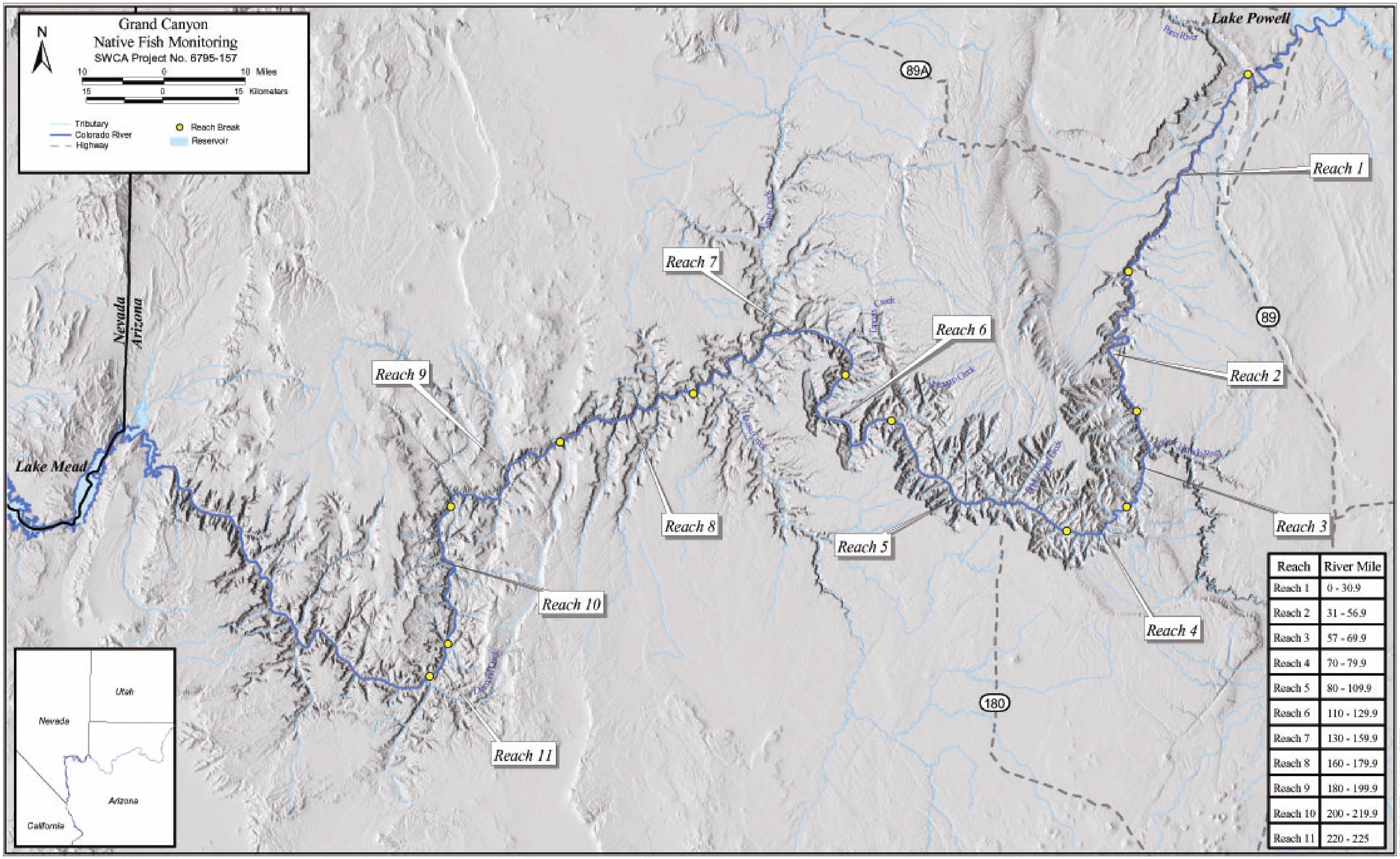


Figure 2. Map of the Colorado River as it flows through the Grand Canyon. River miles (RM) are based on the Stevens river guide (1983). The long-term native fish monitoring study area begins at Lees Ferry (RM 0) and ends just above the confluence of Diamond Creek (RM 226). Stratified-random samples were allocated among 11 geographic reaches. Reaches were designated and defined by Carl Waters (unpublished) based on historic catch data.

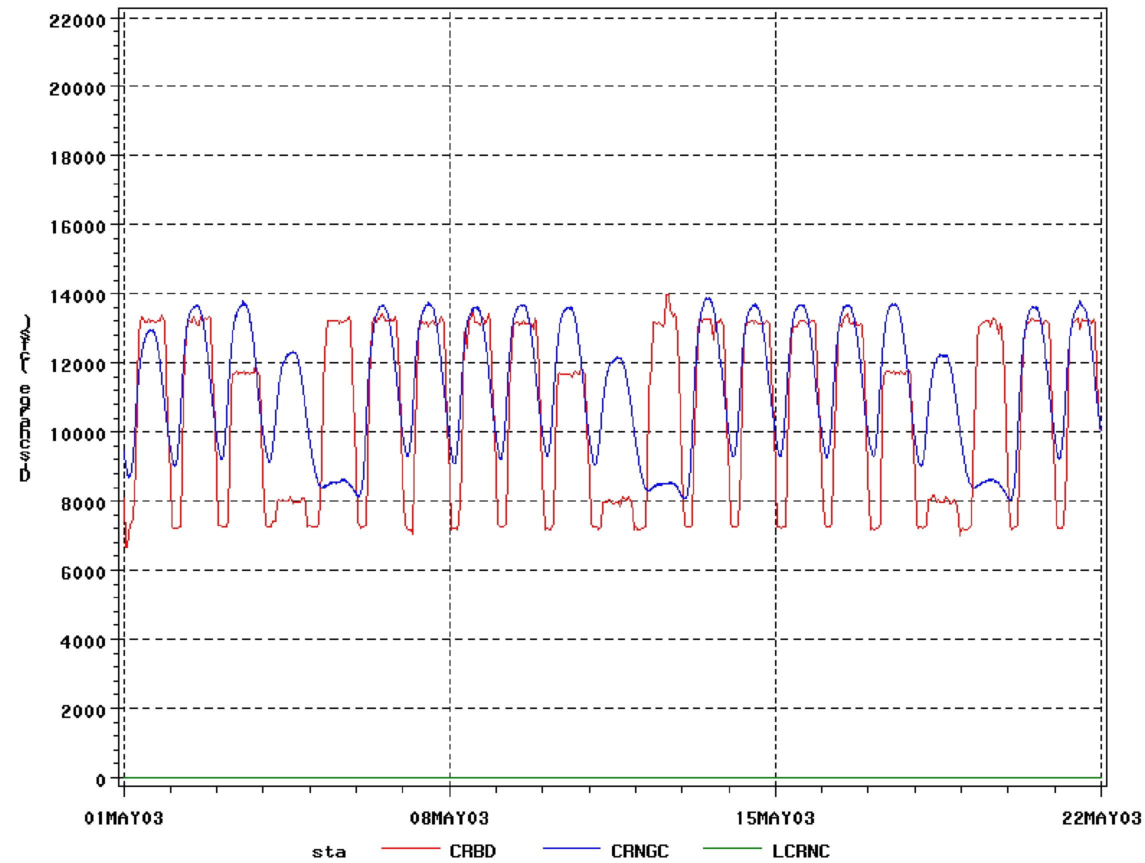


Figure 3. Hydrograph for the Colorado River during the time of native fish monitoring Trip 1 (May 3-21, 2003). Dam releases: (Colorado River below dam (CRBD)) fluctuated between ~6,690 and 13,961 CFS. The Little Colorado River near Cameron (LCRNC) gauge recorded base flows. The gauge near Phantom Ranch, Colorado River near Grand Canyon (CRNGC), recorded flows between ~8,000 and 13,000 CFS.

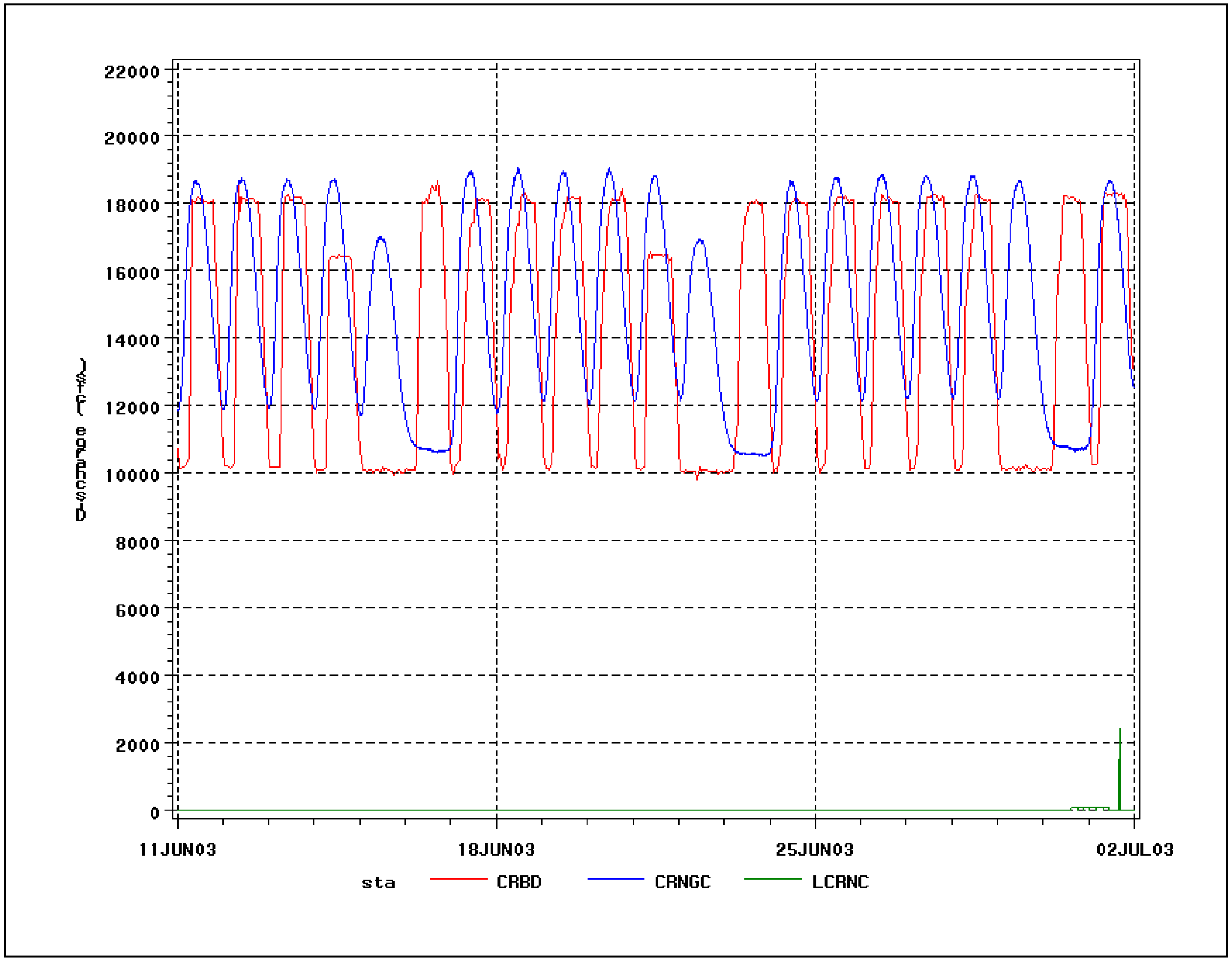


Figure 4. Hydrograph for the Colorado River during the time of native fish monitoring Trip 2 (June 14, 2003–July 1, 2003). Dam releases (Colorado River below dam (CRBD)) fluctuated between ~9,810 and 18,672 CFS. The Little Colorado River near Cameron (LCRNC) gauge recorded base flows with one brief flooding event (under 2,000 CFS). The gauge near Phantom Ranch, Colorado River near Grand Canyon (CRNGC), recorded flows between ~11,000 and 18,800 CFS.

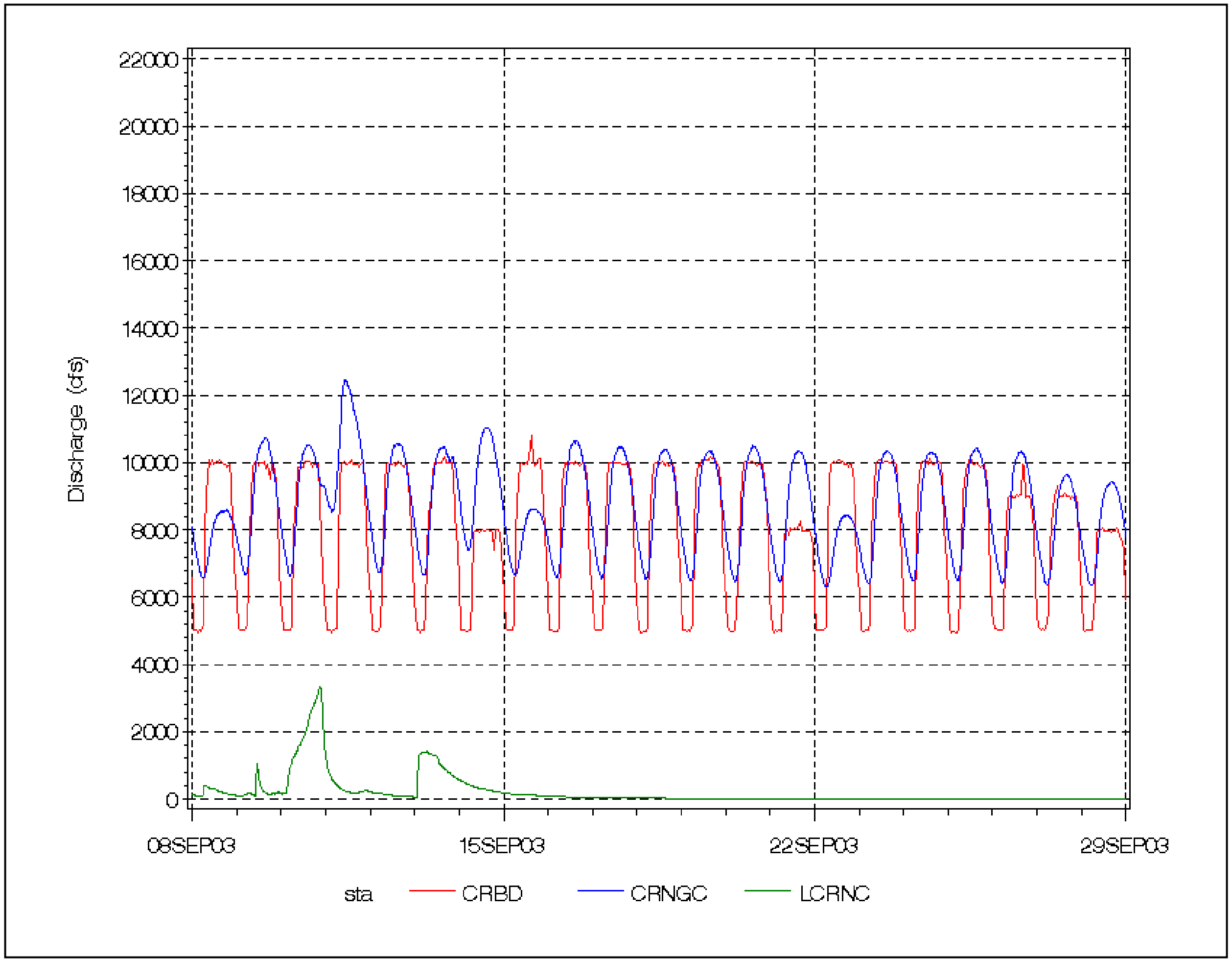


Figure 5. Hydrograph for the Colorado River during the time of native fish monitoring Trip 3 (September 13–29, 2003). Dam releases (Colorado River below dam (CRBD)) fluctuated between ~5,187 and 10,418 CFS. The Little Colorado River near Cameron (LCRNC) gauge recorded two flooding events and then returned to base flows. The gauge near Phantom Ranch, Colorado River near Grand Canyon (CRNGC), recorded flows between ~7,000 and 12,500 CFS.

