Native Fish Monitoring Activities in the Colorado River within Grand Canyon during 2002

Annual Report

Contract # 01WRAG0046

Prepared for

Grand Canyon Monitoring and Research Center

Prepared by

SWCA Environmental Consultants

October 2003

Native Fish Monitoring Activities in the Colorado River within Grand Canyon during 2002

ANNUAL REPORT

Contract # 01WRAG0046

Prepared for

Grand Canyon Monitoring and Research Center
2255 N. Gemini Drive
Flagstaff, Arizona 86001

Prepared by

Helene C. Johnstone, Matt Lauretta, and Melissa Trammell[1]
SWCA Environmental Consultants
114 N. San Francisco St., Suite 100
Flagstaff, Arizona 86001

October 28, 2003

[1] Melissa Trammell is currently employed by the National Park Service
324 South State Street, Suite 218, Salt Lake City, Utah 84145-0155

TABLE OF CONTENTS

List of Tables

List of Tables, continued

List of Figures

List of Figures, continued

1.0 INTRODUCTION

The Grand Canyon Monitoring and Research Center (GCMRC) determined that fish sampling efforts in 2002 should concentrate on developing and implementing a long-term monitoring program to estimate the distribution and relative abundance of selected fish species in the Colorado River ecosystem. A cooperative effort is underway between GCMRC, U.S. Fish and Wildlife Service (FWS), Arizona Game and Fish Department (AGFD), and SWCA Environmental Consultants (SWCA) to accomplish these objectives. The division of sampling and reporting responsibilities between agencies in 2002 is a continuation of the division of labor in 2000 and 2001, with FWS responsible for sampling in the Little Colorado River (LCR), AGFD responsible for non-native salmonids in the mainstem, and SWCA responsible for native fishes and warm-water non-native fishes in the mainstem. This document details the contributions of SWCA to the cooperative effort.

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

A long-term monitoring program for the fishes of Grand Canyon is needed to track the status and trends of the fish community, particularly the endangered humpback chub and other native species. The research and monitoring conducted in the Canyon since 1990 have produced an inconsistently collected body of knowledge of Grand Canyon fishes. The intensity, methods, and range of sampling have varied considerably from year to year with changes in researchers and management agencies. Recent sampling programs have also lacked randomly distributed sample sites. This shortcoming may have resulted in misleading Catch-Per-Effort (CPE) indices for humpback chub (HBC). By sampling only areas of known HBC concentrations (aggregations), CPE could remain stable while the population was actually declining. This condition is described as hyperstability. Fish populations typically show "range contraction" into the most favorable habitats when total abundance declines, and monitoring efforts that do not sample areas outside of aggregations are unlikely to detect either range contraction or expansion (Walters & Korman, unpublished). If the long-term monitoring program is going to track changes in fish densities as a result of management actions, it is necessary to include all available habitats in the sample allocation model.

To at least partially address issues of variance and hyperstability, the strategy developed for long-term monitoring increases the number of samples to be collected and incorporates randomly distributed sample sites. The computer program *Sampling.exe* (Carl Walters, unpublished.) has been used by each of the cooperating agencies to identify a sampling design appropriate to that agency's monitoring responsibilities. Sampling.exe relies on the input of past catches (historical data) and conducts a power analysis to allocate sample effort among reaches. Historical data is biased in that much time was spent sampling at areas of high HBC concentration, and much less in other areas. Sample allocation output for current monitoring was corrected for these problems. In following years, the sample allocation model can be repopulated with more randomly collected data (data collected since 2002). Sample allocations will be adjusted as these data repopulate the Sampling.exe model. At least 5 years of data should be collected under this protocol to discern trends in fish abundance and distribution. It is expected that methods and sample sizes will be refined in response to experience in the field.

This approach pertains to monitoring efforts in both the Colorado River and the Little Colorado River, and to native, warm-water non-native, and salmonid species. Monitoring the entire fish community is important because of potential interaction of other species with the endangered humpback chub, especially predation and competition (Courtenay et al. 1984). A list of species presently occurring in the Grand Canyon is given in Table 1 (adapted from Valdez and Ryel 1995). We consider the priority for monitoring to be high for most species commonly encountered in the Grand Canyon.

Obtaining and maintaining some measure of fish species distribution and relative abundance is essential to assess the effectiveness of management actions. The distribution and abundance of humpback chub, as well as the other species and their interactions may change as a response to management actions or the lack thereof. Management actions are generally intended to benefit the endangered humpback chub by increasing recruitment and population size and expanding their distribution within Grand Canyon. 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 (LSSF) 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 may be directed towards disadvantaging non-native species such as the rainbow trout.

1.2 Monitoring for Native and Warm-Water Non-Native Fishes in 2002

In accordance with this long-term monitoring strategy, SWCA's mainstem monitoring for native species and warm-water non-natives in 2002 included stratified-random sampling in the mainstem with trammel nets, hoop nets, and seines to obtain catch rate statistics, including sample mean and variance, and Catch-Per Effort (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 represent the fish community when used in combination (Valdez and Ryel 1995, Trammell et al. 2002, Trammell and Valdez 2002, AGFD 1996, 2001).

Catch rate statistics will be monitored annually to evaluate the CPE and trends of the target species over periods of at least 5 years. Because of CPE variability, Coefficient of Variation (CV), a measure of relative variability, will be used to determine if catch data will support the long-term monitoring model (discussed in section 3.4). CV values should be close to a target of 0.10 for each species in order for trends to be detectable over 5 year periods.

The sampling design described in the Methods section is intended to evaluate the efficacy of the proposed sampling methods to meet the needs of a long-term monitoring program for native and warm-water 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 warm-water non-native fish populations varies. Precision of measurement varies with species, and is dependent on the abundance and distribution of each species; vulnerability to gears; and sample size and spatial stratification, which is 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 analysis of existing data (Gerrodette 1987, AGFD unpublished data), we do not expect changes in relative abundance to be detectable on time scales less than 5 years.

1.3 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 and 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 (range and relative abundance) of each species in the CRE.
- Estimate annual length distribution of each species in the CRE.

Warm-Water 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 (range and relative abundance) of the warm-water fish community in the CRE.

2.0 METHODS

2.1 Study Area and Methods

The study area is 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 1993). To estimate the relative abundance, distribution, and annual length distribution of the selected fish species within the study area, samples were taken with trammel nets, hoop nets, and seines in a stratified random distribution from RM 0 to 226 and allocated within eleven geomorphic reaches defined by Schmidt and Graf (1988, 1990). CPE was calculated for each gear type. Hoop net CPE was reported as # of fish/set (sets were approximately 18 hours). Trammel net CPE was reported as # of fish/2 hour net set. Seine CPE was reported as # of fish/meter^2. Changes and trends in relative abundance and distribution will be assessed with changes in catch rates over time (CPE index over 5-year periods); significant changes are unlikely to be detected over time intervals smaller than 5 years. The slope of the regression line 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.

This allocation of sampling will be reevaluated at the end of each year of sampling. Although sampling was conducted at randomly chosen river miles; the habitat sampled was still limited to shoreline areas where nets could be effectively set. Typically hoop net areas are characterized by low velocity shoreline, nets were set at depths of three meters or less. Trammel nets are typically set at separation points where eddy current and main current diverge, also known as eddy fences.

2.2 Number of Samples

The number of samples needed to achieve a Coefficient of Variation (CV) of 0.1, given the historic variance, was estimated using the program *Sampling.exe*. The data used as input for this program were historic catch of each species by mile, generated from all sampling conducted in the Colorado River mainstem from 1990 to 2000 (Bill Persons, AGFD, pers. comm.). *Sampling.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 eleven geomorphic reaches, as defined by Schmidt and Graf (1988, 1990). This exercise was completed for each gear type (trammel nets, hoop nets, seines) and eight species: rainbow trout (RBT), brown trout (BNT), common carp (CRP), fathead minnow (FHM), humpback chub (HBC), flannelmouth sucker (FMS), bluehead sucker (BHS), and speckled dace (SPD). Other species were lumped into one group due to low incidence of capture.

2.3 Selection of Gear Types for Species

Gear types vary in capture efficiency for different species. For example, electrofishing 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. This is reflected in the species composition based on the two gear types (Figure 1). 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 2002). Using the appropriate gear type for the target species allows greater precision of measurement with fewer samples. The relative efficiencies of gear types are reflected in the program allocations. For some species/gear combinations, the program calculated a reasonably achievable number of samples; for others, the number of samples calculated would be unreasonable to obtain (Table 2). 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 samples cannot be achieved for most species.

The gear, or combination of gear types, that best suited each species was selected. Not specified in the program but important to consider are the length distributions of fish captured by each gear type and habitats that can be sampled. For example, trammel nets capture large adult fish while hoop nets capture smaller, juvenile fish as well as adults. Seines are the best gear type for collecting YOY native fishes and small-bodied non-natives and can be used to sample backwaters. Thus, all gear types were used to adequately represent the length distribution of the selected species, as well as the relative abundance. 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 may be appropriate for FHM and SPD, depending on availability of habitats.

2.4 Spatial Stratification and Sample Allocation of Gear Types

The *Sampling.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 *Sampling.exe* output allocated a disproportionate number of trammel and hoop samples to areas that were historically sampled, in which samples were not random. Sampling has been conducted primarily at areas of known concentration of HBC and other native fishes. This inequality is greater for trammel net and hoop net sampling than for electrofishing and seining, which have been more evenly distributed. The long-term monitoring program is intended to rectify this inequality; therefore, for the final sample allocation the total number of trammel and hoop net samples needed was increased, and the distribution of samples was adjusted for more equitable sampling in less frequently sampled areas (shaded column in Table 3). Since the distribution of HBC is clumped in smaller areas within the geomorphic 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 six known aggregation sites as described by Valdez and Ryel (1995): 30-mile, LCR, Aisles, Middle Granite Gorge (MGG), Shinumo, and Pumpkin Springs. These data were analyzed independently of randomly collected data. Thus, the long-term native fish monitoring program to date is designed to address two separate issues. 1) Conduct stratified-random sampling for all reaches of the Colorado River and 2) monitor the areas which have high concentrations of native fish especially HBC. The *Sampling.exe* allocation, plus adjustments, resulted in a total of 780 trammel net samples and 936 hoop net samples. The number of seine samples obtained depends on the availability of backwater habitats (determined in the field), but was expected to be less than 200.

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 must include the selected mile, but is 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.

For trammel nets, the *Sampling.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 handling. Therefore, no sampling in addition to that already allocated for FMS and HBC was implemented in the LCR 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 determined to be 30 (the maximum possible per night), irrespective of S*ampling.exe* output (Table 3). Net set locations are constrained by hydrology and were generally set near the top of an eddy at the separation point, or at irregularities along the bank that allow the net to hold away from the shoreline in the current.

Hoop-net sampling prior to 2002 was heavily concentrated near the LCR; therefore, the program allocated nearly all the sampling to the LCR reach. For this sampling design, hoop nets were set concurrently with the trammel nets, which satisfies the program requirements and also supplements program requirements in all other reaches. The minimum number of samples taken at each site was determined to be 36, irrespective of S*ampling.exe* output (Table 3).

The CV of the historical (1990–2002) seine samples was very high for most species, and the *Sampling.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, depending on availability of backwaters, *en route* between net sample sites. At each backwater, 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 subsample of up to 30 of each species (in larger samples) were measured to the nearest 1 mm TL.

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

<u>Hoop Nets</u>: One hoop-net sample is one net, set overnight. 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 # of fish/set.

<u>Seines</u>: One sample is one seine haul. The seine was 3.66 m long by 1.83 m deep and 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, but usually not more than one backwater every two miles. Length and width of haul was recorded to determine effort. CPE is defined as fish/m^2.

2.5 Fish Processing/Data Collection

A standard fish handling protocol was outlined jointly between the GCMRC and the cooperating agencies (Ward 2002). 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 mmTL.
2. Weights (g) were taken on all native fishes >100 mm TL.

3. All native fish and all brown and rainbow trout with an adipose fin clip were scanned for PIT tags. Native fish were PIT-tagged if not already tagged. Trout were not PIT-tagged. All PIT tag numbers were recorded on data sheets and stored in the PIT tag readers for later download.

4. All native fishes were examined for sex, sexual condition, and external parasites.

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

2.6 Sampling Trip Structure and Work Plan

A mainstem sampling program (SWCA and AGFD) incorporating the four gear types was designed to maximize the number of samples obtained on each sampling trip, while minimizing personnel and time requirements. The number of trips and length of each sampling trip was influenced by logistics as well as sampling needs. Four mainstem trips were scheduled, including two electrofishing trips in the spring (AGFD) and two netting trips, one in summer and one in fall (SWCA). The two SWCA netting trips were scheduled in July and September (Tables 4 and 5). The trips were 15 or 17 days long, including one day to rig the boats and equipment, and one day to de-rig. A combination of trammel nets, hoop nets, and seines was used depending on the focus of the trip. The purpose of Trip 1 (July 17–August 2) was to obtain distributional and relative abundance estimates for native fish and to supplement this information for warm-water non-natives. The primary purpose of Trip 2 (September 11–25) was to continue the stratified random sampling initiated on Trip 1. The second purpose of this trip was to sample known HBC aggregations to increase the PIT-tag rate of fish in these areas, and to supplement the estimated number of samples needed in these areas. From 1 to 3 days were spent at each of five main aggregations (30-mile, LCR, Aisles to MGG, Havasu, Pumpkin Springs).

3.0 RESULTS

3.1 Hydrology

Two netting trips were completed as scheduled in July and September. Releases from Glen Canyon Dam followed ROD[2] flows throughout the two sampling periods. Releases fluctuated from approximately 10,000 to 18,000 Cubic Feet per Second (CFS) during Trip 1 (Figure 2a) and from 5,000 to 10,000 CFS during Trip 2. Monsoon storms at the beginning of Trip 2 caused flooding in the tributaries, particularly the LCR (Figure 2b). This affected sampling below the

---

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

LCR because hoop nets could not be set for one night immediately after the flood. Increases in catch of HBC, FHM, plains killifish (PKF), and red shiner (RSH) were observed below the LCR after the flood.

3.2 Distribution of Effort

Stratified-random and aggregation site trammel-net samples totaled 818, and hoop net samples totaled 897 for both trips combined. A total of 148 seine samples were also taken. The number and distribution of samples acquired for each gear type were close to the target numbers of 780 trammel nets, and 936 hoop nets (Table 6). Approximately one-third or 32% (264/818) of trammel nets and 34% (309/897) of hoop nets were fished at aggregation sites (Table 7). Distribution of effort during the two trips is shown in Figure 3.

3.3 Catch and Variance of Species by Reach and Gear Type

Results should be interpreted at two levels. 1) All native fish and exotics captured in stratified-random samples and 2) capture results for HBC aggregation samples. Stratified-random results are reported as total values for all samples and CPE is shown in 10-mile increments. HBC aggregations results are reported by site, because almost all HBC were captured within aggregation samples.

Hoop Nets: FMS was the most dominant native fish in the hoop net catches (48 fish), followed by non-native RBT (46 fish) (Table 8). Of 897 hoop sets, a total of 157 fish were caught (Table 8). Only 17 HBC were caught in hoop nets, with a mean of 0.023 (variance = 0.045) fish per hoop net set. Not surprisingly HBC CPE was greatest in the LCR reach (Figure 4). Hoop net CPE is shown for all species in Figures 4-11. The overall mean CPE, standard error, and CV were calculated for each species captured in hoop nets (Table 9). The target CV of 0.1 was not achieved for any species; however, some species approached this target (FMS CV=0.174, RBT CV=0.171, SPD CV=0.243) (Table 9). CV for BHS, BNT CCF, FHM and HBC however was much higher than the desired target of 0.10.

Trammel Nets: More HBC were captured in trammel nets than in the other two gear types, and all were captured from Reaches 2 through 7 (RM 31–159) (Table 10). The most numerous native species captured by trammel net was BHS (55 fish), and the most numerous non-native species was RBT (163 fish). Out of 818 trammel net sets, 442 fish were caught. Thirty-eight (38) HBC were captured, with a mean of 0.046 (standard error = 0.01) fish per net (Table 11). Trammel net HBC CPE was greatest between river miles 30-39, 120-129, and 150–159 (Figure 4), and represents locations of known aggregations. Trammel net CPE is shown for all species in Figures 4–13. BHS (0.149), CRP (0.193), FMS (0.159), and RBT (0.152) were close to the target CV of 0.1 (Table 11). The overall HBC CV was 0.224 (Table 11) however this value may be biased due to increased sampling at aggregation sites, CV for HBC by aggregation is reported below.

