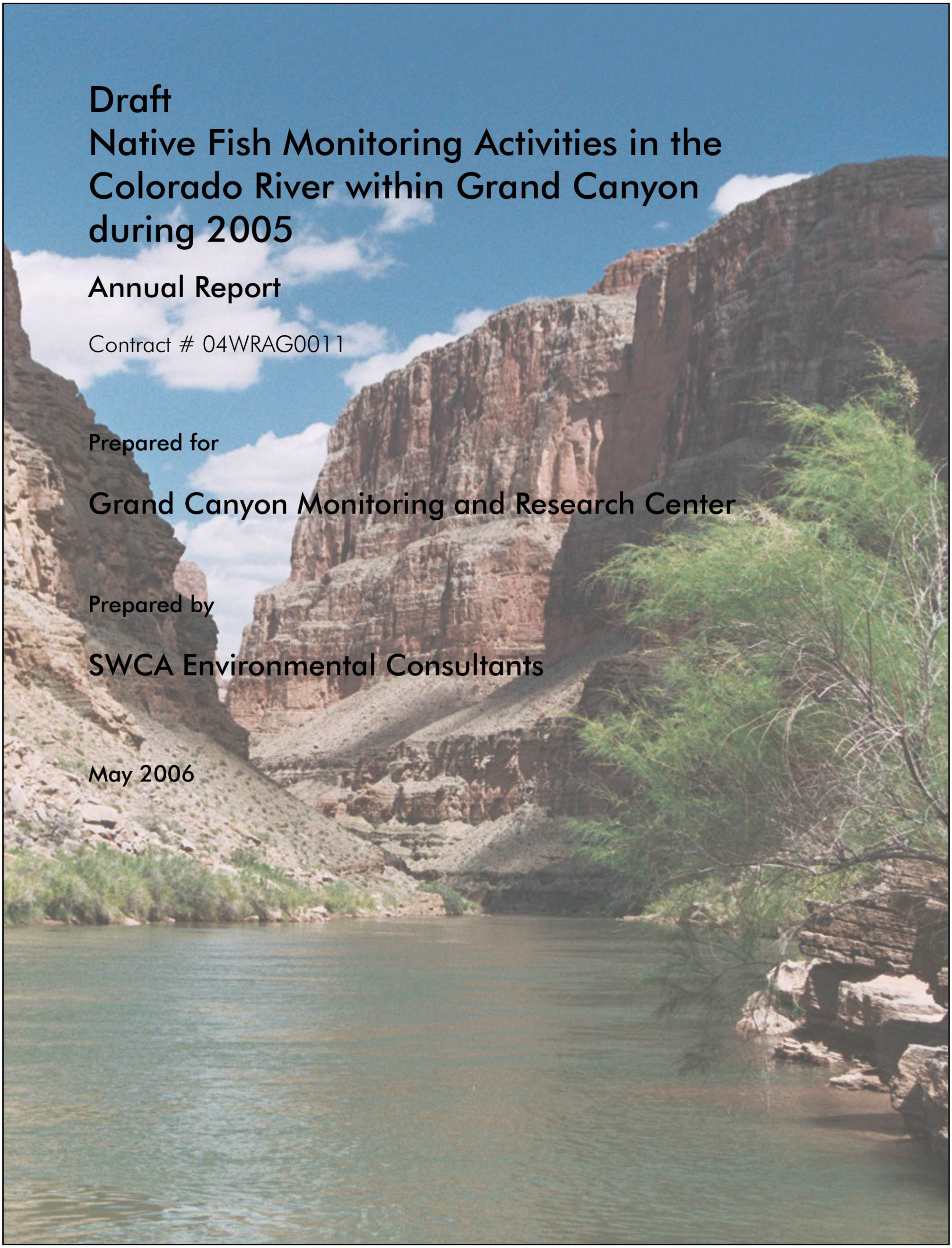

# Draft
# Native Fish Monitoring Activities in the Colorado River within Grand Canyon during 2005

## Annual Report

Contract # 04WRAG0011

Prepared for

Grand Canyon Monitoring and Research Center

Prepared by

SWCA Environmental Consultants

May 2006

# DRAFT
# NATIVE FISH MONITORING ACTIVITIES IN THE COLORADO RIVER WITHIN GRAND CANYON DURING 2005

**ANNUAL REPORT**

**Contract # 04WRAG0011**

Prepared for

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May 2, 2006

## INTRODUCTION

In 2002, the Grand Canyon Monitoring and Research Center (GCMRC) initiated a long-term fish monitoring program for the Colorado River between Lees Ferry and Diamond Creek to track the status and trends of the fish community within Grand Canyon, including the endangered humpback chub (*Gila cypha*) as well as other native and nonnative fishes. The purpose of this program is to develop and implement an effective sampling design for estimating the river-wide distribution and relative abundance of native and nonnative fish species, as well as determine spatial and temporal trends in species' distributions and relative abundances.

The long-term fish monitoring program is a cooperative effort between GCMRC, the U.S. Fish and Wildlife Service, the Arizona Game and Fish Department, and SWCA Environmental Consultants (SWCA). SWCA's responsibility in the long-term monitoring program is to assist in the development, refinement, and implementation of an effective sampling design for estimating the status and trends of native fish species in the mainstem Colorado River.