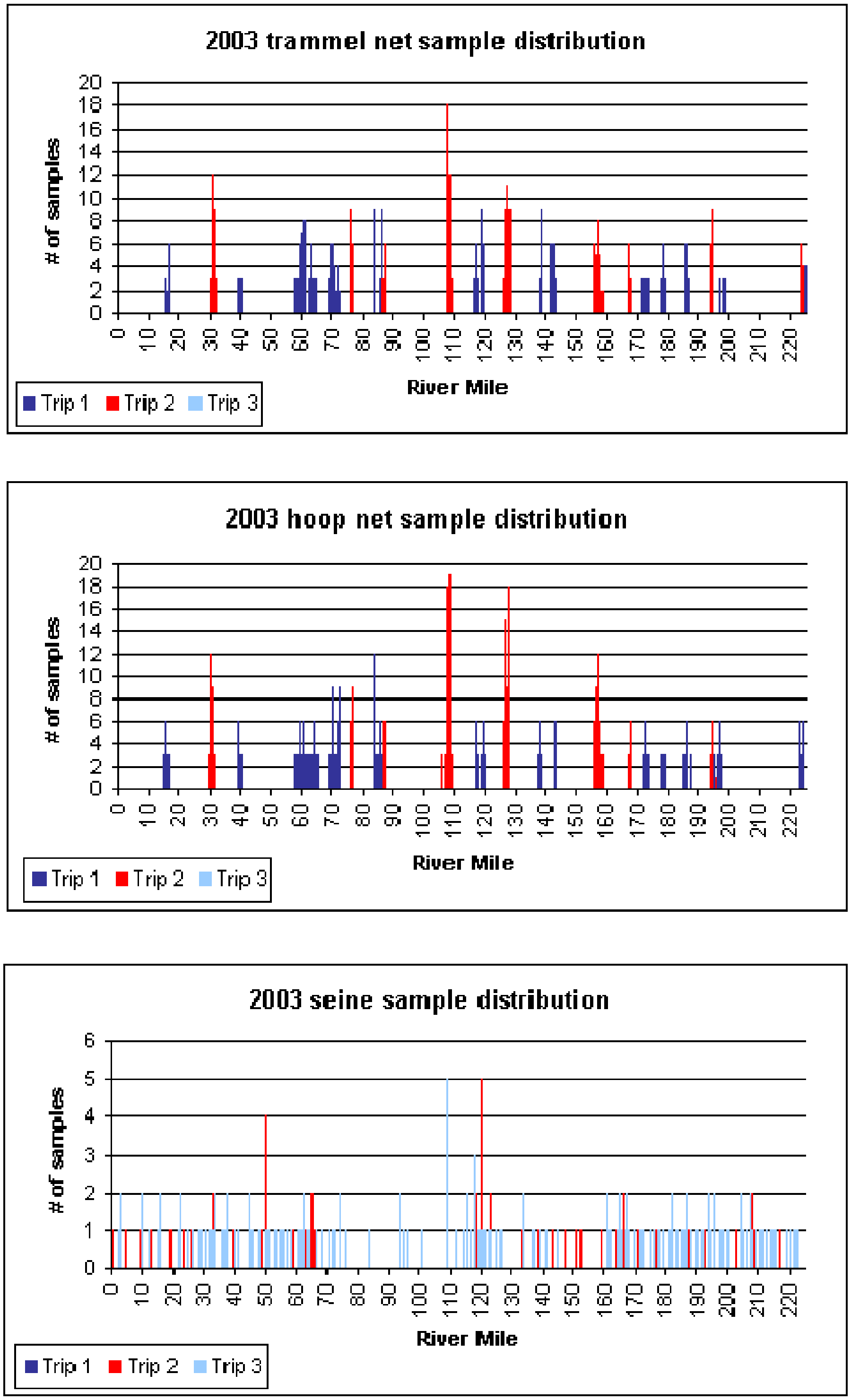
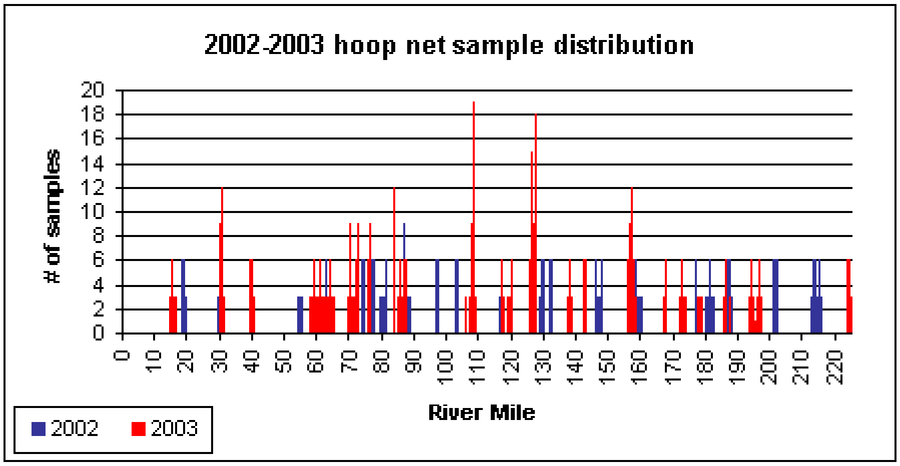
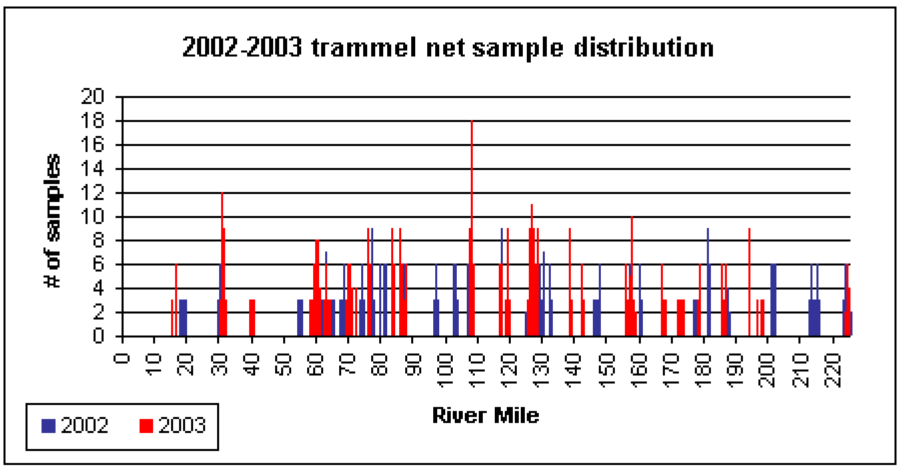


Figure 6. Locations of sample sites for trammel nets, hoop nets, and seines during the native fish monitoring field season 2003.





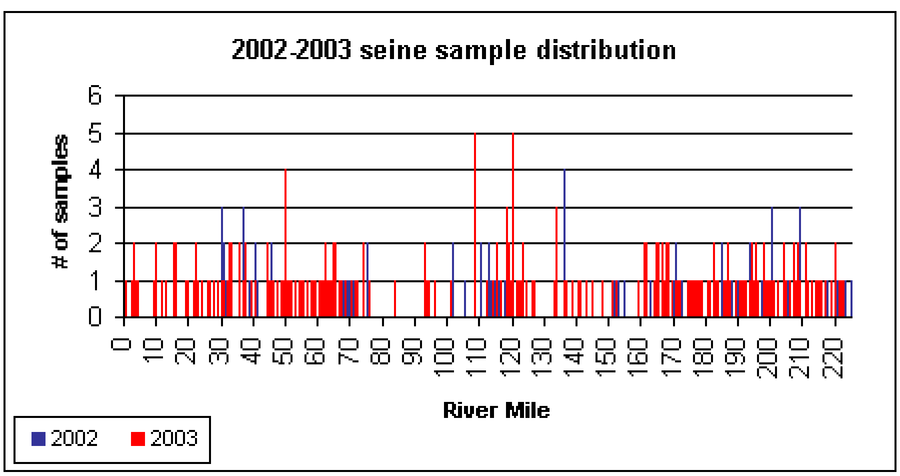


Figure 7. Locations of sample sites for trammel nets, hoop nets, and seines during native fish monitoring field seasons 2002 and 2003.

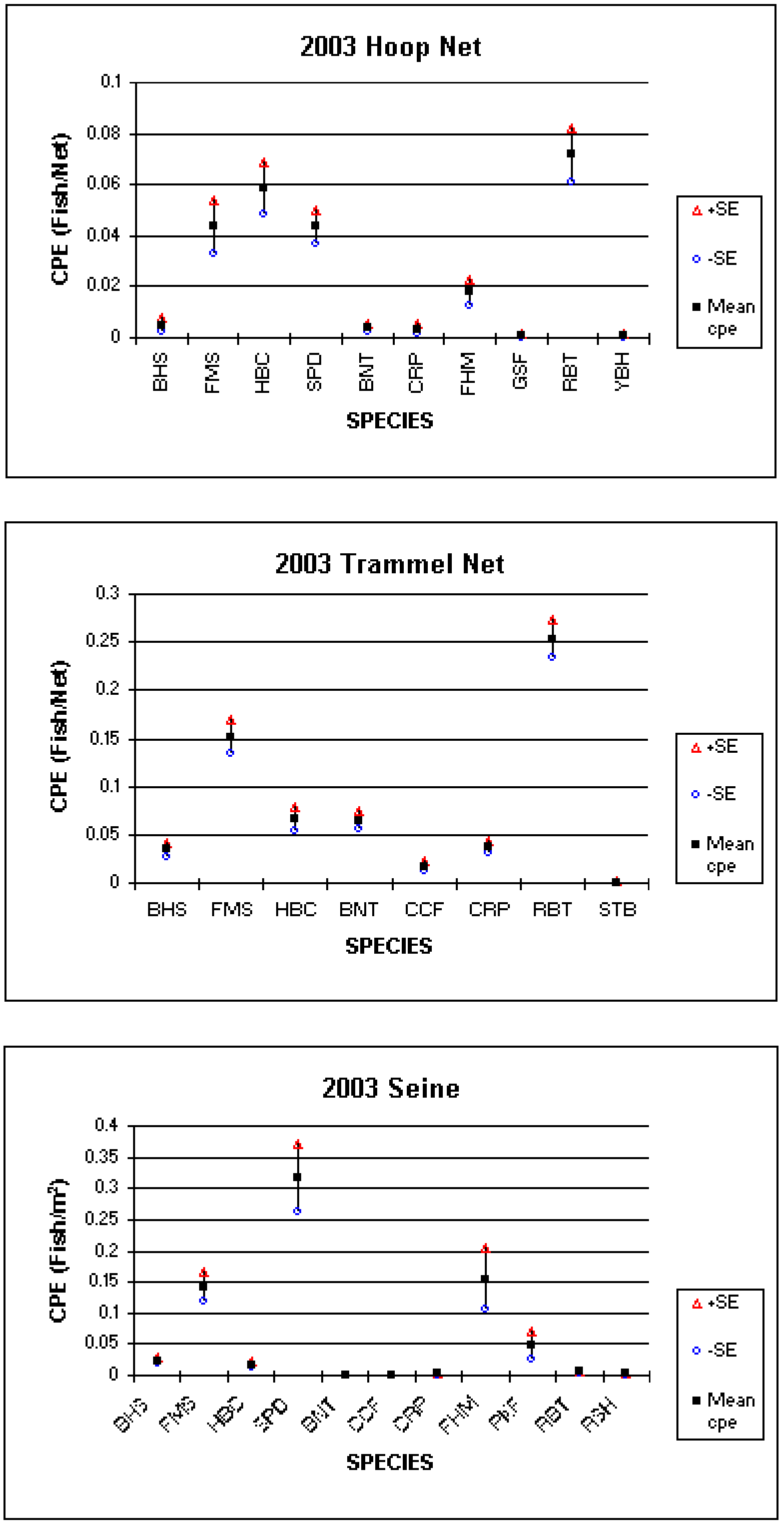


Figure 8. Relative abundance in catch-per-effort (CPE) of fish species captured with each gear type during the 2003 native fish monitoring field season.

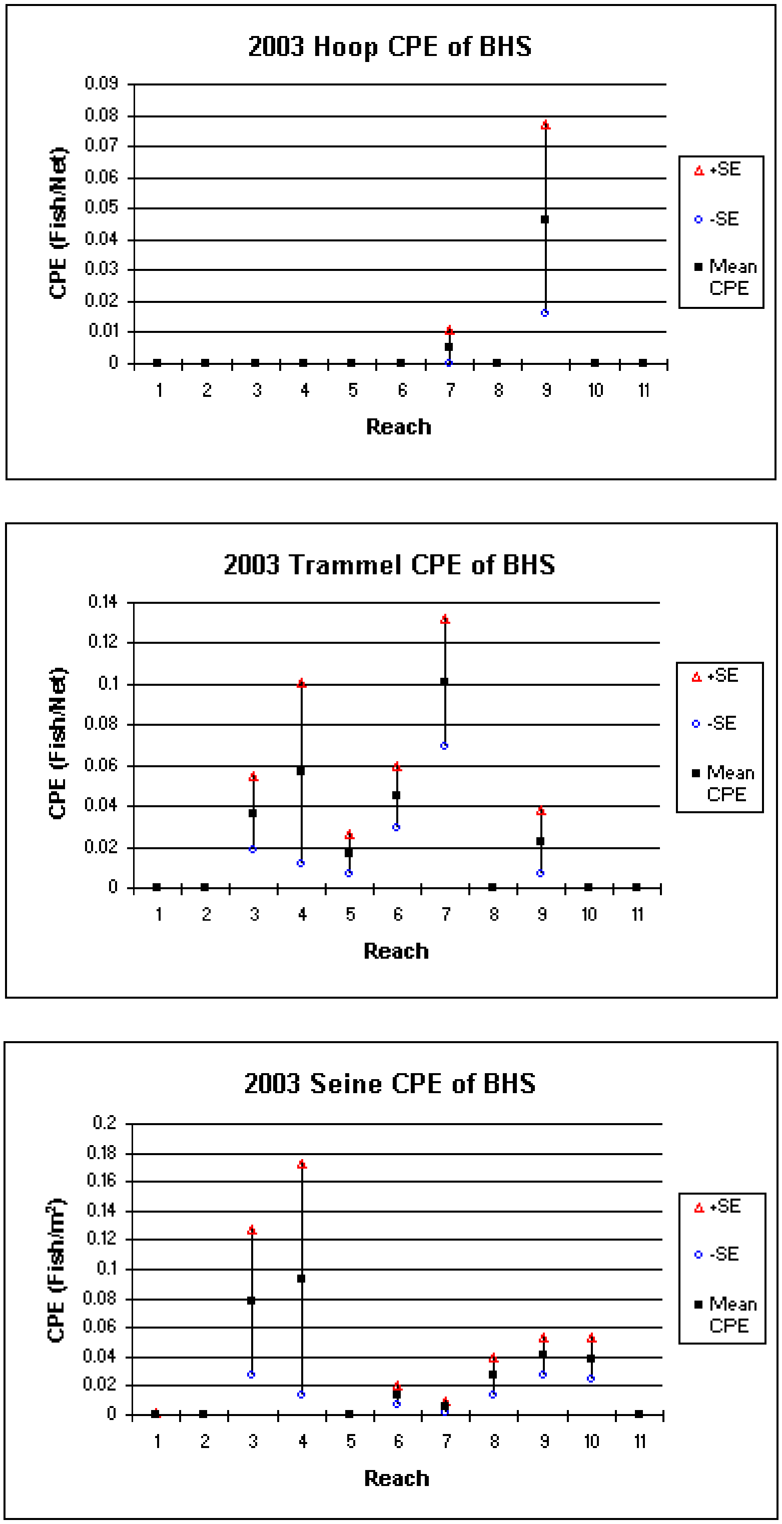


Figure 9. Catch-per-effort (CPE) of bluehead sucker (BHS) captured with trammel nets, hoop nets, and seines during the 2003 native fish monitoring field season.