Seines: SPD were the most numerous species in seine samples, with 1,414 fish caught, primarily in Reaches 8–11. Sucker species were well represented in the seine samples. All suckers captured by seines were YOY; and found in all reaches except Reach 4. Out of 148 seine samples, 1,100 FMS were caught (Table 12). Thirteen (13) HBC were captured at RM 60–70 and 160 (Figure 4). Variance was high for all species (Table 13). Seine CPE is shown for all species in Figures 4–16.

3.3.1 HBC

HBC aggregations were also analyzed separately from stratified-random analysis due to potential bias from increased sampling at these sites. Mean hoop net CPE and CV values were 0.25 (SE 0.08) and 0.34 respectively for the LCR aggregation and 0.06 (SE 0.04) and 0.70 for Lava Chuar to Hance. Trammel net CPE and CV values ranged from 0.33 (SE 0.11) and 0.33 for the Middle Granite Gorge aggregation (MGG), 0.21 (SE 0.17) 0.82 for the 30-mile aggregation, 0.17 (SE 0.08) and 0.48 for the LCR aggregation, 0.03 (SE 0.02) and 0.70 for the Lava Chuar to Hance aggregation (Table 14). CPE values by reach are lower than those reported for aggregations because of the additional samples included in analysis (e.g. the Reach 1 (RM 0–30) mean trammel net CPE = 0.08 (SE 0.07) (Table 11) however mean CPE for the 30-mile aggregation (RM 29.4-30.7) = 0.21(SE 0.08) (Table 14). No HBC were caught in the Aisles, Havasu, or Pumpkin Springs aggregations, as defined by Valdez and Ryel (1995).

3.3.2 Trends

Actual sample sites were reported in Tables 4 and 5; samples are clumped within 1 to 2-mile sections of each study reach due to logistics. The data are summarized into 10-mile sections for graphing purposes. Trends in river-wide distribution as well as length distribution were observed in selected species. Hoop net CPE values for HBC were higher around the LCR (RM 60) than in any other reach, while trammel net CPE values were highest between RM 30-39, RM 120–129, and RM 150–159 (Figure 4). Seine values were highest for HBC <200 mm at RM 160–169. Not surprisingly the bulk of total HBC catches (47/59 or 79.66%) were at known aggregation sites. Of those remaining, 6/12 or 50% HBC were captured within 1 mile of documented aggregations (Valdez & Ryel 1995) and the other 50% were within 2.5 miles of aggregations (Table 15). Interpretation of these trends is addressed in the discussion

BHS were poorly represented in hoop net samples; however, they were the most dominant native species in trammel net catches. In general, BHS increased in numbers downstream from the LCR to RM 150 (Figure 5). FMS were caught in all reaches except reach 1 (Table 8 & 10). FMS hoop and trammel CPE values were highest below the LCR and in RM 160–179. FMS YOY were distributed mostly below RM 160, and represented in the seine samples (Figure 6). SPD CPE increased downstream, especially in seine samples (Figure 7). Unidentified sucker species also increased downstream as shown in the seine samples (Figure 8). BNT trammel net CPE was highest in RM 80 (Figure 9). RBT CPE values decline between Lees Ferry and RM 60 (above the confluence with LCR) (Figure 10). The warm-water non-natives channel catfish (CCF), CRP, striped bass (STB), and FHM all increased in CPE downstream. PKF and RSH were distributed in RM 60–190, but were most abundant at RM 60–70 (Figures 15–16).

Length distribution for HBC and all other species are shown in Figures 17–29. It is important to remember that each of the three gear types is selective for size, which is why the combination of all gears is necessary to adequately sample all size classes. Some species, however, will be under represented because of gear biases, especially the large-bodied non-natives such as CCF and STB. Numbers of small HBC were greater in the Trip 2 samples (Figure 17) following the LCR flooding event (Figure 2b). Two separate size classes were observed for BHS (30–90 mm) and (210–310 mm) (Figure 18). FMS ranged from 15 mm to 600 mm; however, most were between 30 and 100 mm (Figure 19). SPD length distribution is shown in Figure 20. Unidentified sucker species increased downstream as shown in the seine samples (Figure 21). BNT ranged in size from 200 to 430 mm (Figure 22). RBT ranged in size from 20 to 400 mm, with the bulk of fish between 220 and 380 mm (Figure 23). Relative abundance of FMS was highest in hoop net samples followed closely by RBT. RBT were the most abundant fish in trammel nets followed by BNT and BHS (Figure 30). Relative abundance of all species is shown in Figure 30. Sampling year 2002 represents the first year of the 5-year long-term monitoring experiment.

3.4 Testing of Long-Term Monitoring Design

The statistical power of the monitoring program to detect changes in fish abundance over time was tested using the program *TRENDS* (Gerrodette 1987). Power (1-β) was calculated by *TRENDS* given certain assumptions and input. We used the Coefficient of Variation (CV) calculated from the 2002 sampling data as input, and adjusted the desired rate of change to be detected (20% over one year, or 50% over 5 years with an exponential decline). Other assumptions in *TRENDS* input include a 2-tailed test for trends in both negative and positive directions; significance value (α)=0.05; CV remains constant with abundance; and 5 years of monitoring.

The power of the monitoring program to detect a given rate of change varies considerably between gear types and species with the differences in CV, the direction of the trend, and the length of the study (Table 16a and 16b). In general, tests are more sensitive to a negative trend (decline) than a positive trend (increase), and there is a much lower probability of detecting an exponential decline of 20% over 5 years than a 20% decline in 1 year. We therefore calculated the power to detect both a 20% decline in 1 year, and an exponential decline of 50% over 5 years. We also estimated the CV and power if effort (number of samples) was doubled to attempt to reduce the CV towards the desired level of 0.10.

For HBC trammel net samples, there is an 81% chance of detecting a 20% decline in 1 year. However, there is only a 41% chance of detecting a 50% decline over 5 years. If sample size is doubled, the power increases to a 67% chance of detecting a 50% decline over 5 years, and the estimated CV falls to 0.16. For other native fish (bluehead and flannelmouth sucker) doubling the sample size lowers the CV to 0.11 and increases power to 92% (Table 16a). The statistical power for hoop net sampling was generally lower than for trammel net sampling (Table 16b). Doubling the hoop net effort reduces CV towards the desired level of 0.10 for FMS and RBT.

4.0 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 targeted known aggregations of humpback chub or other native fishes might not detect changes to the distribution of these fishes, including expansion or contraction of range, and might not detect early changes in abundance 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 first year of spatial and temporal distributional data (since 1993) for all native and non-native fish species. These data will provide important current baseline information from which to gauge changes as the result of management actions (e.g., mechanical removal of salmonids, temperature control device and experimental flows).

The results of this first year of distributional sampling indicate the HBC has not expanded into additional areas; rather their range of occupied habitat appears to have contracted. In fact HBC were only captured in six of nine aggregation areas reported by Valdez and Ryel (1995) and rarely occurred in random samples outside of aggregations. Areas in which HBC had been previously captured but were not captured in 2002 include Bright Angel Creek inflow (RM 83.8–92.2), Stephen Aisle (RM 114.9–120.1), and Pumpkin Spring (RM 212.5–213.2). Bright Angel Creek inflow was also intensively sampled by electrofishing in 2001 and 2002 by AGFD, but no chubs were captured (R.S. Rogers, AGFD pers. comm.).

The increased number of samples and the stratified-random distribution of sampling in 2002 partially addressed the issues of variance and hyperstability. Annually, historical CV for HBC CPE has ranged from 0.18 to 0.37 for 50 to 250 trammel net samples per year at the aggregation sites (Lew Coggins, USGS unpublished data). With the increased sampling in 2002, sample variance was anticipated to decline, to a CV target level of 0.10. The overall CV of HBC in 2002 was 0.22, CV values were even higher when analyzed by aggregations or reaches (Table 14), so variance and CV did not decline as expected. A comparison of overall HBC CV values and aggregation CV values suggests that the high number of zeros (59 HBC/1,715 HB and TK net sets) in the overall sample caused the CV to be lower than when aggregation sites are analyzed separately. Random monitoring alone, does not appear to be an effective strategy for tracking trends in mainstem HBC. However, when coupled with intensified efforts at aggregations, the dual objectives of the monitoring program should be met (monitor mainstem HBC, and generate baseline distributional and relative abundance data for all other native fishes).

While CVs for BHS, and FMS did not reach the target level in 2002, values were within 0.15 (Table 11). The statistical power of the sampling design to detect trends, showed that increasing the sample size by doubling effort could further reduce CVs and increase power to near the target level. Alternatively, these data could simply be used as presence and absence data. While variability may be too high for statistical comparisons, or modeling of trends, annual or bi-annual river-wide capture data for all species would be a useful monitoring tool.

The distribution of species along the Colorado River captured by seining during this study was generally similar to that observed by Trammell et al. (2002), Valdez and Ryel (1995), and AGFD (unpublished data). Catch and CPE of both native and non-native warm-water species increased downstream, while catch of salmonids decreased downstream from Lees Ferry. The primary difference between the 2002 results and previous findings was in the distribution and abundance of FHM between 2002 and the 2000 LSSF experiment. In 2000, a significant increase was observed in the catch and CPE of FHM over previous years (1991–1997) (Trammell et al. 2002); however, in 2002, the catch and CPE of FHM were similar to those of 1991–1997. The increase seen in this species during 2000 was not long lasting.

The distribution of YOY and juvenile HBC and some other species (FHM, PKF) changed between the two sampling trips. There was an increase in the catch of these species below the LCR inflow during the second sampling trip. Sampling below the LCR occurred immediately after a monsoon storm resulted in a pulse of water from the LCR, which apparently flushed the chub and other species from the LCR into the mainstem where our sampling captured them. The increase in the number of small chubs in the catch below the LCR increased the overall CPE, changed the variance, and extended the apparent distribution downstream. However, these fish are not expected to remain in this area. Temporary increases in numbers and distribution of smaller HBC as a result of monsoon floods have been observed before, with no long-term increase in the distribution of the species (Valdez and Ryel 1995, Trammell et al. 2002). This temporary change in distribution and abundance could be viewed as skewing results by lengthening the distribution of HBC downstream from the LCR and changing the variance of the CPE. Because monsoon floods and subsequent emigration of chubs downstream is a frequent annual event, we expect the intra-annual variation in CPE to contribute to the variance most years. Thus it is an expected component of the variability in catch and should be included in the analyses.

The length distribution of each species was pooled from all gear types. The changes in length distribution seen in HBC, BHS, FHM, PKF, and RSH are a reflection of the increased numbers of these fish captured below the LCR during the second trip, after the monsoon flood. There were increases in the number of fish captured, and particular increases in the number of smaller fish (<300 mm). These fish were captured primarily by seines, but increased numbers of HBC and BHS were also captured with hoop nets and trammel nets. PKF saw the greatest increase from Trip 1 to Trip 2, with almost all PKF captured within 10 river miles below the LCR during Trip 2 with seines. This post-monsoon effect can be expected in any year with sufficient summer (July-September) rains to produce tributary flooding.

These data represent the first data point in what is expected to be a long-term data set. Therefore few conclusions can be drawn regarding changes in distribution or relative abundance until a few more years of data have been collected and analyzed. Five years of data are expected to be needed to adequately determine trends. However high CV values may limit trend-modeling opportunities. We offer some conclusions and recommendations for improving the methods. In addition to the long-term monitoring program outlined herein, periodic short-term population estimates should be considered as part of the long-term monitoring program to obtain absolute abundance estimates on HBC and other species of interest in the mainstem.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 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. Despite the efforts to counter these issues, especially the increase in sample allocation during 2002, CV for all samples was higher than the targeted level of 0.10. Most species however were very close, such as BHS, RBT, FMS, CRP, and possibly HBC (CV 0.149-0.224). With a CV of 0.15 there is a 98% chance of detecting a 20% decline in one year, with a 5-year data set (Table 16a). Therefore, current CV values for these species may prove to be acceptable for long-term monitoring. Doubling sample size would reduce CV to nearly acceptable levels (Table 16b). However, there are funding and time constraints to consider. Additionally, this year's data does provide important presence and absence data, as well as relative distribution of species.

Analysis of results for 2002 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 zero's). Monitoring results in 2002 (as well as 2003) confirmed high affinity of HBC for certain previously described mainstem sites. Under current conditions, additional samples outside of these areas will not increase catch rate or reduce variability for HBC, but, would detect range expansion.

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. This analysis issue should be addressed among the cooperators to ensure all monitoring concerns will be met in the future.

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 it for future monitoring. Now in the second year of the long-term monitoring program, comparisons and distribution trends from years one and two will be addressed in the 2003 final report. In conclusion:

- Sample sizes were inadequate to reach target CV of 0.1 for trammel nets and hoop nets.

- Doubling sample size will 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.

5.2 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.

- Add periodic mark-recapture population estimates to estimate absolute abundance of HBC.

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

6.0 REFERENCES

Arizona Game and Fish Department (AGFD). 1996. Ecology of Grand Canyon backwaters. Final Report to U.S. Bureau of Reclamation, Glen Canyon Environmental Studies. Arizona Game and Fish Department Research Branch, Phoenix.

Arizona Game and Fish Department (AGFD). 2001. Salmonid population size in the Colorado River, Grand Canyon, Arizona. Fishery Fact Sheet. Report to Grand Canyon Monitoring and Research Center, Flagstaff, Arizona. Arizona Game and Fish Department, Phoenix.

Coggins, L., C. Walters, C. Paukert, and S. Gloss. 2003. An overview of the status and trend information for the Grand Canyon population of the humpback chub, *Gila cypha*. Prepared by the Grand Canyon Monitoring and Research Center, Flagstaff, Arizona, for the Glen Canyon Adaptive Management Group Ad Hoc Committee on Humpback Chub. 22 pp.

Courtenay, W.R., Jr., and J.R. Stauffer, Jr. 1984. Distribution, biology, and management of exotic fishes. The Johns Hopkins University Press, Baltimore, Maryland.

Gerrodette, T. 1987. A power analysis for detecting trends. Ecology 68:1364–1372.

Schmidt, J.C., and J.B. Graf. 1988. Aggradation and degradation of alluvial sand deposits, 1965 to 1986, Colorado River, Grand Canyon National Park, Arizona. U. S. Geological Survey Open File Report 87–561 Salt Lake City, Utah. 120 pp.

Schmidt, J.C., and J.B. Graf. 1990. Aggradation and degradation of alluvial sand deposits, 1965 to 1986, Colorado River, Grand Canyon National Park, Arizona. U. S. Geological Survey Professional Paper No. 1439. Salt Lake City, Utah. 74 pp.

Stevens, L. 1993. The Colorado River in Grand Canyon: A guide. Red Lake Books, Flagstaff, Arizona. 115 pp.

Trammell, M.A., R.A. Valdez, S.W. Carothers, and R.J. Ryel. 2002. Effects of a low steady summer flow experiment in the Grand Canyon, Arizona. Final Report to Grand Canyon Monitoring and Research Center, Flagstaff, Arizona. SWCA Environmental Consultants, Flagstaff, Arizona.

Trammell, M.A., and R.A. Valdez. 2002. Population estimates of humpback chub near the LCR inflow, Colorado River in the Grand Canyon, Arizona, in 2001. Final Report to Department of the Interior, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona. SWCA Environmental Consultants, Flagstaff, Arizona.

Valdez, R.A., and R.J. Ryel. 1995. Life history and ecology of the humpback chub (*Gila cypha*) and the Colorado River, Grand Canyon, Arizona. Final report to the Bureau of Reclamation, Salt Lake City, Utah. Contract No. 0-CS-40-09110. BIO/WEST Report No. TR-250-08.

Walters, C. and J. Korman. 2001. Design for long term fish monitoring in Grand Canyon. Unpublished report to Grand Canyon Monitoring and Research Center, Flagstaff, AZ.

Ward, D.M. 2002. Standardized methods for handling fish in Grand Canyon research. Draft Report to Grand Canyon Monitoring and Research Center, Flagstaff, AZ. Arizona Game and Fish Department, Phoenix, AZ.