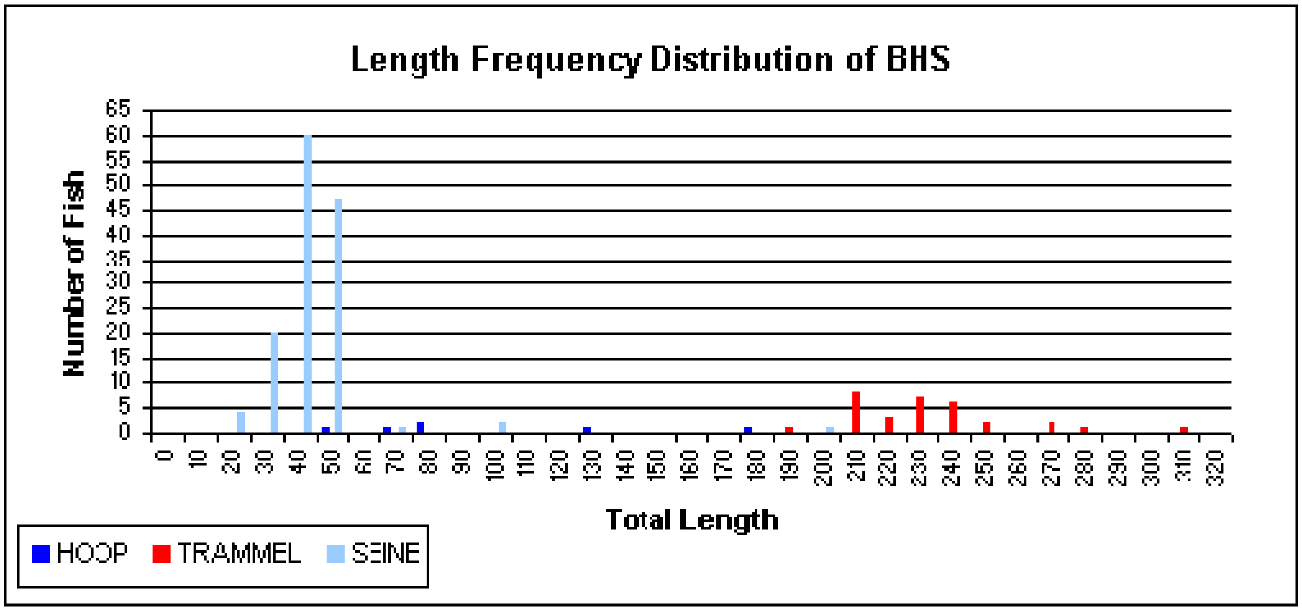
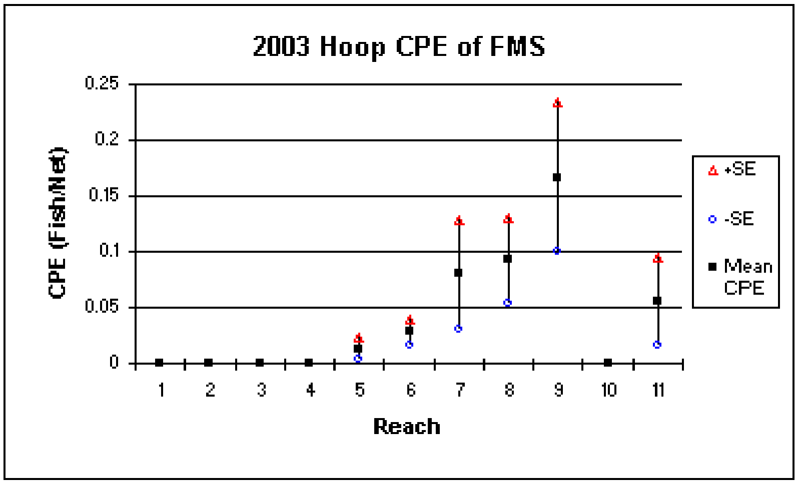
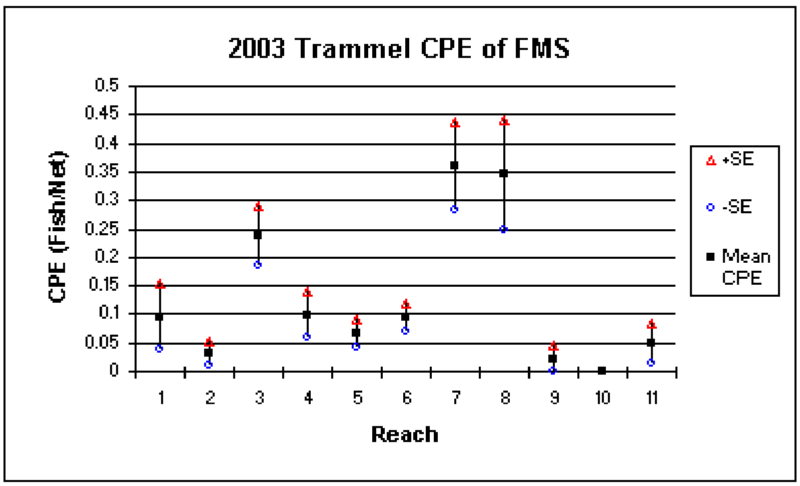


Figure 10. Bluehead sucker (BHS) length frequency distribution for fish captured during the 2003 native fish monitoring field season.





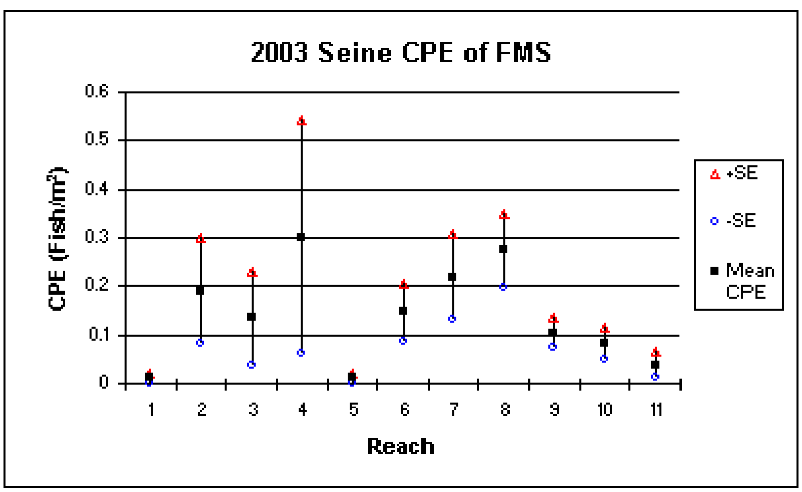


Figure 11. Catch-per-effort (CPE) of flannelmouth sucker (FMS) captured with trammel nets, hoop nets, and seines during the 2003 native fish monitoring field season.

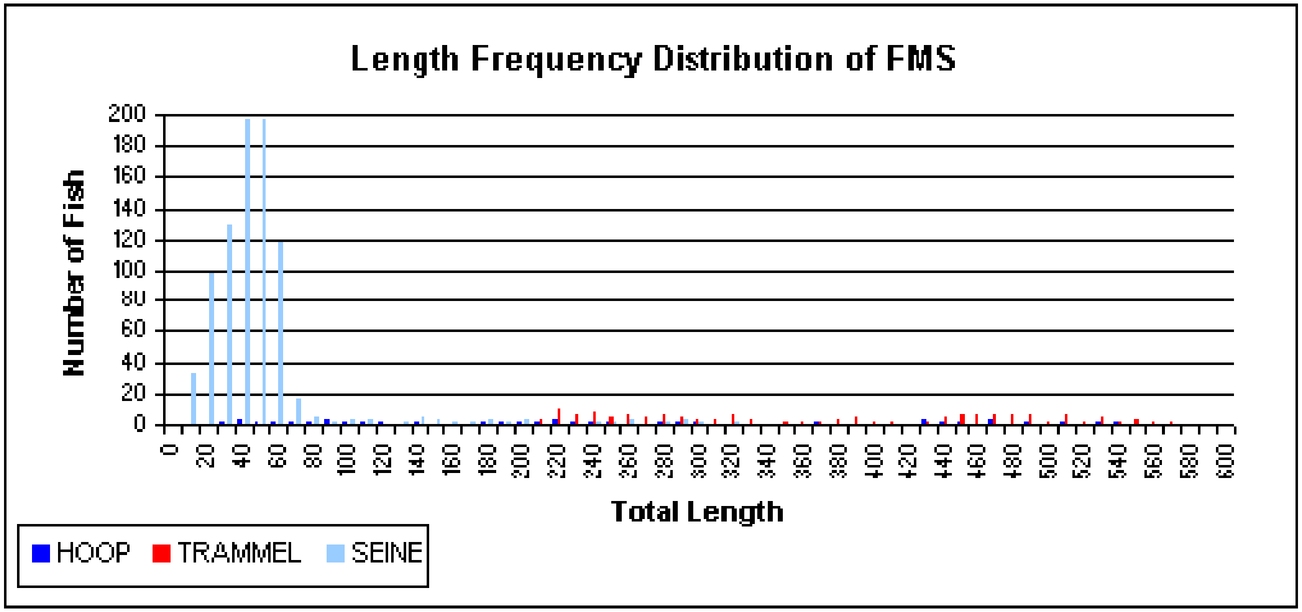


Figure 12. Flannelmouth sucker (FMS) length frequency distribution for fish captured during the 2003 native fish monitoring field season.

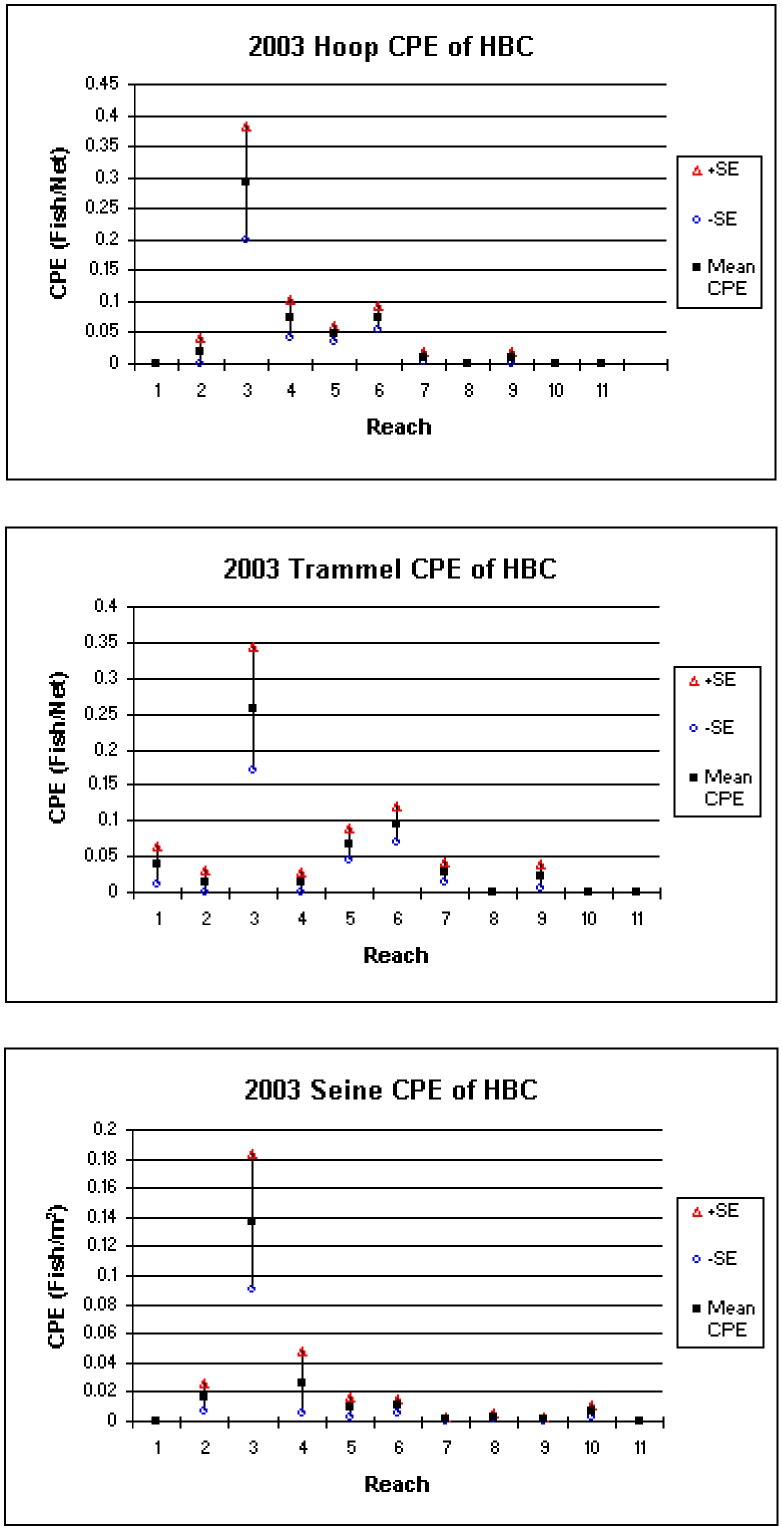


Figure 13. Catch-per-effort (CPE) of Humpback chub (HBC) captured with trammel nets, hoop nets, and seines during the 2003 native fish monitoring field season.

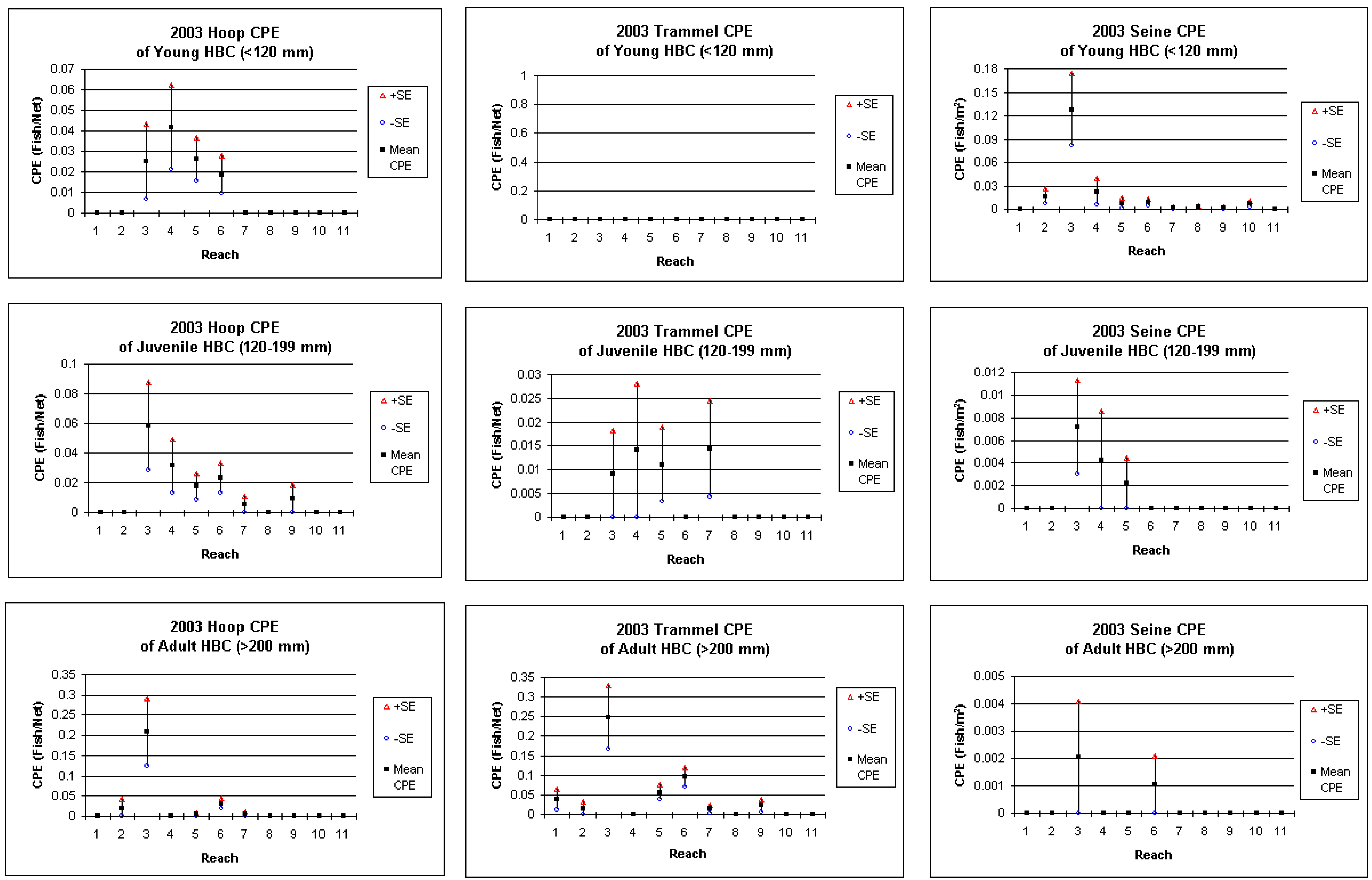


Figure 14. Humpback chub (HBC) by size and gear for fish captured during the 2003 native fish monitoring field season.

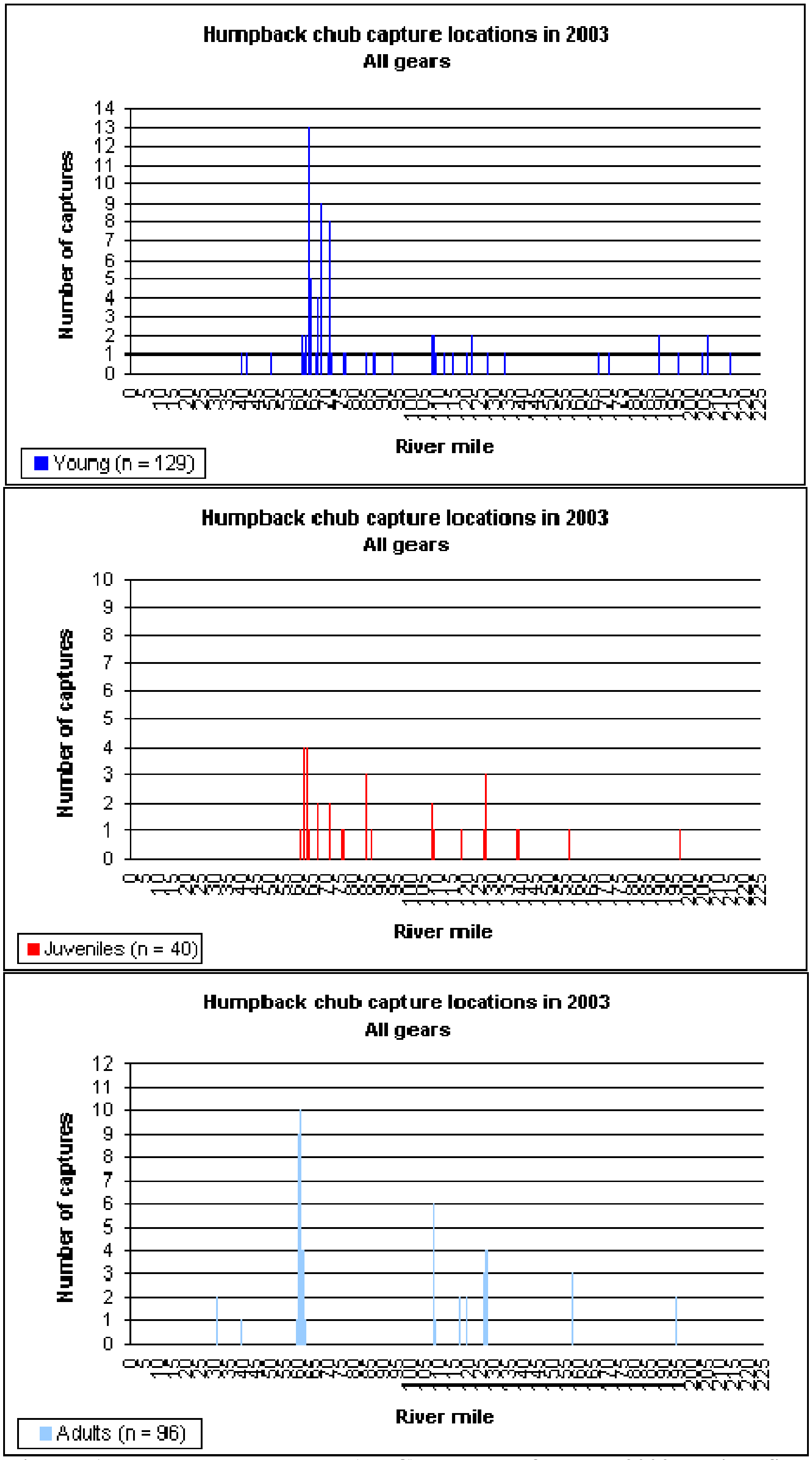


Figure 15. Humpback chub (HBC) capture for the 2003 native fish monitoring field season. Most HBC were captured within close proximity of known aggregations: 30-mile (RM 29.8-31.3), LCR Creek Inflow (RM 57.0–65.4), Lava Chuar to Hance (RM 65.7-76.3), Bright Angel Creek Inflow (RM 83.8–92.2), Shinumo Creek Inflow (RM108.1–108.6), Stephen Aisle (RM 114.9–120.1), Middle Granite Gorge (RM 126.1–129.0) and Havasu Creek Inflow (RM 155.8.0–156.7), Pumpkin Spring Aggregation was not sampled in 2003.

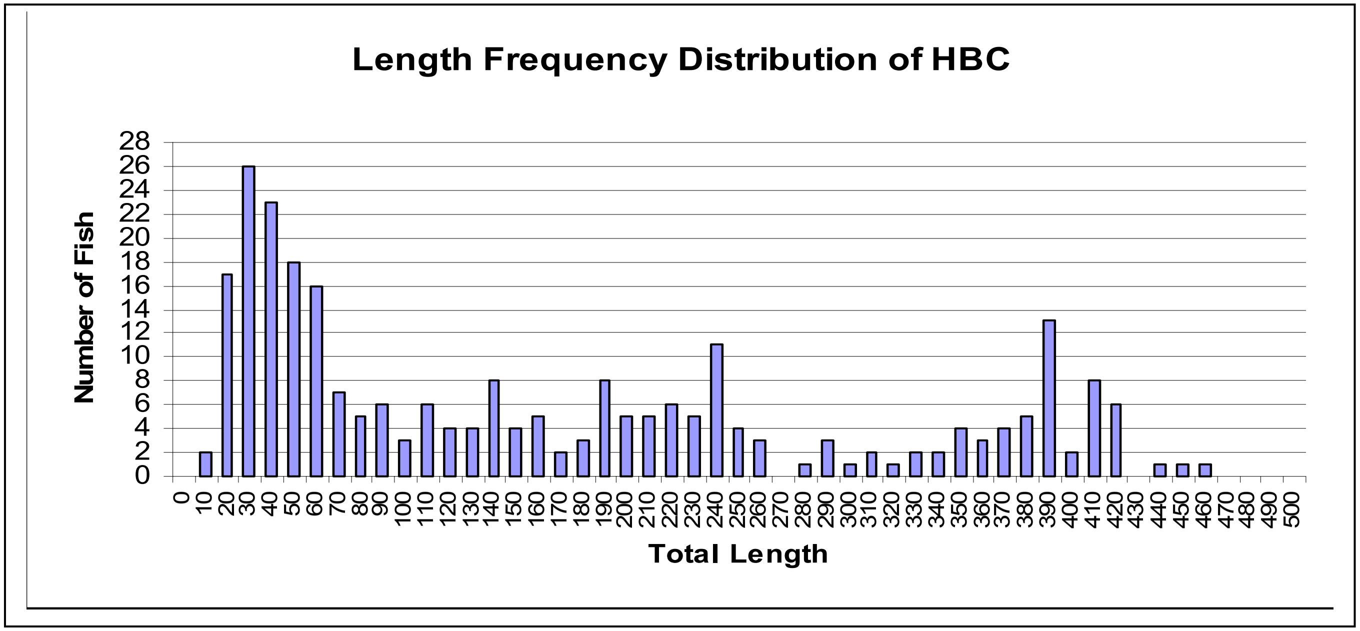
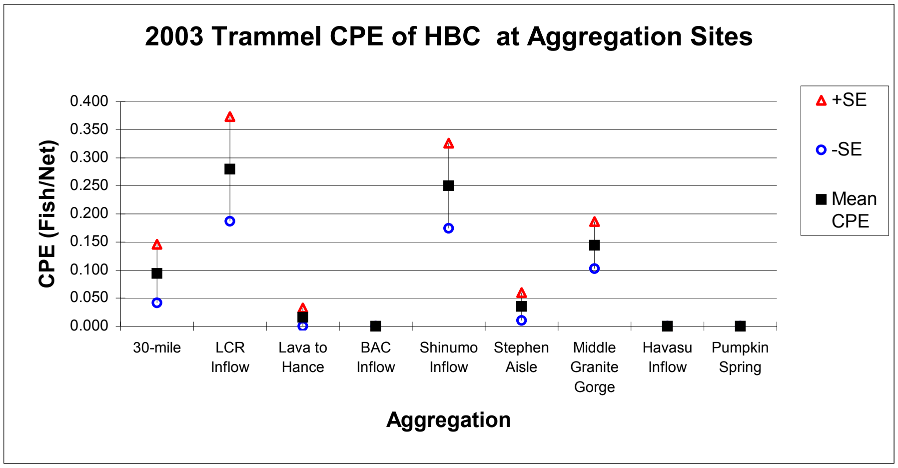
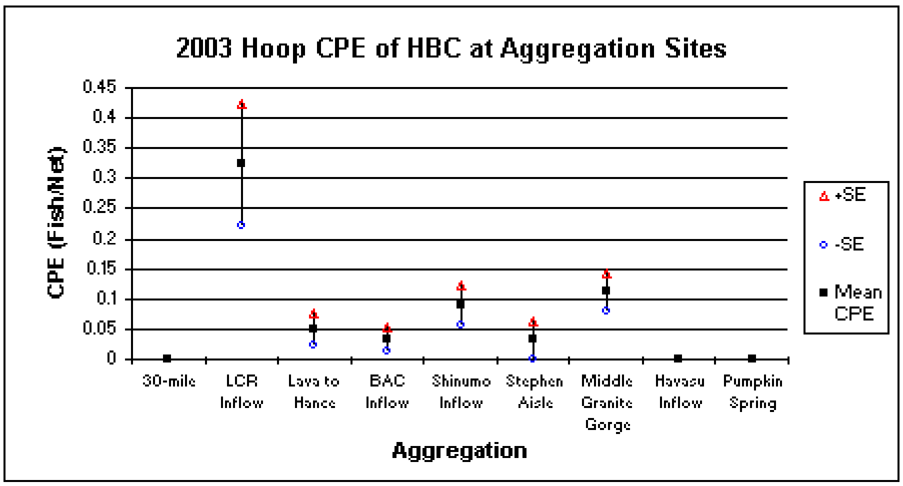


Figure 16. Humpback chub (HBC) length frequency distribution for fish captured during the 2003 native fish monitoring field season.





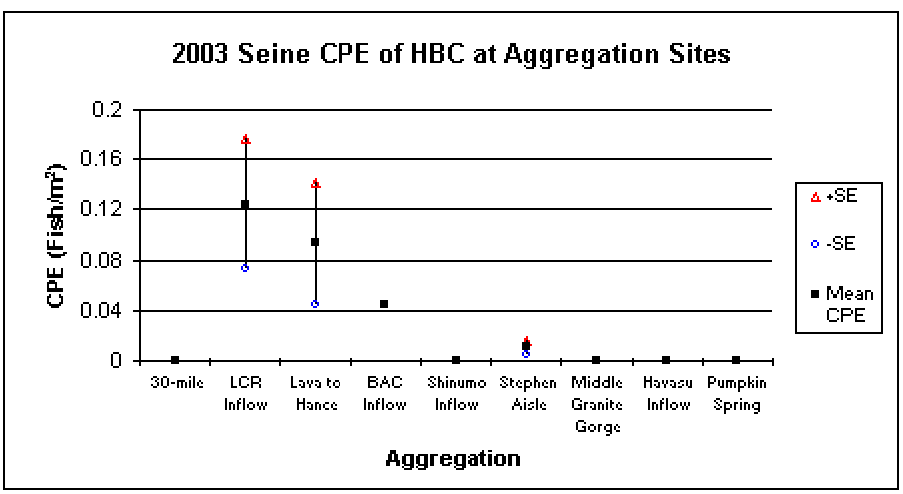


Figure 17. Catch-per-effort (CPE) for humpback chub (HBC) captured at aggregations during the 2003 native fish monitoring field season.