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. Number of samples for each species estimated by program *Sampling.exe*. Appropriate gear types for each species are in bold, inappropriate gear types for each species are shaded areas.

Gear	Species								
	BHS	**BNT**	**CRP**	**FHM**	**FMS**	**HBC**	**RBT**	**SPD**	**OTH**
Trammel nets (TN)	**345**	1000	1000		**132**	**55**	**86**		1000
Electrofishing (ES)	1000	**740**	**300**	**200**	1000	**126**[a]	**110**	**300**	1000
Hoop nets (HP)	1000	1000	1000	1000	1000	**380**	**300**	1000	1000
Seines (SN)	**600**	1000	1000	**86**	**380**	**470**	**280**	**86**	**1000**

[a] Electrofishing is only appropriate for juvenile humpback chub.

Table 3. Final sample number and allocation (shaded columns), and sample number and allocation from *Sampling.exe* output for 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 no/year.

Gear:			Trammel Nets					Hoop Nets				
			Number per Year					Number per Year				
Reach	Start mile	End mile	BHS	FMS	HBC	No/year output	No/year allocated	BHS	FMS	HBC	No/year output	No/year allocated
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			.1	0.09	0.07			0.19	0.32	0.1		

Table 4. Schedule of sample sites, area sampled, and number of samples acquired during Trip 1. Shaded areas are aggregation sites.

Day	Camp	Camp RM	Start Mile	Area Sampled	Number of samples		Sample Miles
July 17	RIG/LF	0			Trammel	Hoop	
July 18	North Canyon	19	19	18.4– 20.0	30	36	1.5
July 19	Nankoweap	53	54	54.0– 55.7	30	36	1.3
July 20	Crash	62.5	62	61.8– 63.1	30	36	1.2
July 21	Crash	62.5	63	63.1– 65.4	30	36	2.3
July 22	Cremation	87	87	86.6– 89.0	30	36	0.9
July 23	Boucher	96.9	98	96.7– 97.7	30	36	1.0
July 24	103	103	103	102.7–103.7	30	36	1.0
July 25	Doll's House	130.4	129	129.2–130.4	29	36	1.2
July 26	Matkatamiba	146	147	146.0–147.9	30	36	1.9
July 27	160	160	159	158.2–160.7	30	36	0.7
July 28	Honga Springs	177	177	176.9–178.5	30	36	1.5
July 29	Hell's Hollow	182.5	181	179.9–182.6	30	36	0.7
July 30	202	202	201	201.0–202.3	30	36	1.3
July 31	Three Springs	216	215	214.9–216.1	30	36	1.2
Aug 1	Last Camp	224.5	223	223.1–224.8	29	0	1.7
Aug 2				De-rig			
	Total				**448**	**504**	

Table 5. Sampling schedule for native fish mainstem sampling Trip 2 (September 11–25), 2002. Shaded areas are aggregation sites.

Day	Camp	Camp RM	Start Mile	Sample area	Number of samples		Sample Miles
Sept 11	RIG/LF	0			Trammel	Hoop	
Sept 12	30 Mile	30	30	29.4– 30.8	30	36	1.4
Sept 13	Espejo	66.9	68	67.6– 68.5	30	0	0.9
Sept 14	Unkar	74.2	75	73.5– 74.9	30	33	1.4
Sept 15	Hance	77	77	77.1– 78.0	30	36	0.9
Sept 16	Grapevine	81.2	81	79.8– 81.6	30	36	1.8
Sept 17	Shinumo	108.6	108.6	107.1–108.6	30	36	1.5
Sept 18	Stephen Aisles	117	117	116.6–118.0	30	36	1.4
Sept 19	Randy's Rock	126.5	126.2	126.5–127.9	30	36	1.4
Sept 20	Dubendorf	134	132	132.2–133.3	30	36	1.1
Sept 21	Havasu	157	157	157.0–158.2	30	36	1.2
Sept 22	186	187	187	187.1–188.0	20	36	0.9
Sept 23	Pumpkin Springs	214	213	212.8–214.0	30	36	1.2
Sept 24	Last camp	225	224	224.5–225.5	20	0	1.0
Sept 25				De-rig			
	Total				**370**	**393**	**16.1**

Table 6. Comparison of trammel net and hoop net samples allocated and acquired in 2002. If sample output for trammel nets was less than 30, the minimum sample size defaulted to 30. If sample output for hoop nets was less than 36, the minimum sample size defaulted to 36.

Reach	Trammel net			Hoop net		
	No/year output	**No/year abllocated**	**No/year actual**	**No/year output**	**No/year allocated**	**No/year actual**
1	30	60	30	36	72	36
2	47	30	60	36	36	72
3	152	150	90	332	180	72
4	46	60	60	36	72	69
5	30	120	150	36	144	180
6	30	90	90	36	108	108
7	30	90	89	36	108	144
8	30	60	60	36	72	36
9	78	30	50	36	36	72
10	30	60	90	36	72	108
11	30	30	49	36	36	0
	533	780	**818**	692	936	**897**

Table 7. Sample allocation and distribution of samples within HBC aggregation sites.

Reach	RM's	Samples allocated	Actual samples	Samples collected w/in aggregation	Aggregation (RM)
1	0–30	60	60	30	29.4–30.7
2	31–56	30	30		
3	57–69	150	90	60	61.8–65.3
4	70–79	60	66	30	73.5–74.9
5	80–109	120	144		
6	110–129	90	80	30,50	116.7–117.4, 126.5–129.7
7	130–159	90	99	24	157.2–157.7
8	160–179	60	60		
9	180–199	30	50		
10	200–219	60	90	27	212.8–213.95
11	220–225	30	49		
Totals		**780**	**818**	**251**	

Table 8. Number of fish captured with hoop nets by species and reach.

Reach	BHS	BNT	CCF	FHM	FMS	HBC	RBT	SPD
1	0	0	0	0	0	0	12	0
2	0	1	0	0	0	0	12	0
3	0	0	1	0	2	18	3	0
4	0	0	2	0	25	2	4	0
5	0	2	0	2	4	0	7	1
6	0	1	0	1	0	1	3	0
7	1	0	0	2	6	0	5	3
8	0	0	0	4	8	0	0	4
9	0	0	2	2	2	0	0	5
10	0	0	0	1	1	0	0	7
Totals	**1**	**4**	**5**	**12**	**48**	**21**	**46**	**20**

Table 9. Mean, variance, and coefficient of variation (CV) of catch per effort (CPE) of hoop net samples.

Hoop	BHS	BNT	CCF	FHM	FMS	HBC	RBT	SPD	Total
FISH	1	4	5	12	48	21	46	20	157
SAMPLES	897	897	897	897	897	897	897	897	897
ST DEV	0.033	0.067	0.088	0.149	0.278	0.213	0.262	0.162	0.52
ST ERROR	0.001	0.002	0.003	0.005	0.009	0.007	0.009	0.005	0.02
VAR/MEAN	1.000	0.997	1.396	1.655	1.448	1.931	1.342	1.179	1.53
CV	1.000	0.499	0.528	0.371	0.174	0.303	0.171	0.243	0.10
Sets with Fish	1	4	4	9	38	17	40	18	121

Table 10. Number of fish captured with trammel nets by species and reach.

Reach	BHS	BNT	CCF	CRP	FMS	HBC	RBT	SPD
1	0	0	0	0	0	0	36	0
2	0	1	0	0	14	5	74	0
83	7	1	0	0	11	10	20	0
4	11	0	0	1	1	5	7	0
5	10	56	0	2	4	2	13	0
6	10	4	2	4	2	11	4	0
7	12	3	0	7	5	5	6	0
8	1	4	3	3	12	0	3	0
9	2	1	9	5	1	0	0	0
10	2	0	11	13	2	0	0	3
11	0	0	1	0	0	0	0	0
Totals	**55**	**70**	**26**	**35**	**52**	**38**	**163**	**3**

Table 11. Mean, variance, and coefficient of variation (CV) of catch per effort (CPE) of trammel net samples.

Trammel	BHS	BNT	CCF	CRP	FMS	HBC	RBT	SPD	Total
FISH	55	70	26	35	52	38	163	3	442
SAMPLES	818	818	818	818	818	818	818	818	818
MEAN	0.067	0.086	0.032	0.043	0.064	0.046	0.199	0.004	0.54
ST ERROR	0.010	0.018	0.008	0.008	0.010	0.010	0.030	0.002	0.04
VAR/MEAN	1.225	2.947	1.663	1.302	1.323	1.903	3.787	0.998	2.71
CV	0.149	0.205	0.253	0.193	0.159	0.224	0.152	0.577	0.08
Sets with Fish	47	45	20	30	44	27	90	3	244

Table 12. Number of fish captured with seines by species and reach.

Reach	BHS	CRP	FHM	FMS	HBC	PKF	RBT	RSH	SPD	SUC
2	0	0	0	1	0	0	13	0	0	0
3	0	1	23	19	3	180	0	4	1	0
4	0	0	21	0	7	75	1	8	1	0
5	0	1	0	3	0	0	0	0	5	1
6	1	2	23	36	0	26	0	0	6	0
7	0	1	10	8	0	2	5	0	10	0
8	11	1	124	790	3	16	0	0	389	4
9	12	1	33	124	0	4	0	1	326	0
10	5	1	66	112	0	5	0	1	625	0
11	0	0	11	7	0	0	0	0	51	2
Totals	**29**	**8**	**311**	**1100**	**13**	**308**	**19**	**14**	**1414**	**7**

Table 13. Mean, variance, and coefficient of variation (CV) of catch per effort (CPE) of seine net samples.

Seines	BHS	CRP	FHM	FMS	HBC	PKF	RBT	RSH	SPD	SUC
FISH	29	8	311	1100	13	308	19	14	1414	7
SAMPLES	148	148	148	148	148	148	148	148	148	148
MEAN	0.196	0.054	2.101	7.483	0.088	2.081	0.128	0.095	9.554	0.05
ST ERROR	0.065	0.019	0.675	1.904	0.046	1.050	0.053	0.061	2.363	0.02
VAR/MEAN	3.17	0.95	32.08	71.22	3.55	78.46	3.21	5.80	86.49	1.53
CV (SE/MEAN)	0.331	0.345	0.321	0.254	0.523	0.505	0.411	0.644	0.247	0.47
Samples with fish	14	8	39	61	6	19	9	4	63	5

Table 14. Mean, variance, and coefficient of variation (CV) of catch per effort (CPE) for HBC aggregations.

HOOP	30-MILE	LCR	RM 65.7-76.3	BAC INFLOW	SHINUMO	AISLES	M.G.G	PUMPKIN
FISH	0	17	2	0	0	0	0	0
SAMPLES	24	69	33	36	27	36	36	9
MEAN	0.00	0.25	0.06	0.00	0.00	0.00	0.00	0.00
ST ERROR	0.00	0.08	0.04	0.00	0.00	0.00	0.00	0.00
VAR/MEAN		1.96	0.97					
CV		0.34	0.7					
Sets with fish	0	13	2	0	0		0	0
TRAMMEL								
FISH	5	10	2	0	0	0	10	0
SAMPLES	24	60	60	30	9	30	30	5
MEAN	0.21	0.17	0.03	0.00	0.00	0.00	0.33	0.00
ST ERROR	0.17	0.08	0.02	0.00	0.00	0.00	0.11	0.00
VAR/MEAN	3.33	2.27	0.98				1.10	
CV (SE/MEAN)	0.82	0.48	0.70				0.33	
CPE	0.21	0.17	0.03				0.33	
Sets with fish	2	6	2	0	0	0	6	0

Table 15. Number and percent of HBC captured within aggregations compared to stratified-random samples.

AGG	VALDEZ & RYEL 1995 RM	OUR SAMPLES 2002 RM	SAMPLES TK	SAMPLES HB	# CAUGHT HBC
30-MILE	29.8–31.3	29.4–30.7	30	36	5
LCR	57.0–65.4	61.8–65.3	60	72	27
LAVA CHUAR-HANCE	65.7–76.3	67.6–74.9	60	33	4
BAC	83.8–92.2	86.6–87.5	30	36	0
SHINUMU	108.1–108.6	108.1–108.6	9	36	0
STEPHENS AISLE	114.9–120.1	116.7–117.4	30	36	0
MGG	126.1–129.0	126.5–127.9	30	36	10
HAVASU	155.8–156.7		0	0	0
PUMPKIN SPR	212.5–213.2	212.0–213.6	15	24	0
		TOTAL FOR AGG	264	309	46
		TOTAL RANDOM	554	588	13
		TOTAL COMBINED	818	897	59
		PERCENT AGG	32.27	34.44	77.96
		PERCENT RANDOM	67.72	65.55	22.03

Table 16a. Estimates of power to detect a given rate of change in abundance of fish, using the coefficient of variation (CV) calculated from 2002 sampling CPE for trammel nets, with the program *TRENDS* (Gerrodette 1987). Assumptions in *TRENDS* input include 2-tailed test for trends in negative and positive directions, significance value (α) = 0.05, CV remains constant with abundance, and 5 years of monitoring.

Trends input			**Power and CV by SPECIES for Trammel net samples**							
Shape of Curve	**Time Step**	**Rate of Change**	**BHS**	**BNT**	**CCF**	**CRP**	**FMS**	**HBC**	**RBT**	**STB**
Linear	1 year	+0.2	.52	.34	.24	.37	.47	.29	.52	.09
	1 year	-0.2	.98	.87	.72	.90	.97	.81	.98	.21
Exponential	5 years	+0.5	.32	.21	.15	.25	.29	.18	.32	.07
	5 years	-0.5	.69	.47	.34	.51	.64	.41	.69	.10
		CV known	.15	.20	.25	.19	.16	.22	.15	.58
Estimates of CV and power if sample size is doubled and variance remains the same.										
		CV estimated	.11	.14	.18	.13	.11	.16	.11	.41
Exponential	5 years	-0.5	.92	.74	.57	.78	.89	.67	.92	.18

Table 16b. Estimates of power to detect a given rate of change in abundance of fish, using the coefficient of variation (CV) calculated from 2002 sampling CPE for hoop nets, with the program *TRENDS* (Gerrodette 1987). Assumptions in *TRENDS* input include 2-tailed test for trends in negative and positive directions, significance value (α) = 0.05, CV remains constant with abundance, and 5 years of monitoring.

Trends input			**Power and CV by SPECIES for Hoop net samples**							
Shape of Curve	**Time Step**	**Rate of Change**	**BHS**	**BNT**	**CCF**	**FHM**	**FMS**	**HBC**	**RBT**	**SPD**
Linear	1 year	+0.2	NA	.10	.09	.14	.43	.18	.43	.25
	1 year	-0.2	NA	.27	.25	.43	.95	.58	.95	.75
Exponential	5 years	+0.5	NA	.08	.08	.10	.27	.12	.27	.16
	5 years	-0.5	NA	.13	.12	.19	.59	.26	.59	.36
		CV known	1.0	.50	.53	.37	.17	.30	.17	.24
Estimates of CV and power if sample size is doubled and variance remains the same.										
		CV estimated	NA	.35	.37	.26	.12	.21	.12	.17
Exponential	5 years	-0.5	NA	.21	.20	.33	.85	.44	.85	.60

Figures

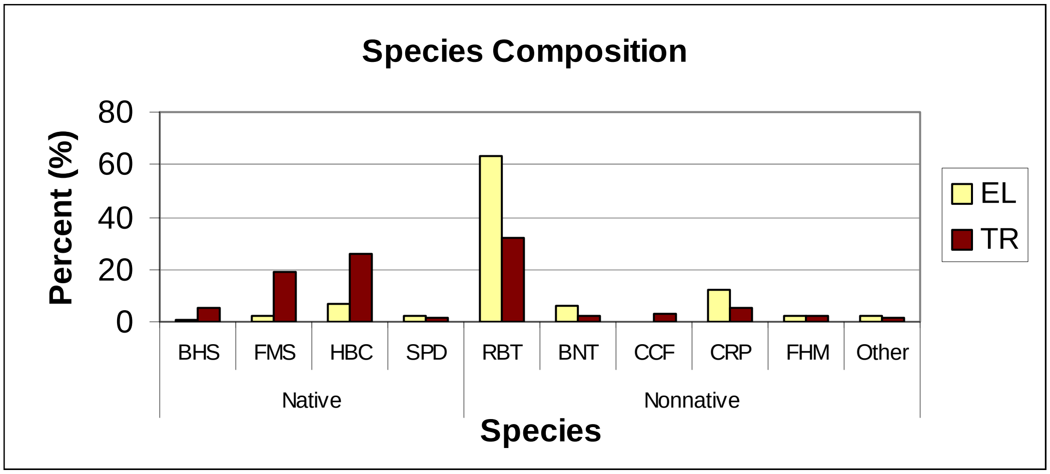


Figure 1. Species composition of fish captured by electrofishing and trammel nets, 1990–2000.