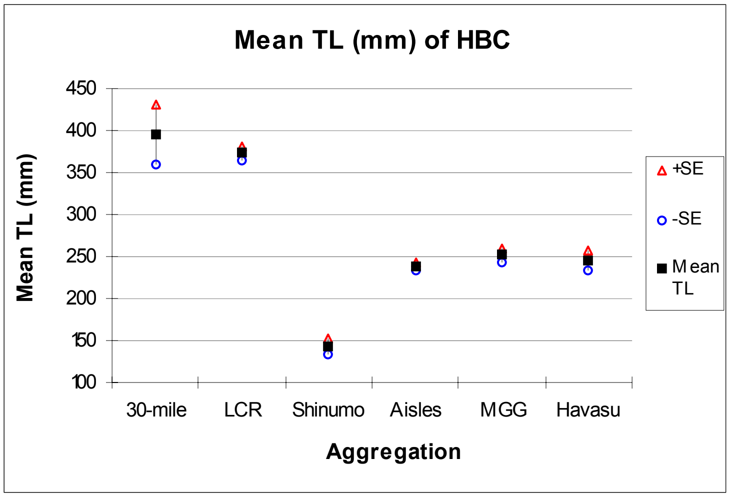


Figure 18. Mean total length (TL) of all humpback chub (HBC) captured within selected aggregation sites during the 2003 native fish monitoring field season.

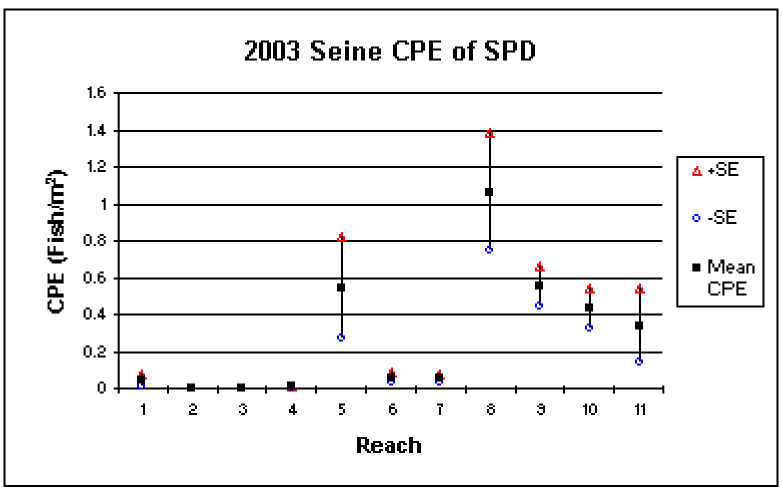
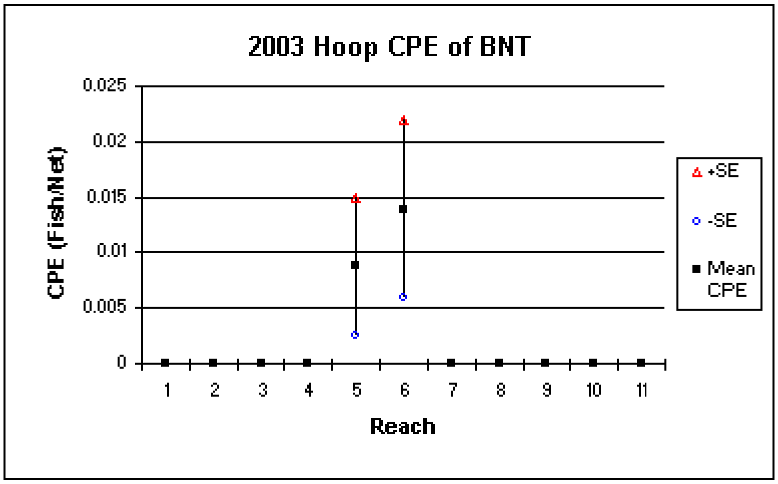
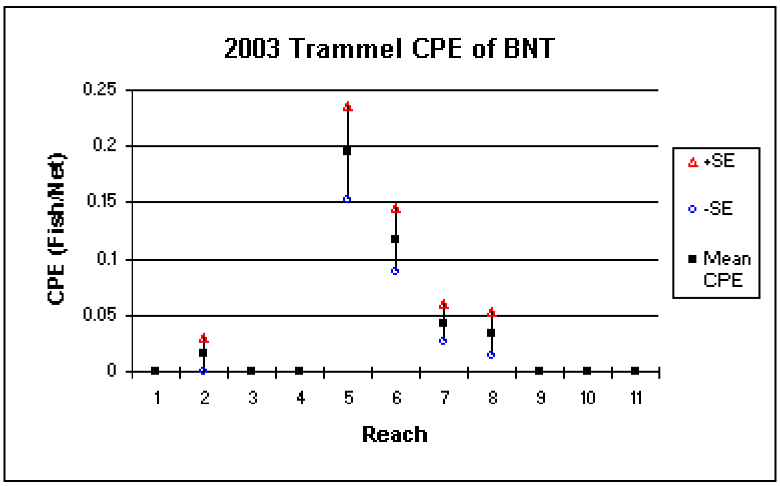


Figure 19. Catch-per-effort (CPE) of speckled dace (SPD) captured with seines, during the 2003 Native Fish Monitoring field season. SPD (55 fish) were also captured with hoop nets.





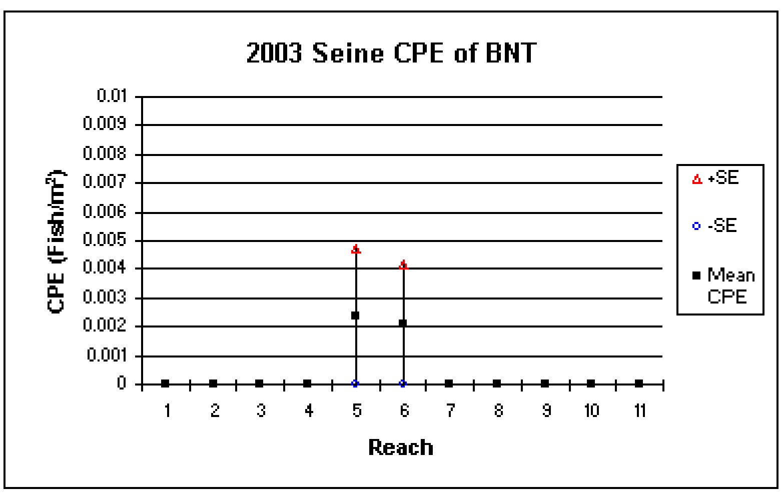


Figure 20. Catch-per-effort (CPE) of brown trout (BNT) captured with hoop nets and trammel nets. No BNT were captured with seines.

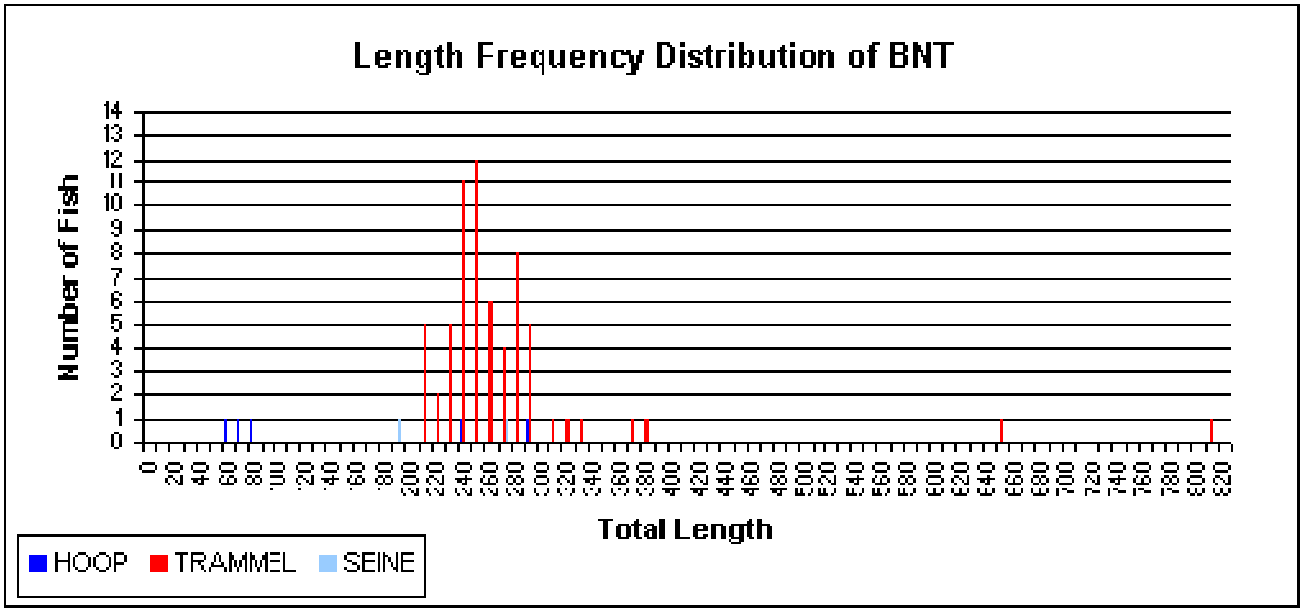


Figure 21. Brown trout (BNT) length frequency distribution for fish captured during the 2003 native fish monitoring field season.

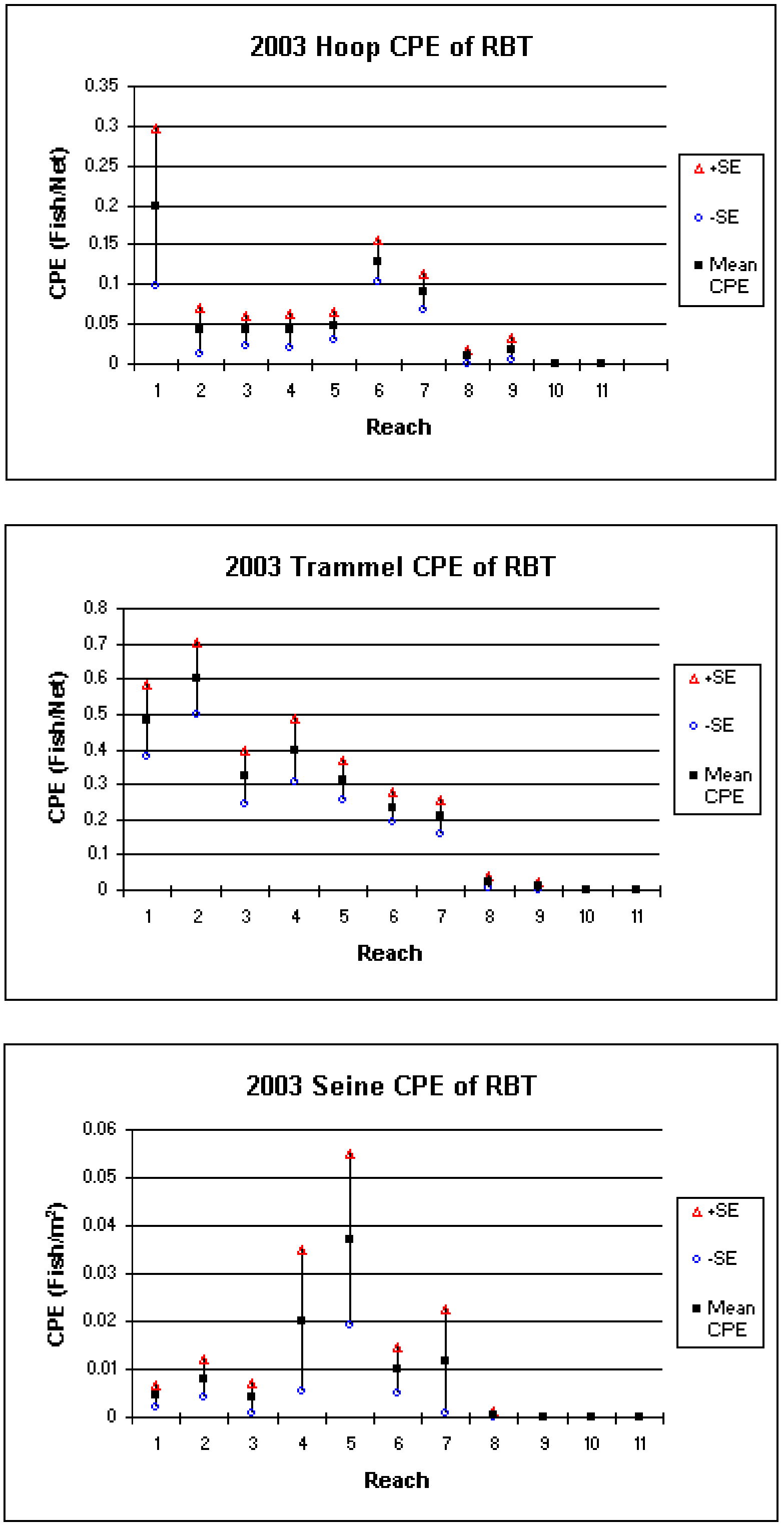


Figure 22. Catch-per-effort (CPE) of rainbow trout (RBT) captured with trammel nets, hoop nets, and seines during the 2003 native fish monitoring field season.

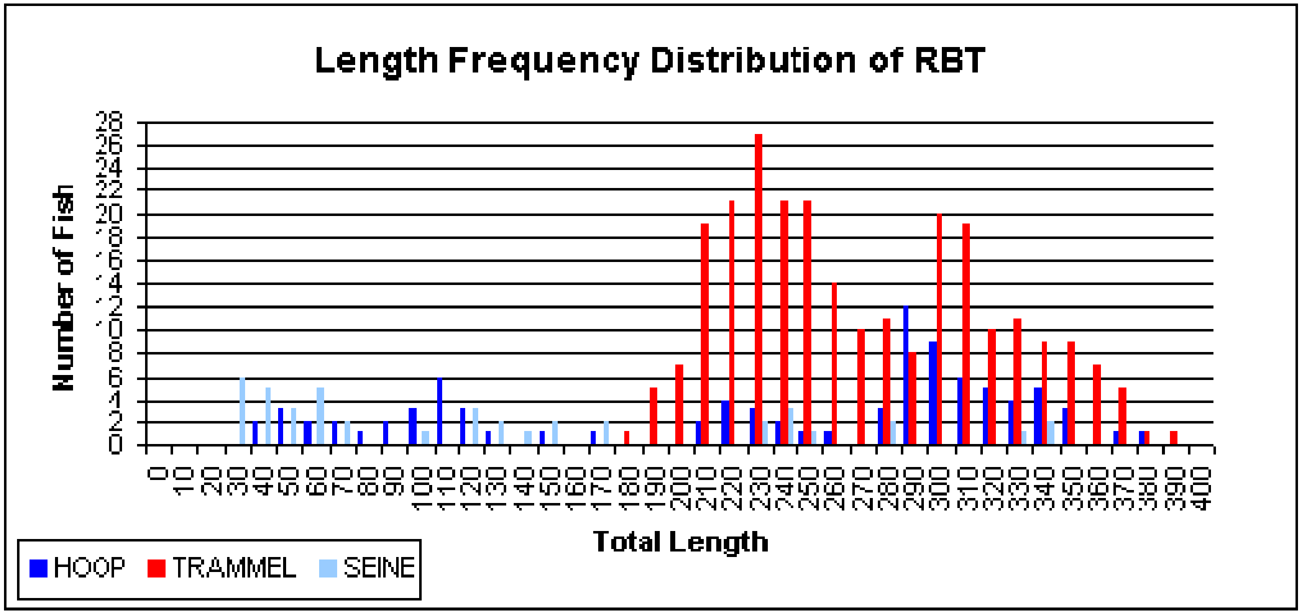


Figure 23. Rainbow trout (RBT) length frequency distribution for fish captured during the 2003 native fish monitoring field season.

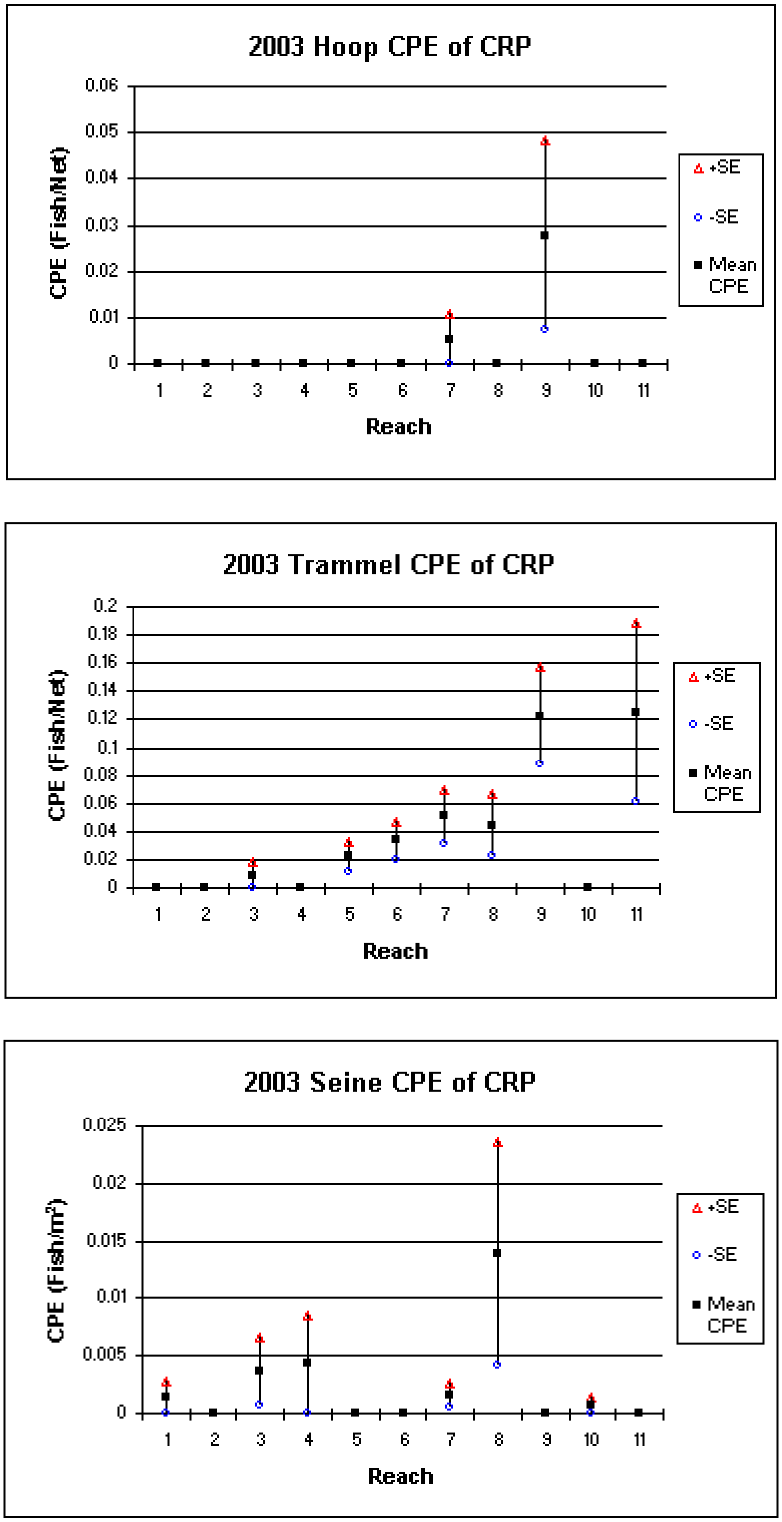


Figure 24. Catch-per-effort (CPE) of common carp (CRP) captured with trammel nets and seines during the 2003 native fish monitoring field season. No CRP was captured with hoop nets.

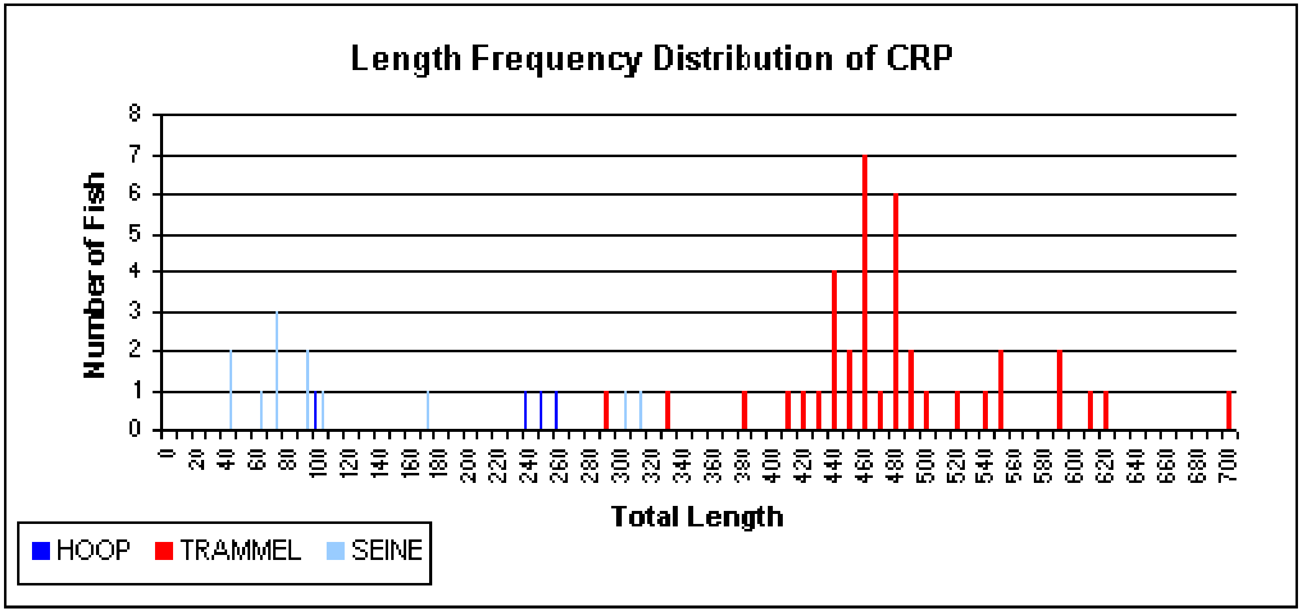


Figure 25. Common carp (CRP) length frequency distribution for fish captured during the 2003 native fish monitoring field season.

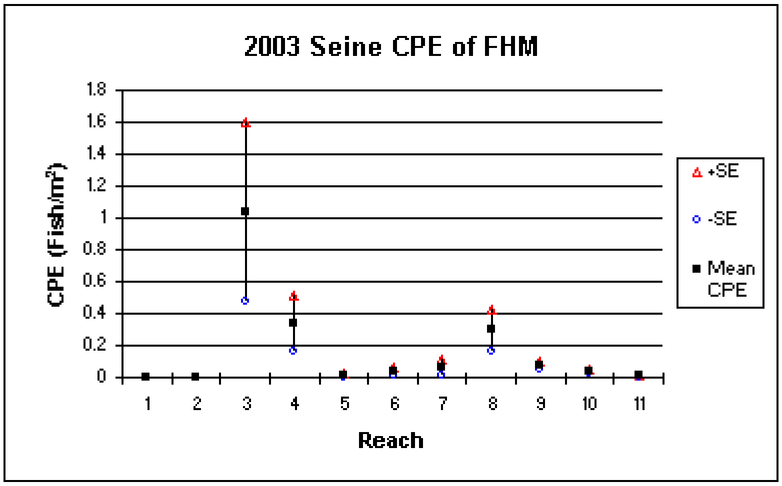


Figure 26. Catch-per-effort (CPE) of fathead minnow (FHM) captured with hoop nets and seines during the 2003 native fish monitoring field season. No FHM were captured with trammel nets.

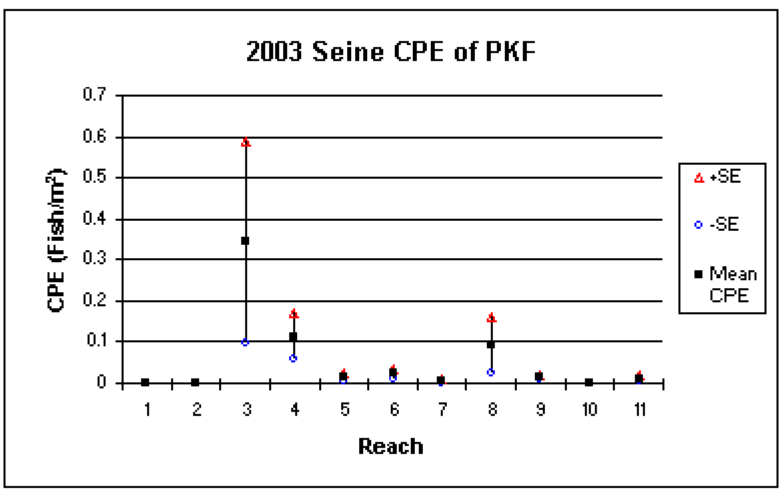


Figure 27. Catch-per-effort (CPE) of plains killifish (PKF) captured with seines during the 2003 native fish monitoring field season. No PKF were captured with hoop nets or trammel nets.

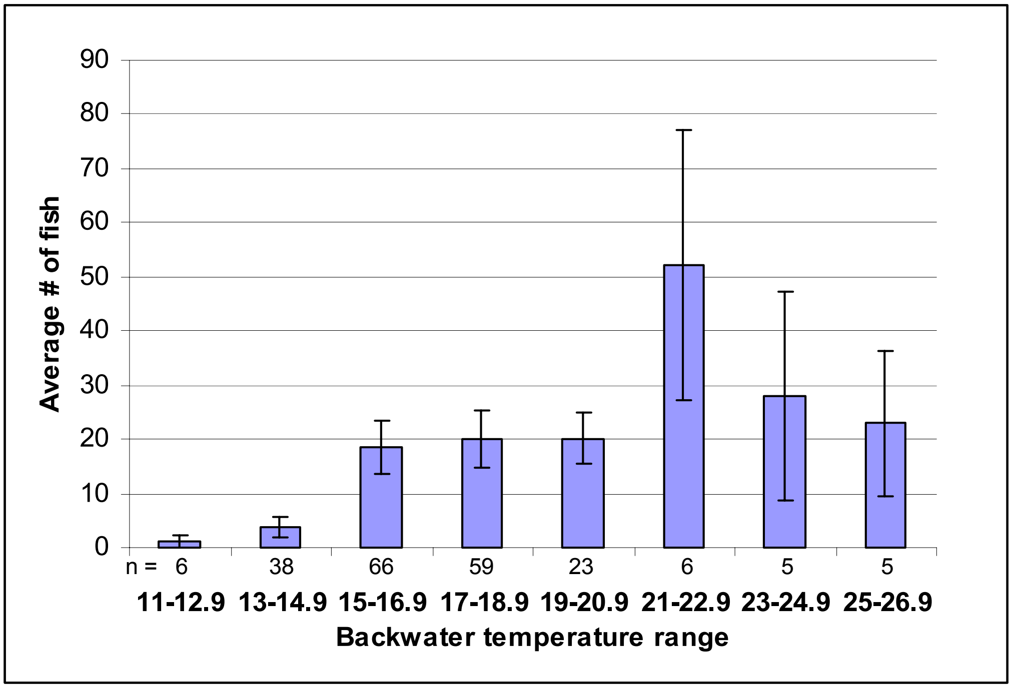


Figure 28. Average catch-per-seine haul in backwaters across a range of temperatures for native fish monitoring Trip 3, September 13-29, 2003.

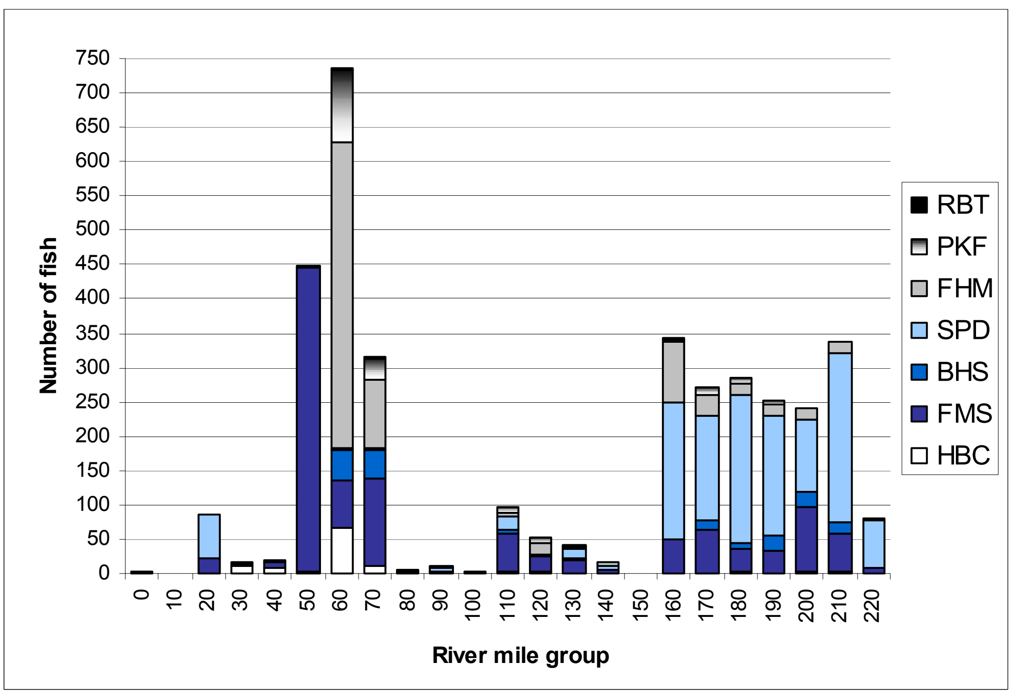


Figure 29. Species Composition for SWCA for native fish monitoring Trip 3, September 13-29, 2003.. Note: Species with total numbers less than 20 are not included in this summary (Table 8c). BHS=bluehead sucker; FMS=flannelmouth sucker; HBC=humpback chub; SPD=speckled dace; FHM=fathead minnow; PKF=plains killifish; RBT=rainbow trout.

Appendix A

APPENDIX A. BACKWATER, SHORELINE VEGETATION, AND TRAMMEL NET MAPPING EFFORT, SEPTEMBER 2003

INTRODUCTION

This appendix summarizes the mapping effort conducted during native fish monitoring Trip 3, September 13–30, 2003. Trip 3 included backwater seining (addressed in the main text) and additional mapping efforts requested by Carl Walters and the Grand Canyon Monitoring and Research Center (GCMRC), in July 2003. These mapping efforts (backwater area, length of inundated shoreline vegetation and number of possible trammel net-sets) were outside of the 2003 scope of work and are therefore reported as an appendix.

Following the discussion at the 2003 stock synthesis meeting, it was decided that on the 2003 SWCA fall seining trip, in addition to seining, total backwater area would be quantified. Backwaters in the Colorado River provide low-velocity and seasonally warmed environments that are likely important to the recruitment of native fish (AGFD 1996). In the last several years, summer river flows have fluctuated between 10,000 and 20,000 cubic feet per second (cfs). Under current sand bar elevations, backwaters typically become inundated at flows >16,000 cfs. When sand bars are over-topped, backwaters typically cease to provide flow and thermal refugia. Shoreline vegetation was hypothesized to provide secondary cover and flow and thermal refugia for juvenile fishes at higher water. Therefore length in meters of shoreline vegetation that would be inundated at higher flows (>10,000 cfs) was documented. As a result of the 2003 stock synthesis meeting, it was also decided that the number of potential trammel net sites within each known humpback chub (HBC) aggregation would be documented. These data will help to address some modeling issues regarding sample allocation and power analysis for the Grand Canyon fisheries monitoring program.