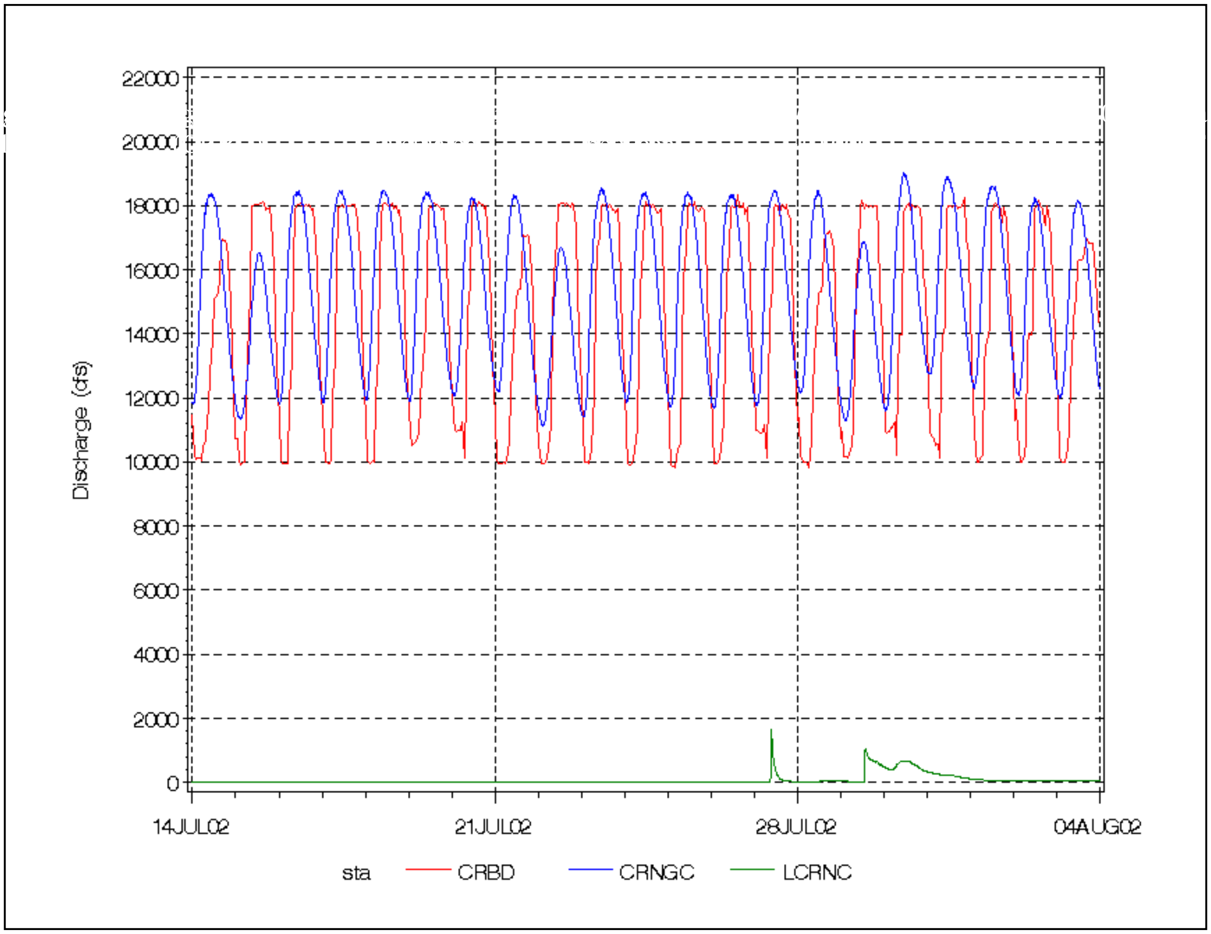


Figure 2a. Hydrograph for the Colorado River during the time of trip 1 (July 17, 2002–August 2, 2002). Dam releases (CRBD) fluctuated between ~10,000 –18,000 CFS. The Little Colorado River (LCRNC) was at base flows with two brief flooding events (under 2,000 CFS). The gauge near Phantom Ranch (CRNGC) recorded flows between ~11,500–19,000 CFS.

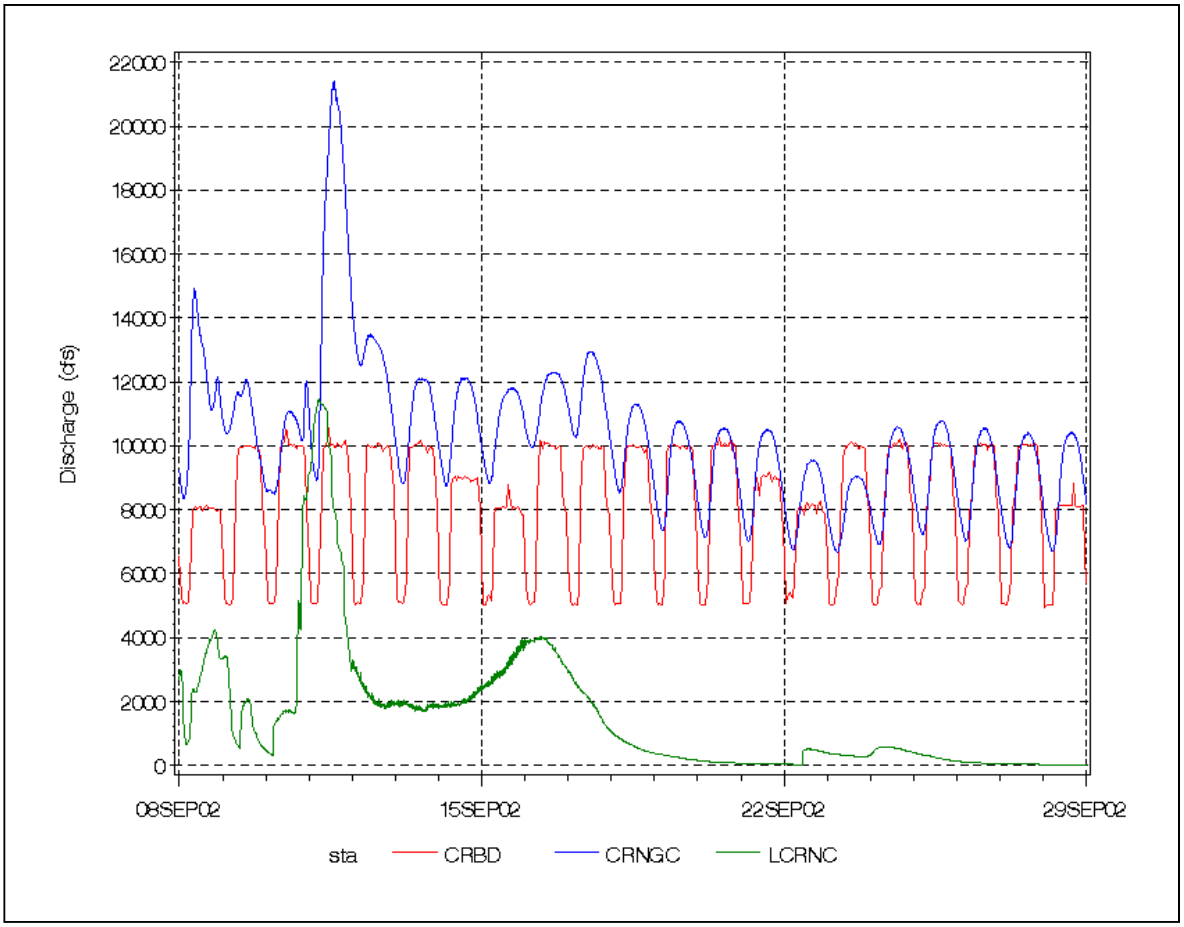
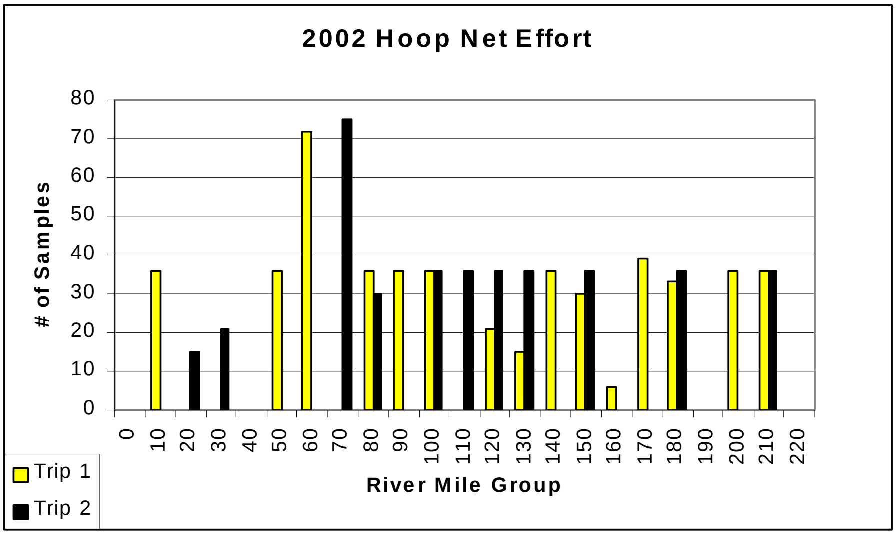
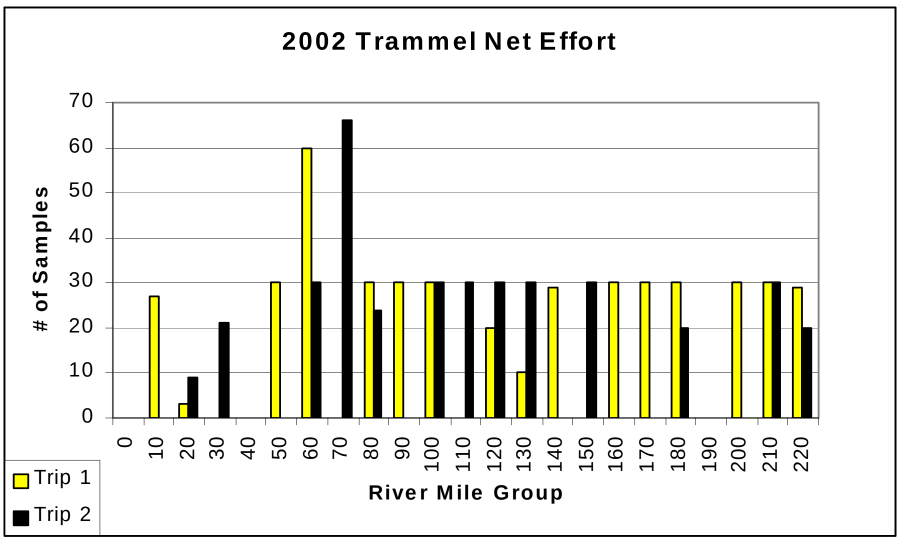


Figure 2b. Hydrograph for the Colorado River during the time of trip 2 (September 11, 2002–September 25, 2002). Dam releases (CRBD) fluctuated between ~5,000 –10,000 CFS. Flooding in the Little Colorado River reached flows > 10,000 CFS at the LCR gauge near Cameron, AZ (LCRNC). The gauge near Phantom Ranch (CRNGC) recorded flows between ~7,000-21,000 CFS.





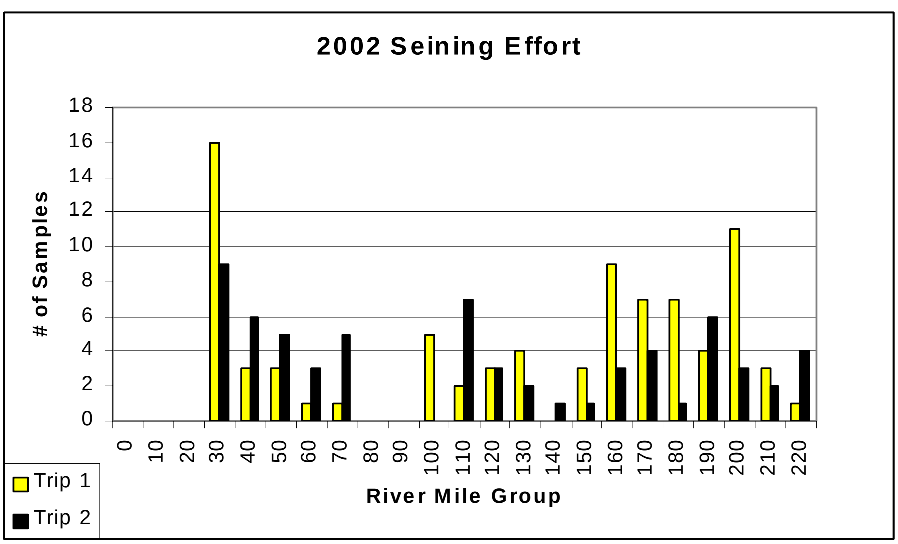
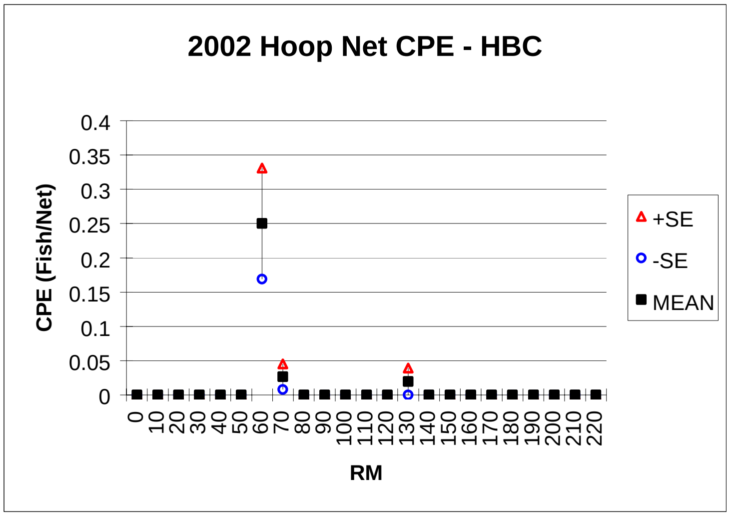
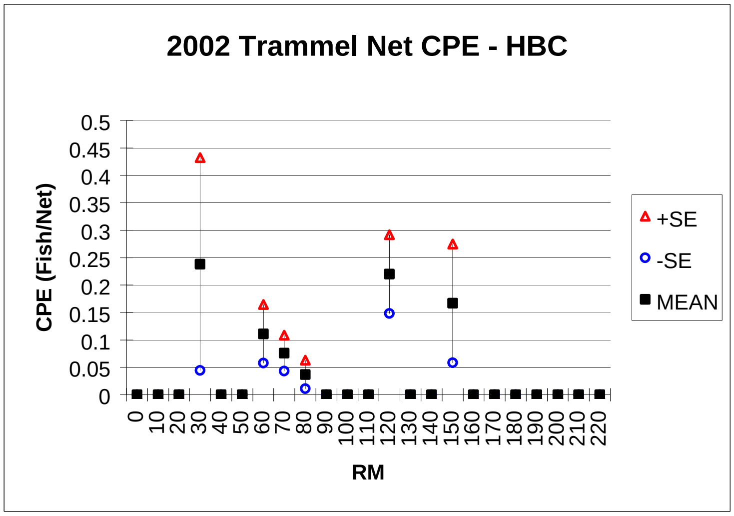


Figure 3. Location of sample sites for trammel nets, hoop nets, and seines during 2002.