METHODS

GCMRC provided SWCA staff with ortho-rectified, digitized aerial imagery taken in May 2002 during steady flows of 8,000 cubic feet per second (cfs). Imagery covered the study area (river mile (RM) 0–226), and was printed at a scale of 1:3000. SWCA bound imagery into booklets, each covering ~25 river miles.

The following details were hand-drawn, in the field, onto aerial imagery:

a. Total area (length x average width (meters)) of each backwater that was sampled.
b. Total area (length x width) of each seine sample.
c. Approximate length of shoreline vegetation thought to be potential fish habitat when inundated was visually estimated from the boat and drawn onto imagery. Start and stop locations for vegetation were approximated by matching shoreline landmarks to those observable on imagery. Total length was calculated in GIS.
d. Possible trammel net locations within known HBC aggregations: 30-mile (RM 29.8–31.3), Little Colorado River Inflow (RM 57.0–65.4), Shinumo Creek Inflow (RM 108.1–108.6), Stephen Aisle (RM 114.9–120.1), Middle Granite Gorge (RM 126.1–129.0), Havasu Creek Inflow (RM 155.8–156.7), and Pumpkin Spring (RM 212.5–213.2).

Total backwater areas were drawn onto imagery based on field measurements and using river topography of the imagery. Approximations were made on drawings; at times water levels were either higher or lower than the 8,000 cfs imagery. Water levels, fluctuated between 5,187 and 10,418 cfs during the trip (Figure 5, main text). An example of field documentation is shown in Figure 1. An example of information when entered into GIS coverage is shown in Figure 2.

Shoreline vegetation that was visibly below the summer high-water line (20,000 cfs) was recorded linearly onto imagery. Length of shorleline vegetation was based on visual estimates from the boat. Most vegetation was identified to genus. Estimated river level (low or high) at which the vegetation would be inundated was documented (low was considered <10,000 cfs, high was considered >10,000 cfs). Water levels were estimated using visual observation of the water line created by the previous 24-hour flows and the knowledge of the Glen Canyon Dam release schedule. Any vegetation that was inundated when encountered was sampled by sweeping a dip net along its entire length or to the extent possible depending on the current in the area.

Trammel net locations were marked as points along the shoreline where the net would be attached to shore. These locations were based on visual observation within eddies that appeared to have slow enough currents to set a trammel net without tangling or drifting from the set location.

All mapping data were digitized using Arc Map software to transfer hand-drawn backwater areas, vegetated shorelines, and trammel points onto the digital imagery as accurately as possible. Data were then summarized in tables as total backwater area (m^2) and total linear meters of vegetated shoreline by Reach, based on GIS calculations from Arc Map. A comparison of total backwater area by Reach was made based on Arc Map calculations and field measurements. Trammel net locations were summarized as total number of trammel net locations per HBC aggregation site.

RESULTS

Total backwater areas are summarized for each Reach in Table 1. Two separate values are given: the first is the sum of each backwater area created in Arc Map, and the second is the sum of the backwater areas calculated from the length and width measurements taken in the field. The difference between the calculations is given for comparison of the two methods.

Table 2 lists the estimate total length of vegetated shoreline habitat for each Reach based on our field observations. These data are representative of total linear meters of shoreline that may be available as vegetative cover for fish at high flows (>10,000 cfs). The amount of vegetation available as cover for fish at flows less than 10,000 cfs was negligible, with total lengths as follows: 117.9 m in Reach 2, 289.0 m. in Reach 4, 30.0 meters in Reach 7, 28.6 meters in Reach 8, and 27.6 meters in Reach 9. These data are included in the total lengths of vegetated shoreline for each Reach at high flows listed in Table 2.

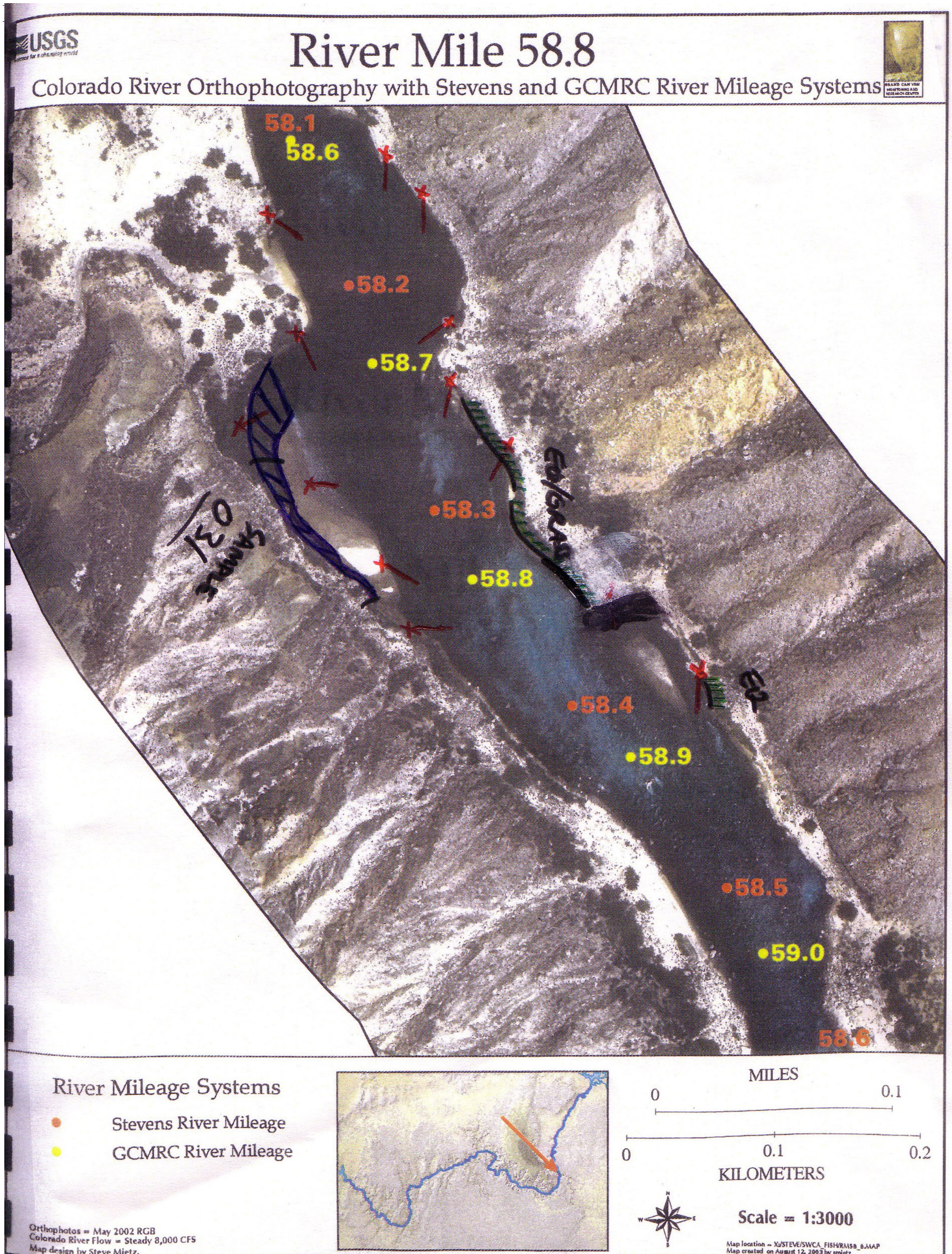
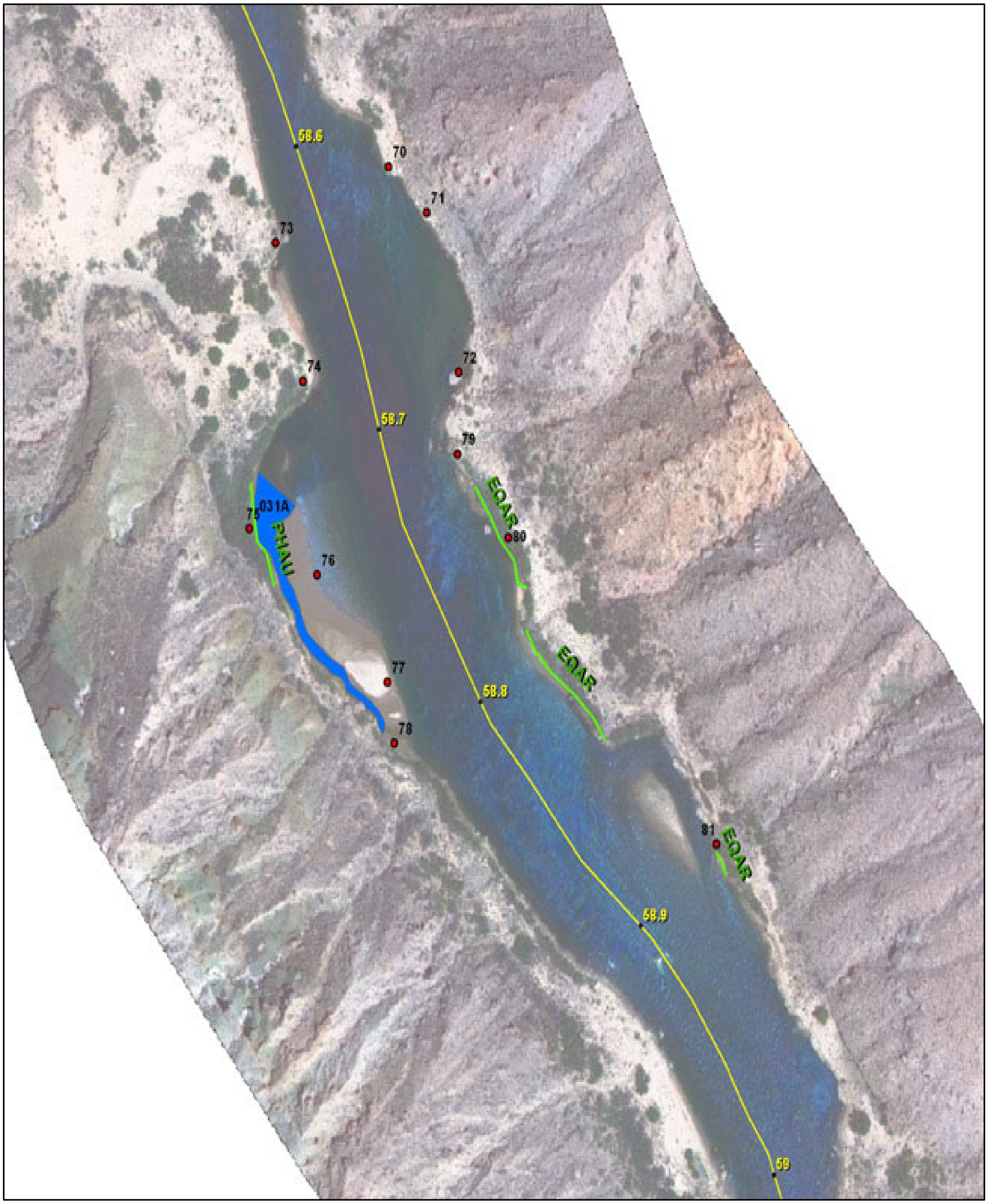


Figure 1. Example of an aerial photograph with hand drawn backwater area, vegetated shoreline, and trammel net location.



58.6
70
71
73
74
72
58.7
79
EQAR
031A
75
PHAU
80
76
EQAR
77
58.8
78
81
EQAR
58.9
59

Figure 2.

Table 1. Backwater areas by Reach calculated by Arc Map (GIS) and field measurements (Field), and the difference in the calculations.

Reach	RM Group	GIS Total BW Area	Field Total BW Area	Difference
1	0–30.9	5727.5	1423.0	4304.5
2	31–56.9	9144.5	6811.6	2332.9
3	57–69.9	3711.8	3630.7	81.1
4	70–79.9	740.8	1835.1	-1094.3
5	80–109.9	2549.8	3390.8	-841.0
6	110–129.9	2203.0	1946.8	256.3
7	130–159.9	269.7	181.4	88.3
8	160–179.9	2856.1	2044.4	811.7
9	180–199.9	5568.1	3846.0	1722.1
10	200–219.9	2722.3	2509.3	213.0
11	220–225.7	465.9	582.6	-116.7

Table 2. Total vegetated shoreline available as cover for fish by Reach at high flows (>10,000 cfs).

Reach	RM Group	Total Vegetated Shoreline (m)
1	0–30.9	2819.41
2	31.0–56.9	10559.69
3	57.0–69.9	4317.52
4	70.0–79.9	2902.99
5	80.0–109.9	816.90
6	110.0–129.9	812.53
7	130.0–159.9	938.22
8	160.0–179.9	10337.99
9	180.0–199.9	8668.13
10	200.0–219.9	6112.99
11	220.0–225.7	1997.92

Table 3 lists the total number of trammel net locations within each HBC aggregation site. These data are based on visual observations of areas suitable for setting a trammel net, particularly eddies with slow and steady currents without physical obstructions. These observations were made during flows ranging from 5,000 to 10,000 cfs, and some locations may not be suitable at higher flows.

Figure 1 gives an example of digital imagery with a hand-drawn backwater area, vegetated shoreline, and trammel net location. Figure 2 gives an example of the same imagery with the digitized backwater area, vegetated shoreline, and trammel net location created in Arc Map.

Table 3. Total number of trammel net locations by HBC aggregation site at flows less than 10,000 cfs.

HBC Aggregation Site	RM Group	Number of Trammel Net Locations
30-mile	29.8–31.3	69
LCR	57.0–65.4	154
Shinumo	108.1–108.6	30
Stephen Aisle	114.9–120.1	76
Middle Granite Gorge	126.1–129.0	44
Havasu	155.8–156.7	101
Pumpkin Spring	212.5–213.2	71

DISCUSSION

Backwater areas differed considerably between GIS calculations and field estimations (Table 1). For Reaches 4, 5, and 11, GIS calculations were less than estimated field areas. GIS calculations for all other Reaches were larger than estimated field areas. The difference in total backwater areas suggests that the GIS calculations, the field measurement estimates, or both were inconsistent in estimating total backwater area. We suggest that both methods have limitations, and that total area estimates from either calculation should only be used for comparison on a relative scale.

Several factors may account for the variation in Arc Map estimates of backwater areas. Because backwater areas were hand-drawn based on visual observation onto imagery at a scale of 1:3000, there is a high potential for imprecision, despite the use of shoreline and sand bar features. The fact that the imagery was taken at a steady flow of 8,000 cfs and the samples were taken with flows ranging from 5,000 to 10,000 cfs also may cause imprecision in defining backwater shape and features. The imprecision of Arc Map software caused many backwater areas to be overestimated. The Snap distance parameter of the mapping program limited the accuracy of the digitized areas. Distances less than 3 meters were defaulted to 3 meters, by the program. Consequently backwaters with a width of less than 3 meters were not correctly represented. Settings will be adjusted should this project be replicated in the future.

As described previously, field estimates were made based on a single measurement of width and length. These estimates did not adequately account for the geometry of the backwater. Because of the difficulties associated with both methods of estimating backwater area it is hard to identify which method is more precise.

Estimating the extent of fish habitat as vegetative cover also may be biased. The ordinary high-water line was assumed to occur at flows of 20,000 cfs and be defined by shoreline characteristics such as debris deposition, deposit stained rocks, non-wetland vegetation level, and sand bar morphology. The recent high-water line was assumed to occur during flows of 10,000 cfs and defined by the highest extent the water reached on the shoreline in the last 24-hour period as evidenced by cut banks on sand bars, recently wetted sand bars , rocks, and vegetation. The extent of the vegetated shoreline that would become inundated under high flows is left to the judgment of the data recorder. These visual judgments may differ from one data recorder to the next. The scale of the photographs may make it difficult to outline the extent of vegetation from a visual observation. Finally, the accuracy of digitizing data into Arc Map may have an effect on estimates of total vegetated shoreline length.

Estimating the number of possible trammel net locations was a straight forward task in comparison to estimating backwater area and vegetation; however, a net set location that appeared suitable for a trammel net from midstream may have unknown difficulties such as inconsistent currents, swift currents, rocky substrates, or poor anchor locations. Additionally, sites that seemed fitting during a certain flow regime may become unsuitable under other flows. We will continue to estimate number of possible trammel net locations on future sampling trips in order to address this issue.

Appendix B

Appendix B. Humpback chub PIT tag recapture summary. Recaptures are organized by PIT tag number

	Start RM	River	Start Date	Species	TL	Pit Lot	Recap	PIT Tag
1	126.0	COR	5/13/1993	HBC	205	-	N	1F0C6F0165
	127.5	COR	7/18/1993	HBC	220	-	Y	1F0C6F0165
	127.5	COR	7/14/2000	HBC	302	-	Y	1F0C6F0165
	127.9	COR	9/19/2002	HBC	317	-	Y	1F0C6F0165
	127.4	-	-	HBC	318	-	Y	1F0C6F0165
2	58.2	COR	11/05/1993	HBC	364	-	N	1F1F6E3C18
	59.4	-	05/06/2003	HBC	371	-	Y	1F1F6E3C18
3	30.7	COR	10/09/1993	HBC	390	-	N	1F20443647
	30.5	COR	11/04/1993	HBC	391	-	Y	1F20443647
	30.8	-	06/15/2003	HBC	402	-	Y	1F20443647
4	64.8	COR	08/04/2001	HBC	390	-	Y	1F7A331F15
	62.1	-	05/08/2003	HBC	394	-	Y	1F7A331F15
5	108.4	-	06/19/2003	HBC	213	-	N	3D9.1BF198C462
	108.3	-	06/20/2003	HBC	214	-	Y	3D9.1BF198C462
6	119.4	-	05/13/2003	HBC	240	-	N	3D9.1BF198E677
	108.1	-	06/18/2003	HBC	241	-	Y	3D9.1BF198E677
7	127.2	-	6/21/2003	HBC	235	-	N	3D9.1BF198E685
	127.4	-	6/22/2003	HBC	230	-	Y	3D9.1BF198E685
8	138.6	-	05/14/2003	HBC	195		N	3D9.1BF198F3C4
	139.0	-	05/14/2003	HBC	197		Y	3D9.1BF198F3C4
9	-	COR	06/04/2001	HBC	199	-	N	423D296412
	126.8	-	06/21/2003	HBC	242	-	Y	423D296412
10	127.3	COR	03/11/2002	HBC	214	-	N	426E052C0D
	126.4	-	06/23/2003	HBC	245	-	Y	426E052C0D
11	157.3	COR	09/21/2002	HBC	251	C6845	N	436301731F
	157.4	-	06/26/2003	HBC	263	-	Y	436301731F
12	127.0	COR	09/19/2002	HBC	235	C6845	N	4364034F16
	126.4	-	06/23/2003	HBC	238	-	Y	4364034F16
13	108.3	COR	09/23/1999	HBC	243	-	N	532111101D
	108.3	-	06/18/2003	HBC	298	-	Y	532111101D
	108.3	-	06/20/2003	HBC	302	-	Y	532111101D
14	126.3	COR	09/19/2000	HBC	258	-	N	53211D3A37
	126.4	-	06/23/2003	HBC	295	-	Y	53211D3A37

Appendix B continued.

	Start RM	River	Start Date	Species	TL	Pit Lot	Recap	Pit Tag
15	30.2	COR	05/09/1993	HBC	448	-	N	7F7B017115
	30.8	COR	09/10/1993	HBC	448	-	Y	7F7B017115
	30.8	-	06/15/2003	HBC	452	-	Y	7F7B017115
16	60.69	COR	09/16/1997	HBC	406	-	Y	7F7B1A0B7C
	61.2	-	05/06/2003	HBC	397	-	Y	7F7B1A0B7C
17	61.2	COR	05/16/1991	HBC	400	-	N	7F7D081F06
	61.2	COR	05/14/1993	HBC	402	-	Y	7F7D081F06
	60.8	COR	08/30/2001	HBC	412	-	Y	7F7D081F06
	60.7	-	05/06/2003	HBC	415	-	Y	7F7D081F06
18	58.2	COR	07/09/1992	HBC	387	-	N	7F7D085406
	58.2	COR	09/13/1993	HBC	401	-	Y	7F7D085406
	60.2	-	05/07/2003	HBC	416	-	Y	7F7D085406
19	60.7	COR	07/15/1994	HBC	320	-	Y	7F7D173645
	60.7	COR	08/28/1998	HBC	351	-	Y	7F7D173645
	60.7	-	05/06/2003	HBC	368	-	Y	7F7D173645
20	60.7	COR	08/28/1998	HBC	319	-	Y	7F7D176639
	60.3	-	05/06/2003	HBC	333	-	Y	7F7D176639
21	61.2	COR	02/15/1992	HBC	340	-	Y	7F7D176F35
	60.3	-	05/06/2003	HBC	386	-	Y	7F7D176F35
22	62.5	COR	07/17/1992	HBC	371	-	Y	7F7D2A7A12
	60.2	-	05/07/2003	HBC	397	-	Y	7F7D2A7A12
23	61.5	COR	02/17/1993	HBC	338	-	Y	7F7D2F4367
	60.1	-	05/06/2003	HBC	390	-	Y	7F7D2F4367
24	60.1	COR	09/16/1997	HBC	325	-	Y	7F7D300C7D
	60.3	-	05/06/2003	HBC	370	-	Y	7F7D300C7D
25	60.6	COR	09/16/1997	HBC	391	-	Y	7F7D301F0A
	60.7	-	05/06/2003	HBC	399	-	Y	7F7D301F0A
26	60.1	COR	06/14/1993	HBC	390	-	Y	7F7F082B74
	59.6	-	05/06/2003	HBC	425	-	Y	7F7F082B74
27	60.0	COR	08/28/1998	HBC	331	-	Y	7F7F0F756D
	60.2	-	05/07/2003	HBC	340	-	Y	7F7F0F756D
28	61.5	COR	11/11/1991	HBC	395	-	Y	7F7F217274
	62.1	-	05/08/2003	HBC	414	-	Y	7F7F217274

Appendix B continued.

	Start RM	River	Start Date	Species	TL	Pit Lot	Recap	Pit Tag
29	60.3	COR	09/15/1997	HBC	339	-	Y	7F7F217A63
	60.3	-	05/06/2003	HBC	353	-	Y	7F7F217A63
30	60.4	COR	01/15/1993	HBC	402	-	Y	7F7F220655
	60.2	-	05/07/2003	HBC	427	-	Y	7F7F220655
31	60.4	COR	09/12/1992	HBC	321	-	N	7F7F284B23
	60.0	-	05/07/2003	HBC	379	-	Y	7F7F284B23
32	-	LCR	06/15/1993	HBC	404	-	N	1F0C7D3028
	-	LCR	07/19/1993	HBC	405	-	Y	1F0C7D3028
	61.2	-	05/06/2003	HBC	425	-	Y	1F0C7D3028
33	-	LCR	01/16/1995	HBC	337	-	N	1F3E5E360F
	60.8	-	05/06/2003	HBC	412	-	Y	1F3E5E360F
34	-	LCR	12/14/1993	HBC	394	-	N	1F46646F48
	60.7	-	05/06/2003	HBC	395	-	Y	1F46646F48
35	-	LCR	03/24/1995	HBC	328	-	N	1F7B660D73
	60.0	-	05/07/2003	HBC	364	-	Y	1F7B660D73
36	-	LCR	04/09/2002	HBC	102	-	N	423E235810
	62.7	-	05/08/2003	HBC	149	-	Y	423E235810
37	-	LCR	10/05/2001	HBC	187	-	N	430F643C3F
	62.1	-	05/08/2003	HBC	211	-	Y	430F643C3F
38	-	LCR	04/14/2002	HBC	403	-	N	43472D737C
	60.0	-	05/07/2003	HBC	394	-	Y	43472D737C
39	-	LCR	05/21/2002	HBC	190	-	N	53267C7528
	-	LCR	10/24/2002	HBC	226	-	Y	53267C7528
	60.7	-	05/06/2003	HBC	233	-	Y	53267C7528
40	60.7	-	05/06/2003	HBC	415	-	Y	7F7D081F06
	60.2	-	05/07/2003	HBC	416	-	Y	7F7D085406
41	-	LCR	07/08/1991	HBC	357	-	N	7F7D175014
	-	LCR	07/11/1991	HBC	360	-	Y	7F7D175014
	-	LCR	02/13/1993	HBC	368	-	Y	7F7D175014
	-	LCR	03/08/1993	HBC	365	-	Y	7F7D175014
	-	LCR	05/17/1993	HBC	364	-	Y	7F7D175014
	60.7	-	05/06/2003	HBC	390	-	Y	7F7D175014

Appendix B continued.

	Start RM	River	Start Date	Species	TL	Pit Lot	Recap	Pit Tag
42	-	LCR	06/05/1991	HBC	350	-	Y	7F7D180530
	-	LCR	04/19/1995	HBC	372	-	Y	7F7D180530
	-	LCR	04/24/1996	HBC	384	-	Y	7F7D180530
	61.2	-	05/06/2003	HBC	412	-	Y	7F7D180530
43	-	LCR	02/14/1992	HBC	388	-	N	7F7D255916
	-	LCR	03/08/1993	HBC	385	-	Y	7F7D255916
	59.9	-	05/07/2003	HBC	396	-	Y	7F7D255916
44	-	LCR	08/21/1991	HBC	420	-	N	7F7D2B3E31
	60.4	-	05/07/2003	HBC	425	-	Y	7F7D2B3E31
45	-	LCR	11/15/1991	HBC	150	-	N	7F7D2C1A6D
	60.4	-	05/07/2003	HBC	358	-	Y	7F7D2C1A6D
46	-	LCR	03/19/1992	HBC	364	-	N	7F7D2F1D40
	60.3	-	05/06/2003	HBC	382	-	Y	7F7D2F1D40
47	-	LCR	08/18/1991	HBC	388	-	N	7F7D302131
	-	LCR	07/18/1992	HBC	384	-	Y	7F7D302131
	-	LCR	17/16/1993	HBC	394	-	Y	7F7D302131
	-	LCR	11/13/1993	HBC	396	-	Y	7F7D302131
	-	LCR	10/22/2002	HBC	420	-	Y	7F7D302131
	61.2	-	05/06/2003	HBC	413	-	Y	7F7D302131
48	-	LCR	05/12/1993	HBC	310	-	N	7F7D3C4F54
	-	LCR	04/17/1994	HBC	314	-	Y	7F7D3C4F54
	-	LCR	04/30/2001	HBC	389	-	Y	7F7D3C4F54
	-	LCR	04/16/2002	HBC	403	-	Y	7F7D3C4F54
	59.9	-	05/06/2003	HBC	392	-	Y	7F7D3C4F54
49	-	LCR	05/20/1989	HBC	272	-	N	7F7E55493B
	-	LCR	05/21/1989	HBC	269	-	Y	7F7E55493B
	-	LCR	04/16/2002	HBC	376	-	Y	7F7E55493B
	60.2	-	05/07/2003	HBC	371	-	Y	7F7E55493B
50	-	LCR	05/12/1989	HBC	375	-	N	7F7F050428
	-	LCR	04/26/1990	HBC	365	-	Y	7F7F050428
	-	LCR	01/15/1995	HBC	381	-	Y	7F7F050428
	-	LCR	04/19/1995	HBC	382	-	Y	7F7F050428
	-	LCR	05/11/1997	HBC	380	-	Y	7F7F050428
	-	-	04/17/1999	HBC	390	-	Y	7F7F050428
	-	LCR	05/07/2001	HBC	387	-	Y	7F7F050428
	61.1	-	05/07/2003	HBC	388	-	Y	7F7F050428

Appendix B continued.

	Start RM	River	Start Date	Species	TL	Pit Lot	Recap	Pit Tag
51	-	LCR	02/12/1993	HBC	330	-	N	7F7F156328
	-	LCR	03/08/1993	HBC	329	-	Y	7F7F156328
	-	LCR	02/15/1995	HBC	335	-	Y	7F7F156328
	-	LCR	03/06/1995	HBC	333	-	Y	7F7F156328
	-	LCR	04/30/2001	HBC	345	-	Y	7F7F156328
	60.7	-	05/06/2003	HBC	339	-	Y	7F7F156328
52	-	LCR	11/12/1992	HBC	481	-	N	7F7F173735
	-	LCR	12/10/1993	HBC	383	-	Y	7F7F173735
	-	LCR	06/12/2001	HBC	405	-	Y	7F7F173735
	60.2	-	05/07/2003	HBC	406	-	Y	7F7F173735
53	-	LCR	03/08/1993	HBC	443	-	N	7F7F200124
	60.7	-	05/06/2003	HBC	448	-	Y	7F7F200124
54	-	LCR	03/08/1993	HBC	403	-	Y	7F7F206304
	60.2	-	05/07/2003	HBC	411	-	Y	7F7F206304
55	-	LCR	03/19/1993	HBC	274	-	N	7F7F21726D
	-	LCR	02/15/1994	HBC	375	-	Y	7F7F21726D
	-	LCR	05/11/1996	HBC	368	-	Y	7F7F21726D
	59.9	-	05/07/2003	HBC	395	-	Y	7F7F21726D
56	-	LCR	05/13/1993	HBC	420	-	Y	7F7F267D5E
	-	LCR	05/18/1995	HBC	418	-	Y	7F7F267D5E
	60.7	-	05/06/2003	HBC	421	-	Y	7F7F267D5E
58	61.2	COR	03/11/1991	HBC	391	-	Y	7F7F3E2460
	-	LCR	04/20/1993	HBC	395	-	Y	7F7F3E2460
	60.0	COR	08/15/1993	HBC	402	-	Y	7F7F3E2460
	-	LCR	12/14/1993	HBC	395	-	Y	7F7F3E2460
	-	-	04/11/1999	HBC	400	-	Y	7F7F3E2460
	-	LCR	05/02/2001	HBC	403	-	Y	7F7F3E2460
	-	LCR	04/08/2002	HBC	410	-	Y	7F7F3E2460
	-	LCR	04/11/2002	HBC	410	-	Y	7F7F3E2460
	60.2	-	05/06/2003	HBC	399	-	Y	7F7F3E2460
59	-	LCR	04/27/1990	HBC	399	-	N	7F7F45656B
	60.7	-	05/06/2003	HBC	419	-	Y	7F7F45656B