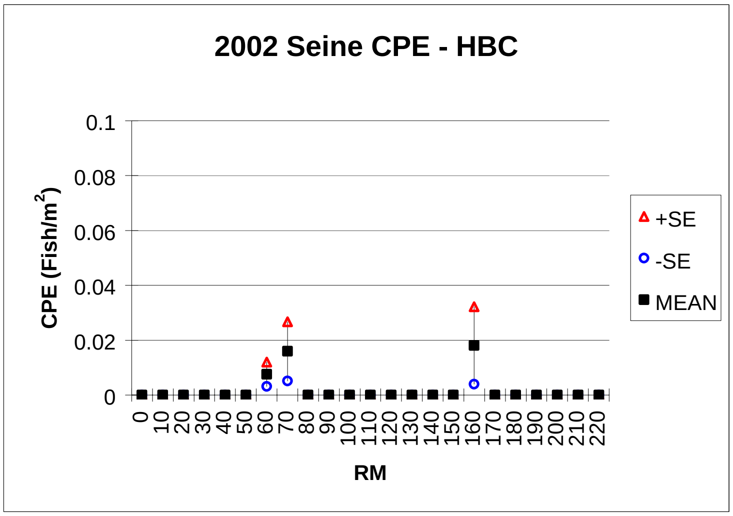
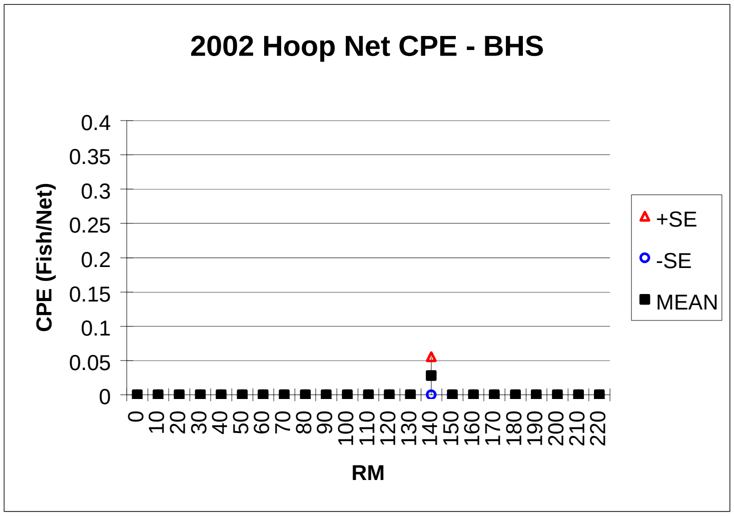
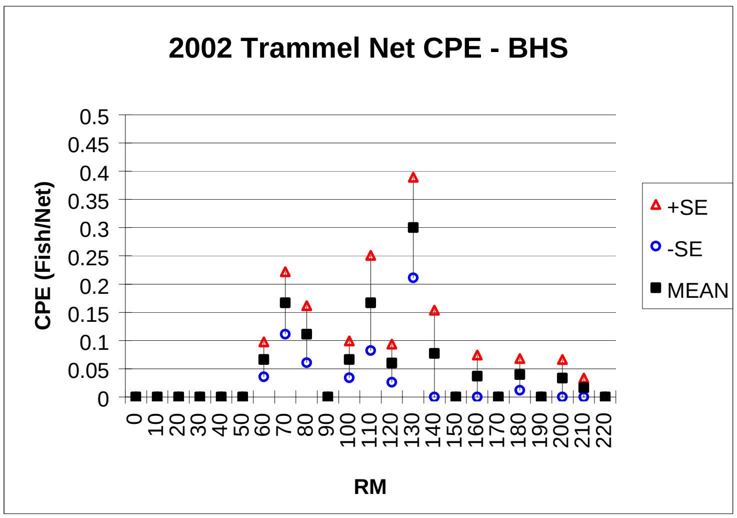


Figure 4. Catch per effort (CPE) of Humpback chub (HBC) captured with trammel nets, hoop nets, and seines, 2002.





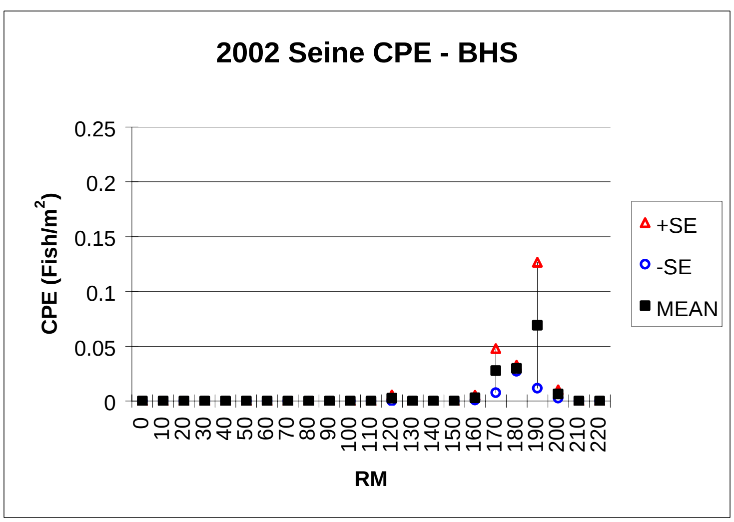
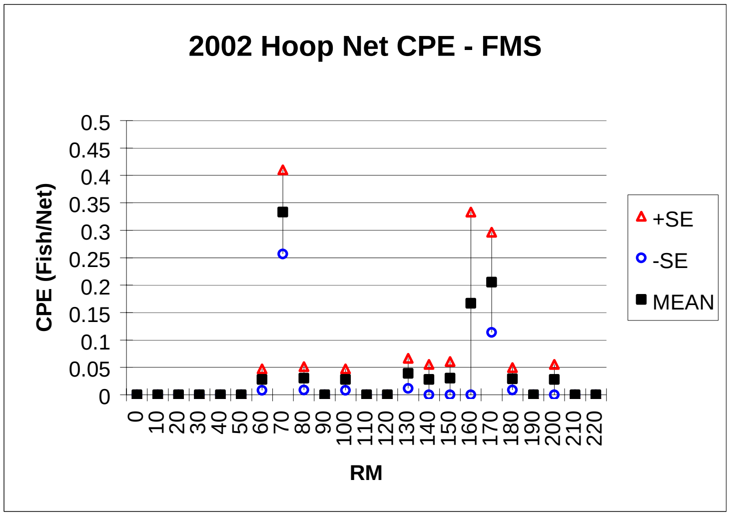
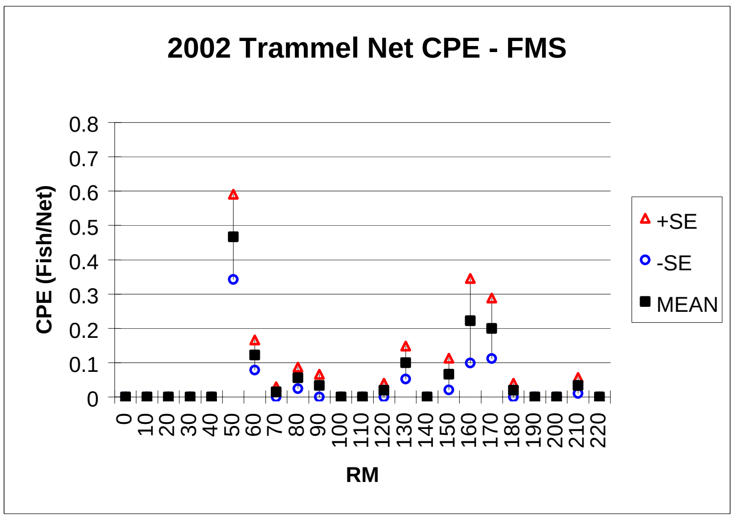


Figure 5. Catch per effort (CPE) of bluehead sucker (BHS) captured with trammel nets, hoop nets, and seines, 2002.





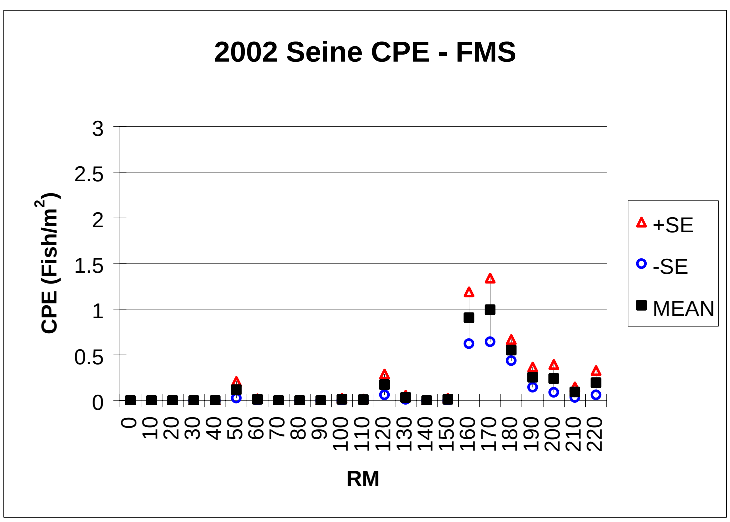
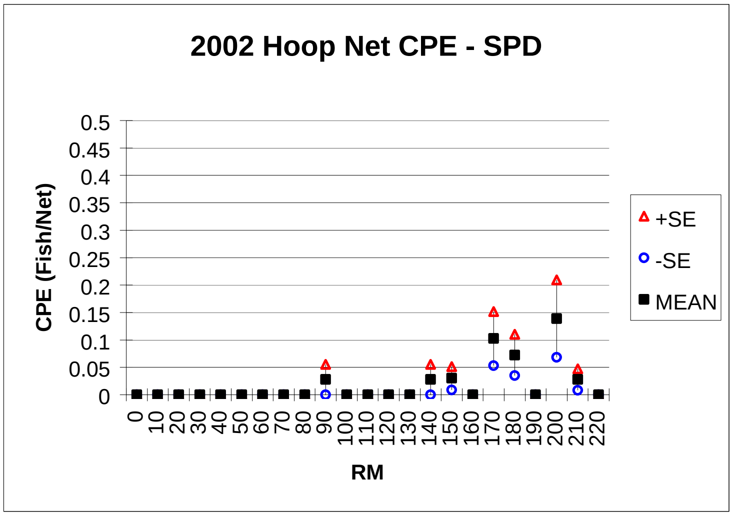


Figure 6. Catch per effort (CPE) of flannelmouth sucker (FMS) captured with trammel nets, hoop nets, and seines, 2002.



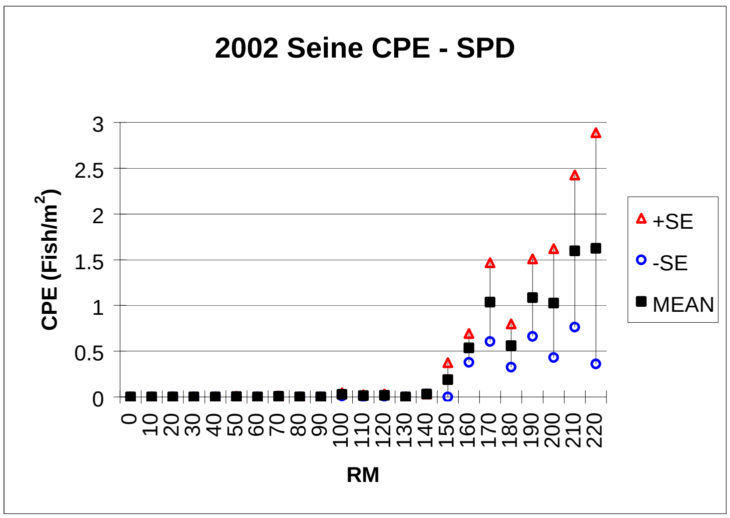


Figure 7. Catch per effort (CPE) of speckled dace (SPD) captured with hoop nets and seines, 2002. No SPD were captured with trammel nets.

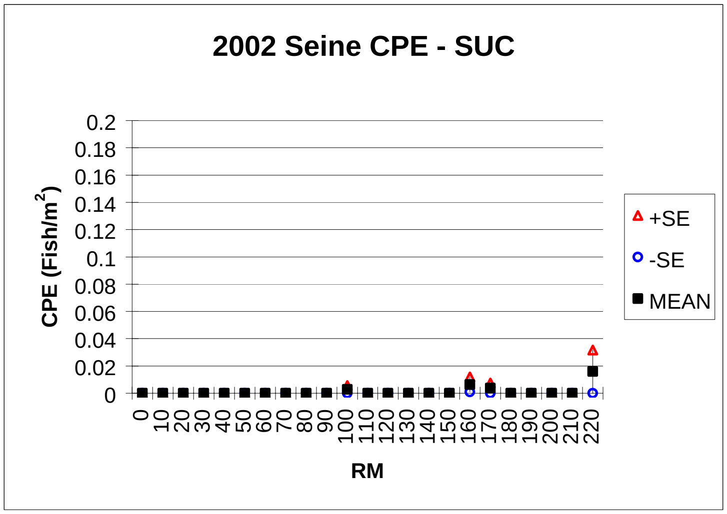
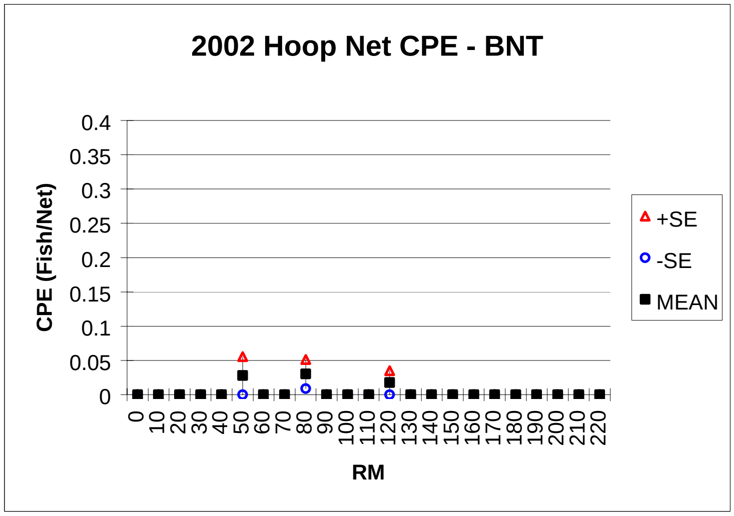


Figure 8. Catch per effort (CPE) of unidentifiable sucker larvae (SUC) captured with seines, 2002.



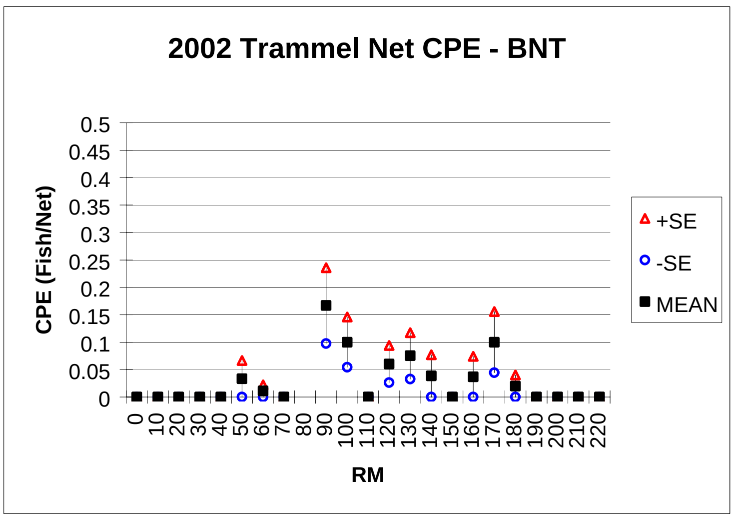
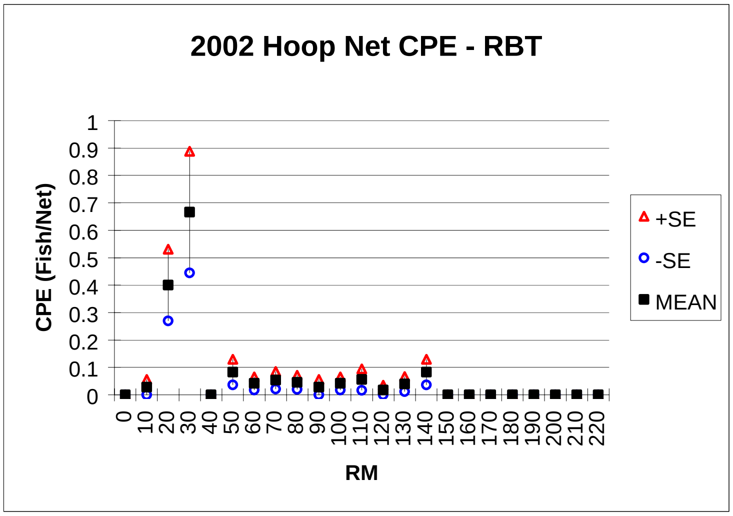
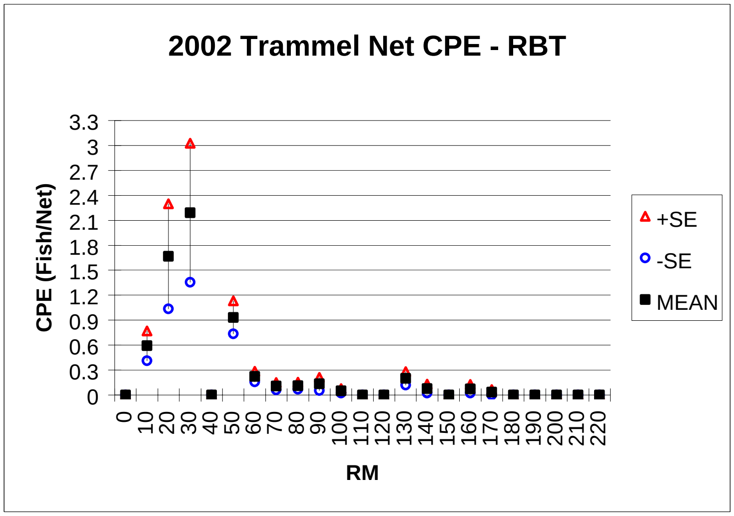


Figure 9. Catch per effort (CPE) of brown trout (BNT) captured with hoop nets and trammel nets. No BNT were captured with seines.





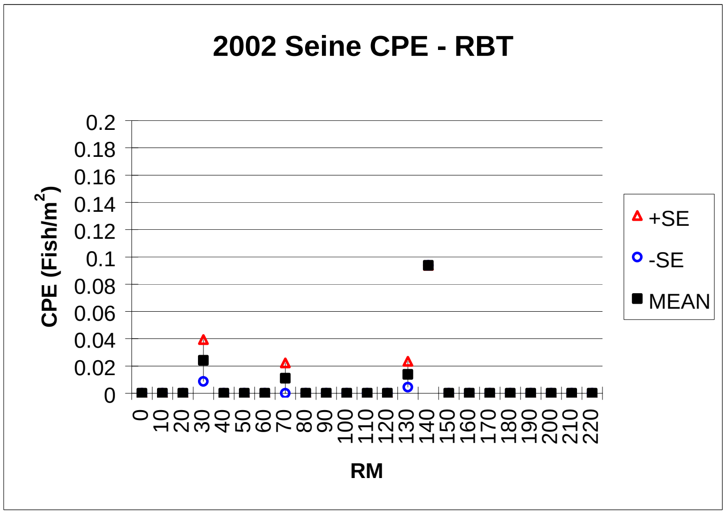
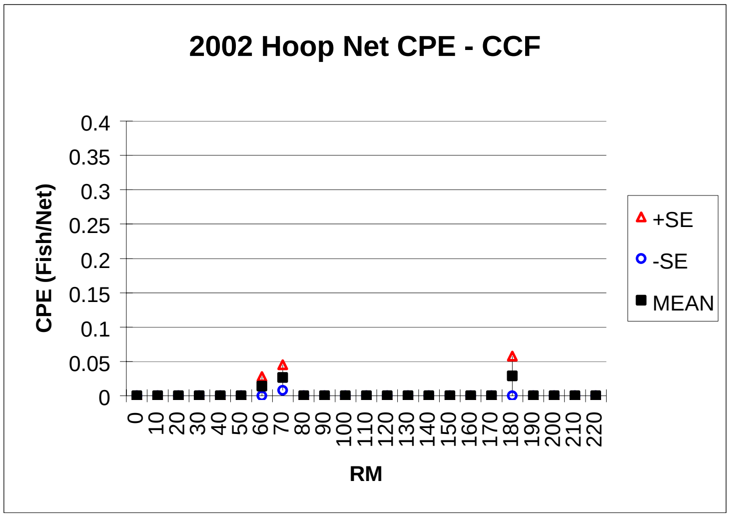


Figure 10. Catch per effort (CPE) of rainbow trout (RBT) captured with trammel nets, hoop nets, and seines, 2002.



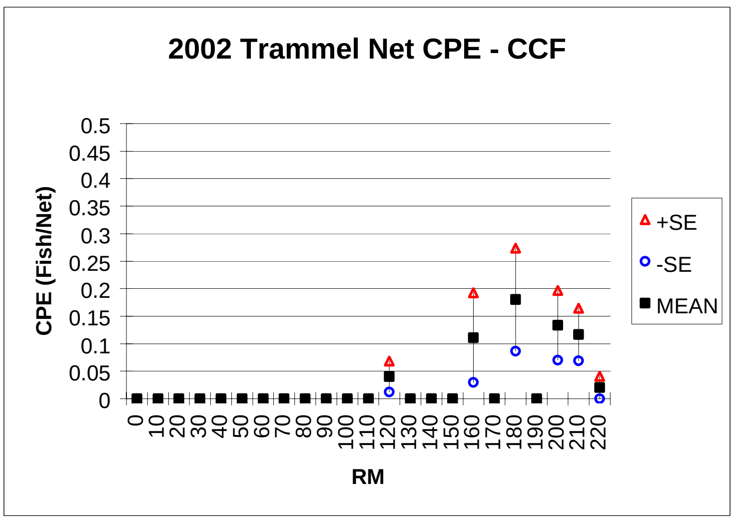
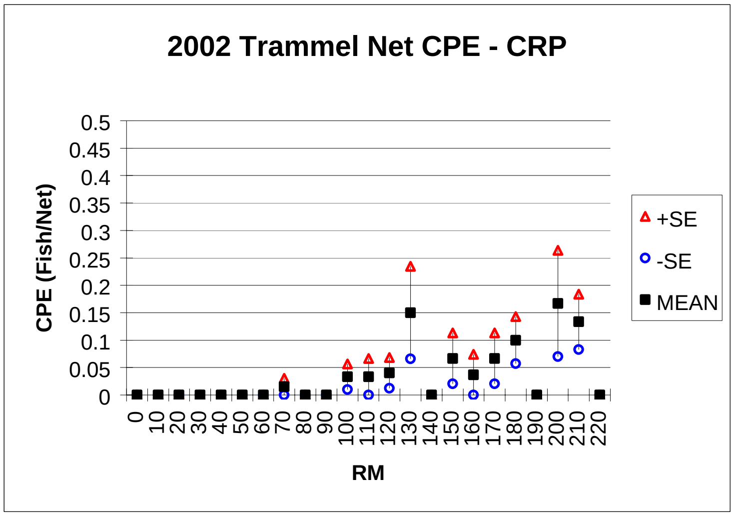


Figure 11. Catch per effort (CPE) of channel catfish (CCF) captured with hoop nets and trammel nets, 2002. No CCF were captured with seines



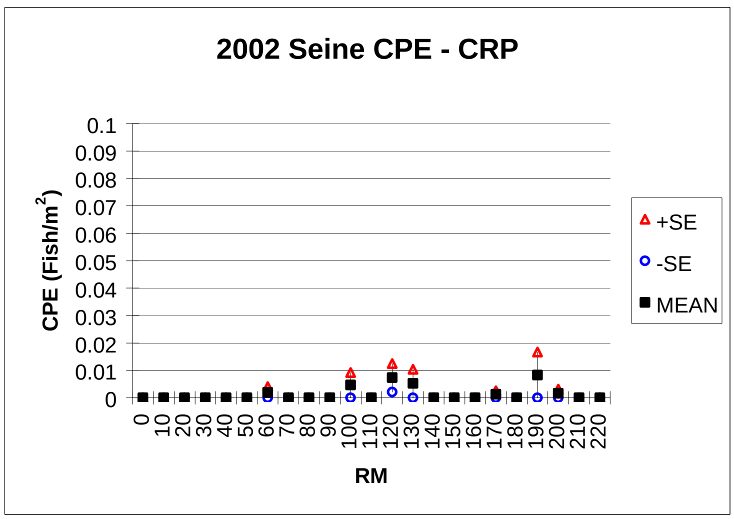


Figure 12. Catch per effort (CPE) of common carp (CRP) captured with trammel nets and seines, 2002. No CRP were captured with hoop nets.

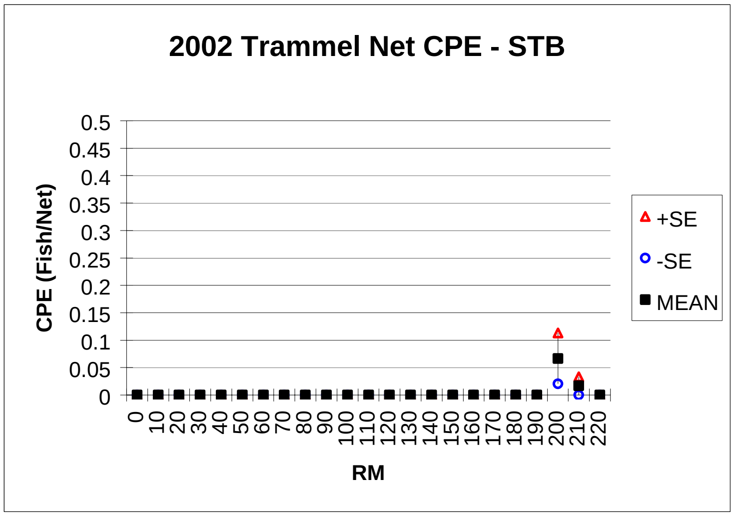
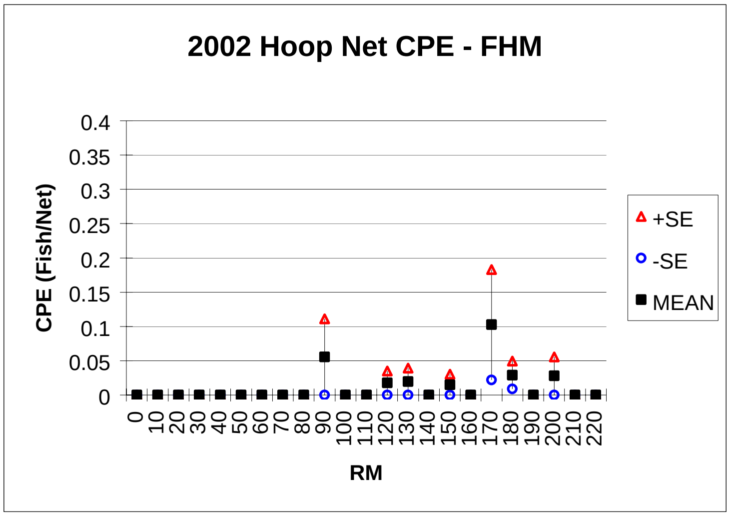


Figure 13. Catch per effort (CPE) of striped bass (STB) captured with trammel nets, 2002. No STB were captured with hoop nets or seines.



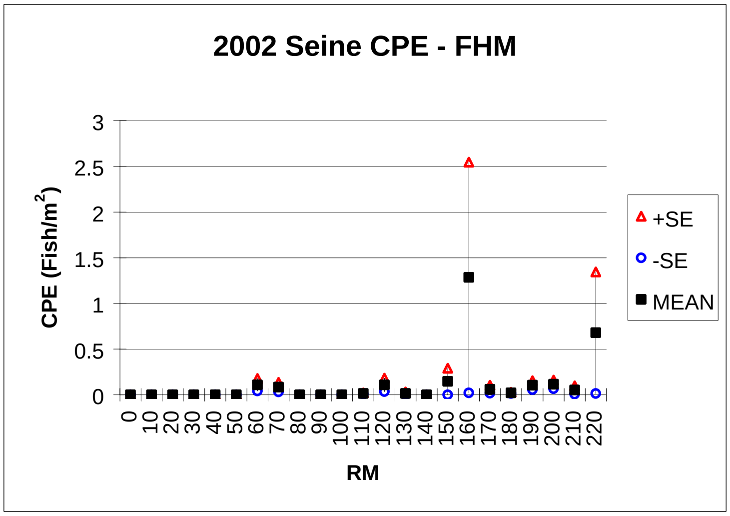


Figure 14. Catch per effort (CPE) of fathead minnow (FHM) captured with hoop nets and seines, 2002. No FHM were captured with trammel nets.

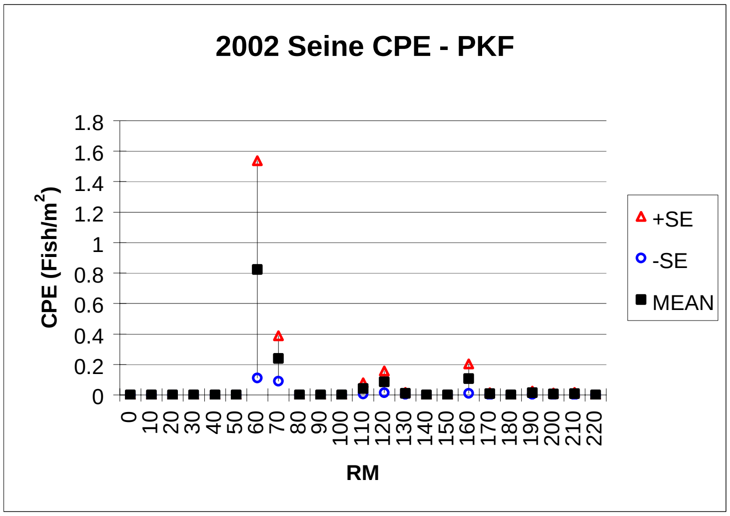


Figure 15. Catch per effort (CPE) of plains killifish (PKF) captured with seines, 2002. No PKF were captured with hoop nets or trammel nets.

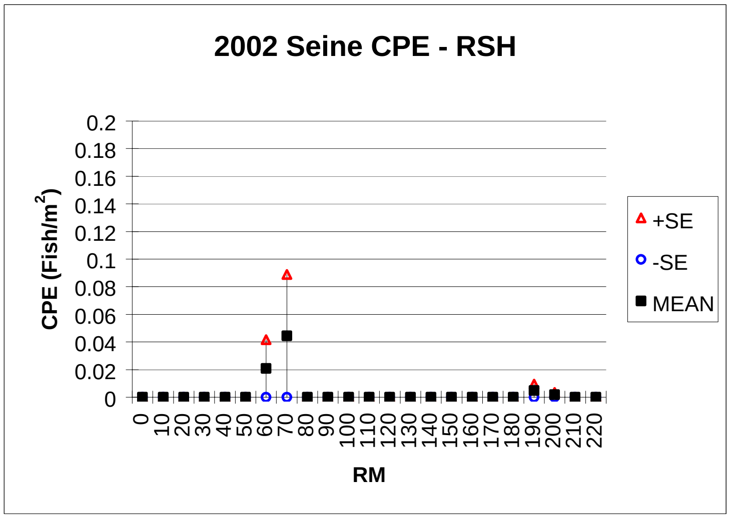


Figure 16. Catch per effort (CPE) of red shiner (RSH) captured with seines, 2002. No RSH were captured with hoop nets or trammel nets.

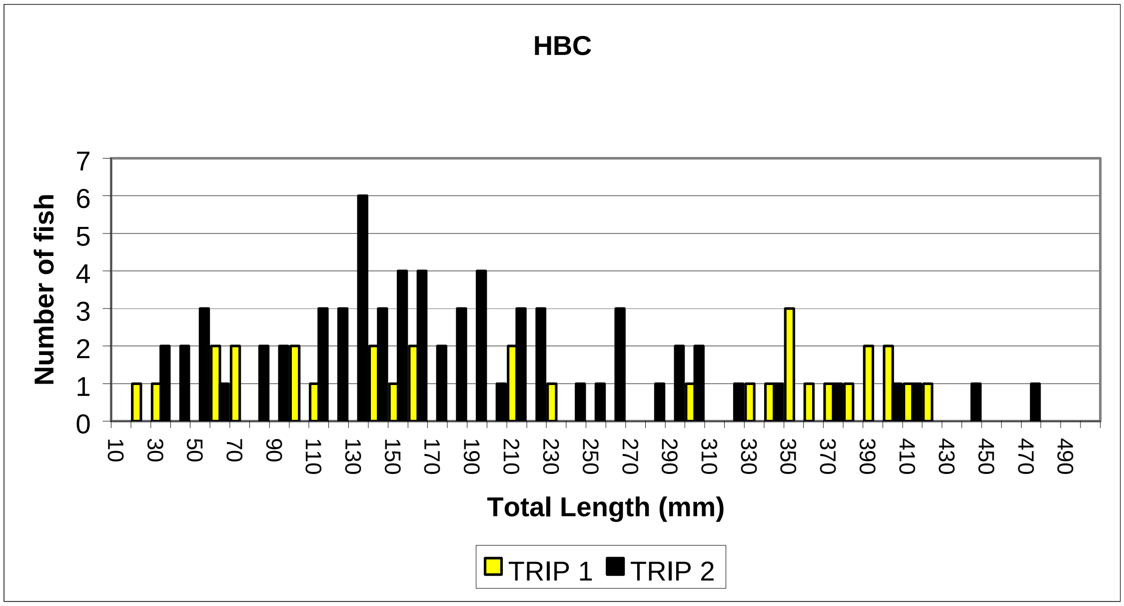


Figure 17. Humpback chub length frequency distribution.

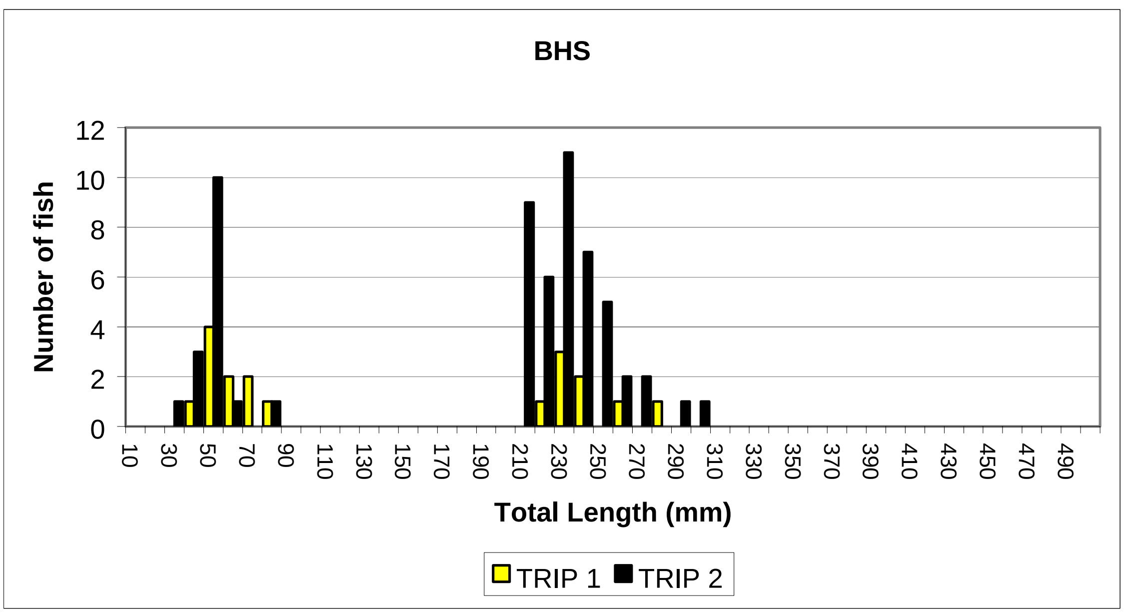


Figure 18. Bluehead sucker length frequency distribution.

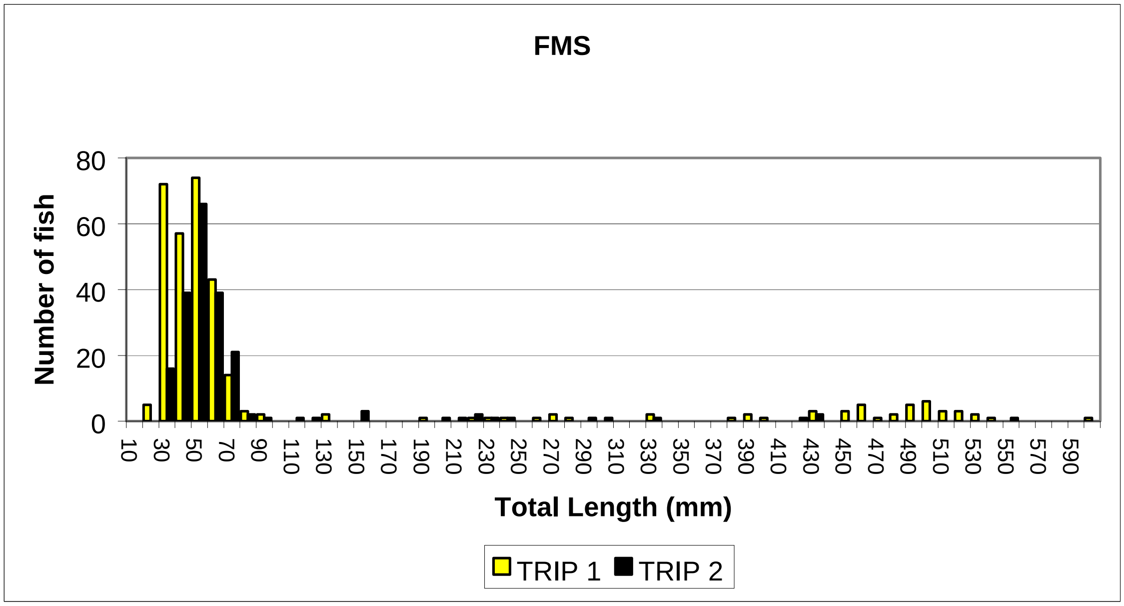


Figure 19. Flannelmouth sucker length frequency distribution.

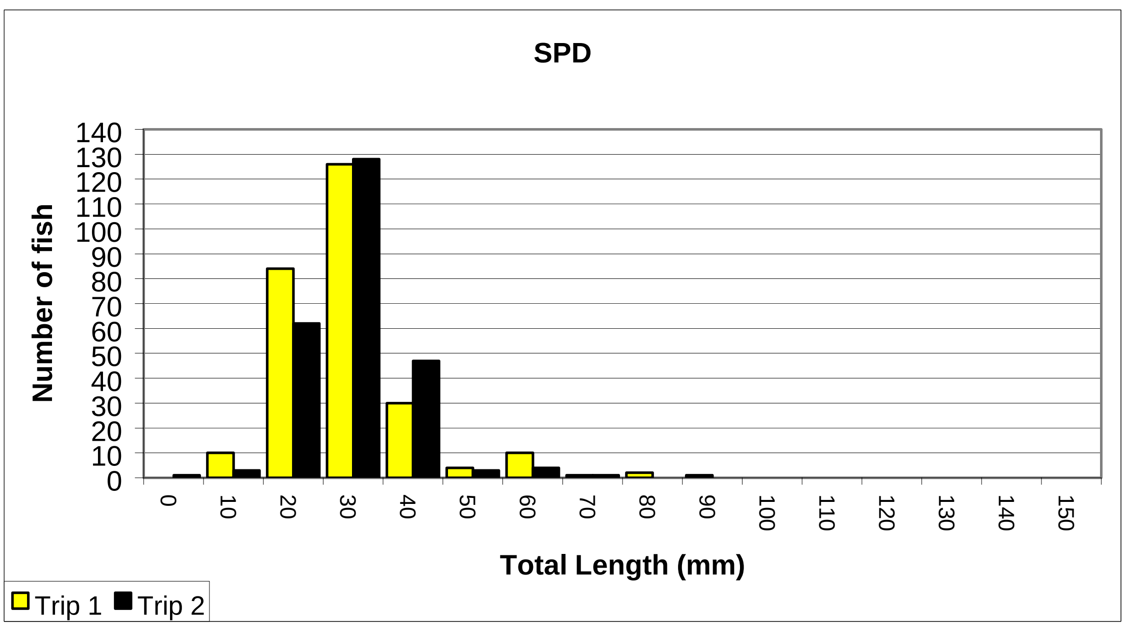


Figure 20. Speckled dace length frequency distribution.

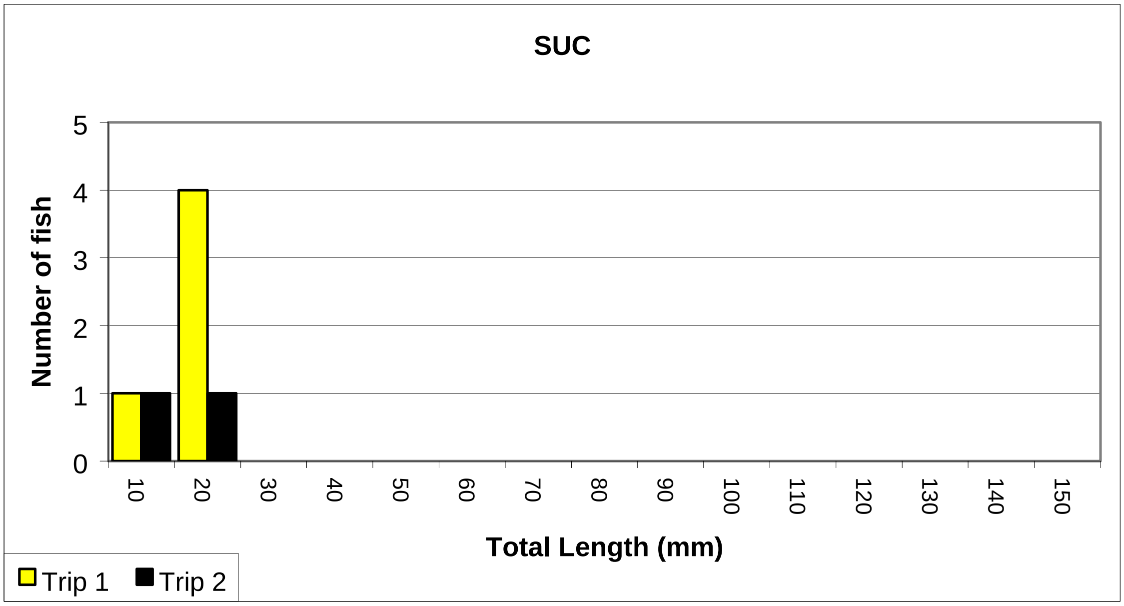


Figure 21. Unidentified sucker length frequency distribution.

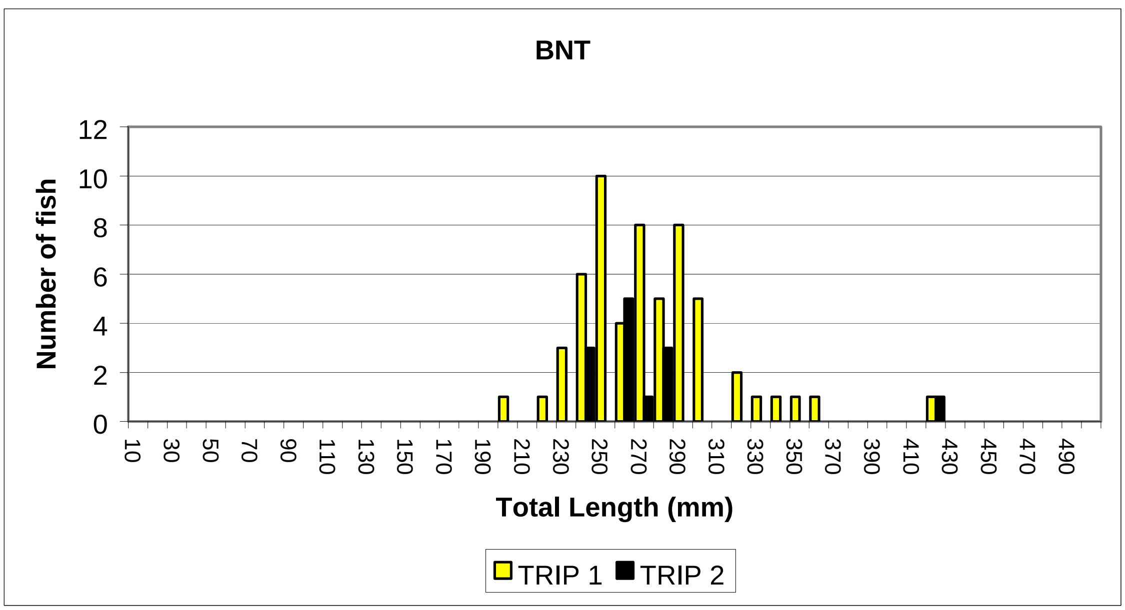


Figure 22. Brown trout length frequency distribution.

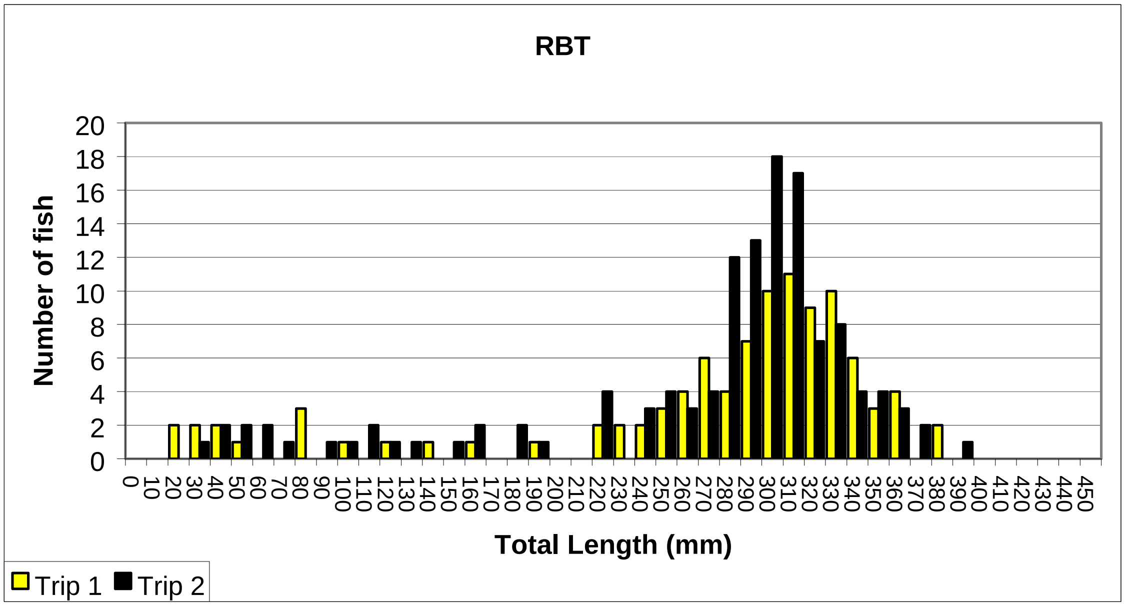


Figure 23. Rainbow trout length frequency distribution.

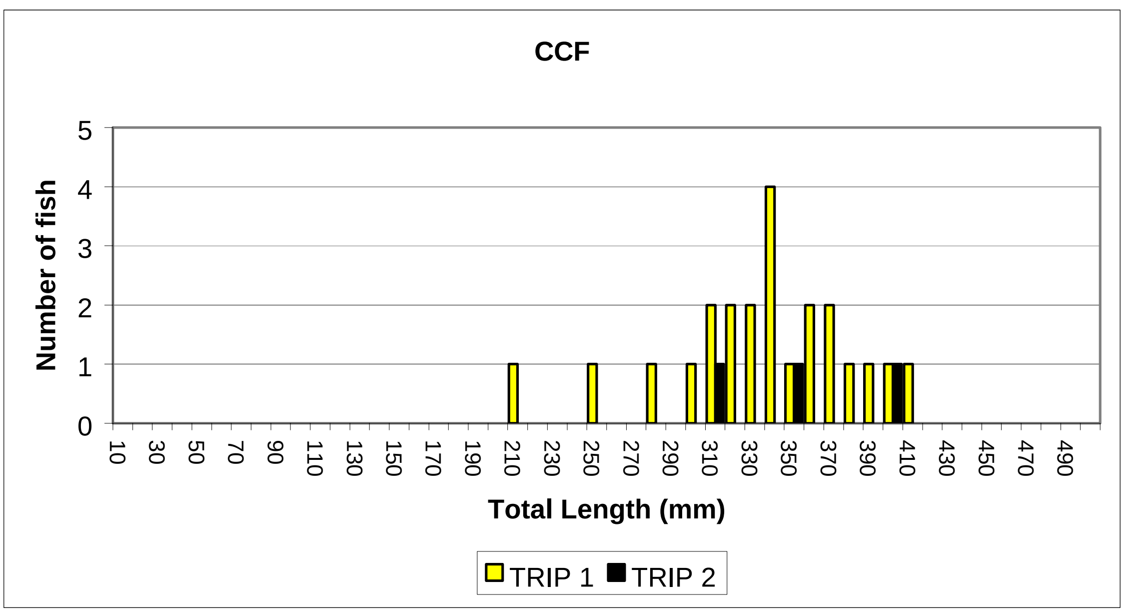


Figure 24. Channel catfish length frequency distribution.

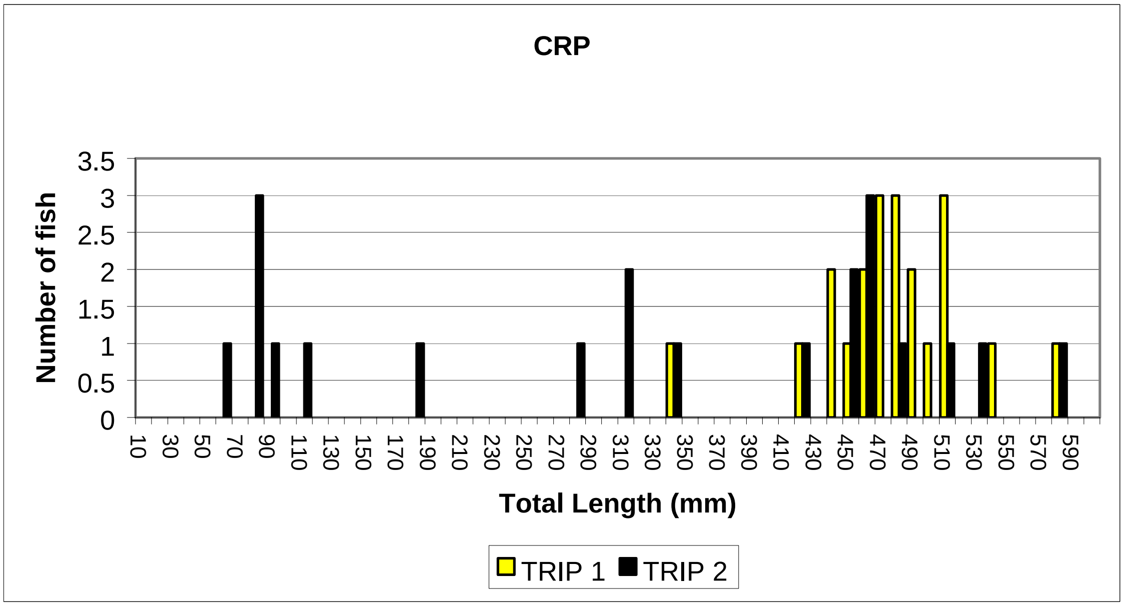


Figure 25. Common carp length frequency distribution.

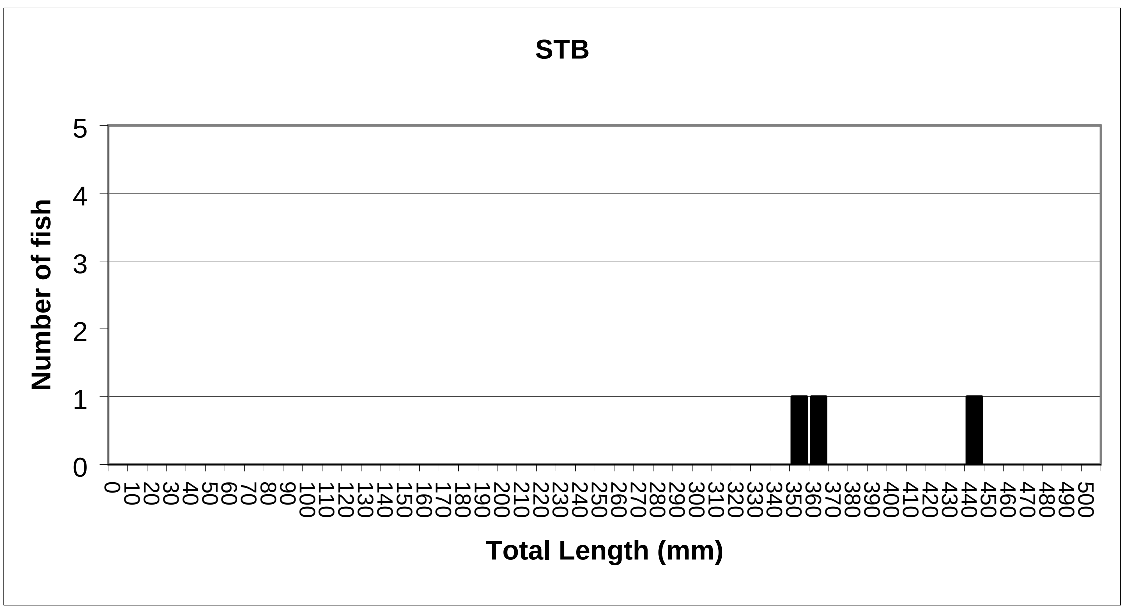


Figure 26. Striped bass length frequency distribution.

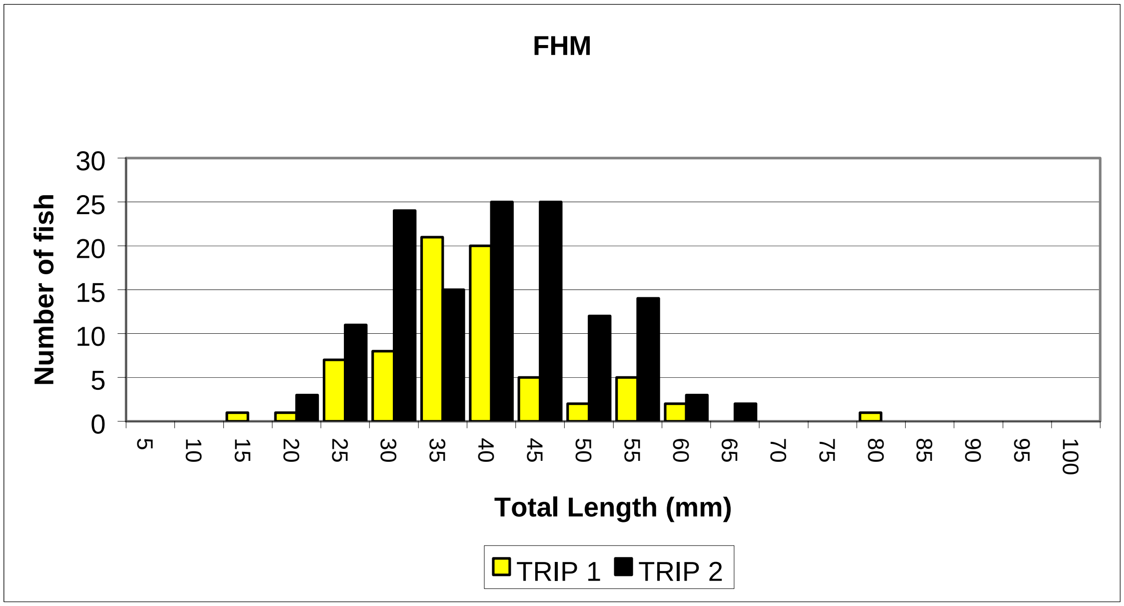


Figure 27. Fathead minnow length frequency distribution.

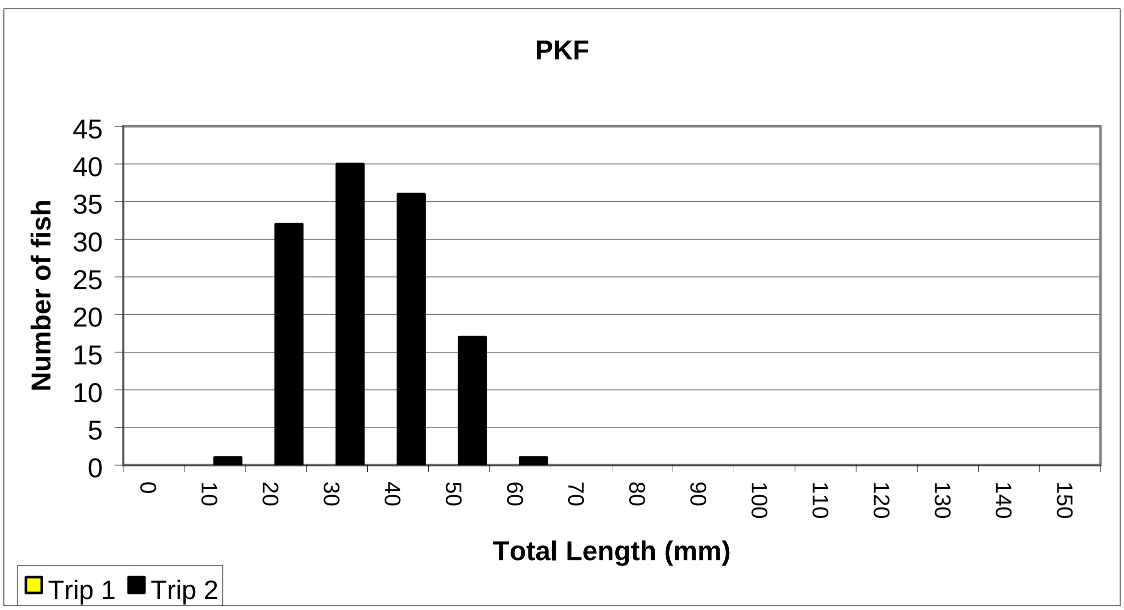


Figure 28. Plains killifish length frequency distribution.

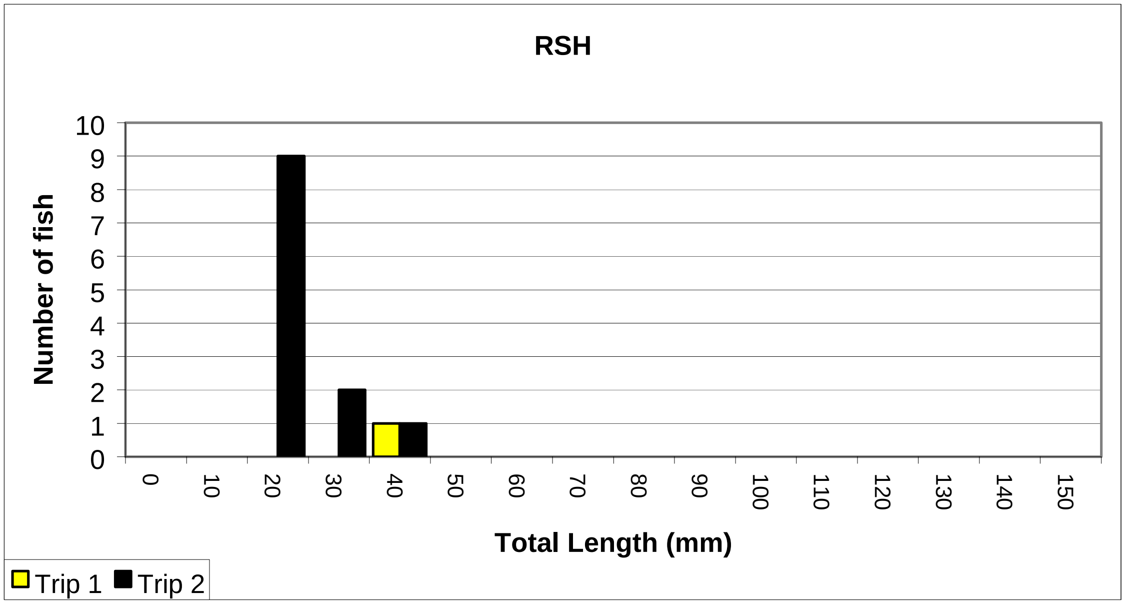
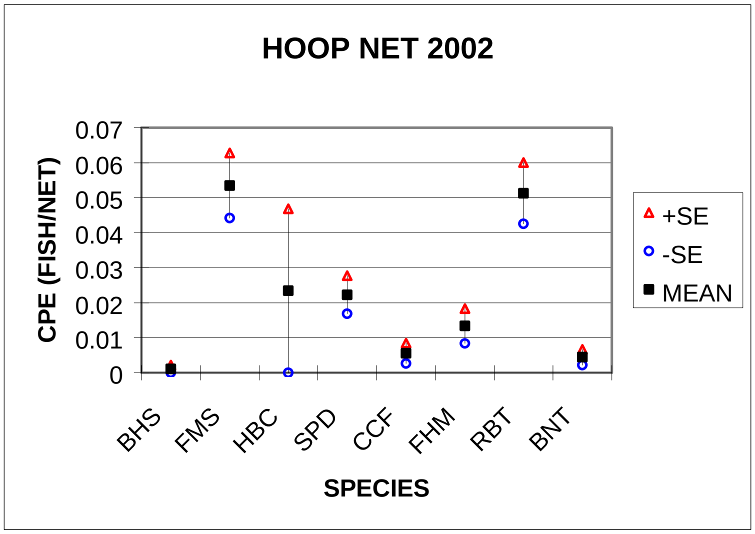
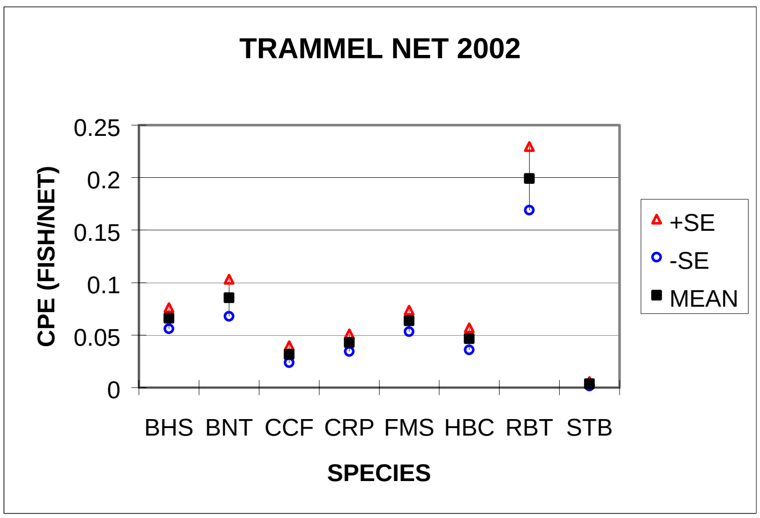


Figure 29. Red shiner length frequency distribution.





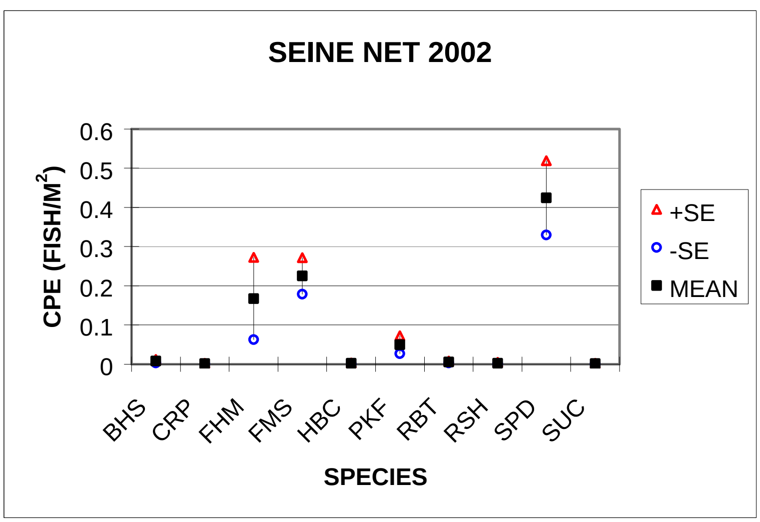


Figure 30. Relative abundance in catch per effort (CPE) of fish species captured with each gear type.