The four extant native fishes of the Colorado River in Grand Canyon are humpback chub, flannelmouth sucker (*Catostomus latipinnis*), bluehead sucker (*Catostomus discobolus*), and speckled dace (*Rhinichthys osculus*). Nonnative fishes include but are not limited to black bullhead (*Ictalurus melas*), brown trout (*Salmo trutta*), channel catfish (*Ictalurus punctatus*), common carp (*Cyprinus carpio*), fathead minnow (*Pimephales promelas*), green sunfish (*Lepomis cyanellus*), plains killifish (*Fundulus zebrinus*), rainbow trout (*Oncorhynchus mykiss*), red shiner (*Cyprinella lutrensis*), and striped bass (*Morone saxatilis*). Common and scientific names of all fish species referenced in this report are provided in Table 1.

A sampling strategy was developed by the cooperating agencies to monitor native fishes in the Colorado River that involved a combination of river-wide sampling within designated longitudinal reaches (Table 2, Figure 1), and intensive sampling at known humpback chub aggregations (Table 2, Figure 2). The longitudinal reaches were defined using historical catch data and a modified version of the sample allocation program *Sample.exe* (Carl Walters 2001, unpublished). The humpback chub aggregations were identified and monitored by Valdez and Ryel (1995) to document the life history and ecology of the humpback chub in the early 1990s. These aggregations are discrete areas of the Colorado River in which adult humpback chub exhibit high site fidelity. Gear types were selected that have been shown in the past to be effective at capturing humpback chub and other native species, including trammel nets, hoop nets, and seines (Valdez and Ryel 1995).

## METHODS

Except for a September backwater seining trip, the sampling strategy used in 2005 differed from that of previous years. In 2002–2004, two netting trips were conducted and sampling efforts were distributed among the 11 longitudinal reaches and within defined aggregations using trammel and hoop nets, and seining occurred opportunistically in backwater habitats. Additionally, in 2003 and 2004, a separate seining trip was conducted in September that sampled every available backwater habitat along the mainstem Colorado River. In 2005, sampling efforts deviated from the developed sampling strategy to increase the mark rate and recapture information of humpback chub and other native species within Reach 3, particularly the Little Colorado River (LCR) Inflow Aggregation. No river-wide trammel and hoop netting was conducted; however, river-wide backwater seining efforts were conducted in September 2005, similar to the two previous years.

In 2005, 12 days were spent sampling the Colorado River in Grand Canyon within two humpback chub aggregations from June 12 to 23, 2005, including 10 days sampling at the LCR Inflow Aggregation (river miles [RM] 57.0–65.4) and 2 days sampling at the Lava Chuar-Hance Aggregation between Lava Chuar and Tanner Rapids (RM 65.6–68.7). Additionally, while sampling the LCR Inflow Aggregation several samples were collected directly upstream in the lower section of Reach 2 (RM 56.2–56.9) to detect the presence or absence of humpback chub in this section. The LCR Inflow Aggregation was divided into five subreaches, and sampling occurred within a different subreach each night (Table 3). Approximated 2-mile subreaches included RM 56.0–58.0, RM 58.0–60.0, RM 60.0–62.0, RM 62.0–64.0, and RM 64.0–65.4; Table 3 lists the actual subreaches sampled. In a few cases, the subreach was adjusted to allow for five trammel net sets without overlapping a sample site from the previous night, mainly in areas where swift current prevented setting a trammel net. Hoop nets were set in the subreach below each day's designated trammel net subreach to avoid overlap of the gear types. Each subreach was sampled twice with a total of 5 nights between sampling efforts.

Trammel nets and scented hoop nets were used at both aggregations. Crews used two netting sport boats to set five trammel nets and 18 hoop nets per boat, each night (10 trammel nets and 36 hoop nets total per night). Set and pull times, habitat parameters, net depth, river mile, and fish information were recorded on field data sheets for each sample. Trammel nets were typically set at separation points where eddy currents and the main current diverge, also known as eddy fences. Trammel nets were set each night between 1700 and 1800 hours and checked every 2 hours for three hauls. The nets were pulled on the final set, between 2300 and 2400 hours. Trammel nets were 22.86 m long by 1.83 m deep, with 2.54 cm mesh and 30.48 cm outside panel. Hoop nets were set each day between 0700 and 1000 hours, and checked and reset the following morning. Hoop nets were 0.5–0.6 m in diameter, 1.0 m in length, 6 mm mesh, with a single 10 cm throat. Hoop nets were baited with commercial trout food (Aqua-Max). Bait was suspended inside the nets in perforated PVC containers, which allowed odor to escape but prevented fish from feeding on the bait. Hoop nets were set along shorelines at depths of three meters or less in areas with low velocity.

In September 2005, every backwater encountered along the mainstem was seined with a 3.65-m-wide, 1.82-m-deep, 3.18-mm-mesh straight seine. Backwater habitat data for each sample site were recorded, including length, depths (mouth, center, end, and maximum), widths (mouth, center, end, and maximum), shoreline habitat, cover, substrate, and water surface temperatures (mouth, center, and end). Additional water quality measurements were taken at approximately half the sites, including conductivity, dissolved oxygen, pH, salinity, and turbidity. River mile and backwater locations were recorded on ortho-rectified, digitized aerial imagery (1:5000) provided by the GCMRC.

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 nonnative fishes. Fork lengths were taken on all native fishes.

2. Weights were no longer taken in an effort to reduce handling stress.

3. Native fish (≥150 mm), brown and rainbow trout with an adipose fin clip, and carp with a dorsal clip were scanned for passive integrated transponder (PIT) tags using both new and old PIT tag scanners. All tagged and untagged native fish (≥ 150 mm) were PIT tagged if not already tagged with a "new" 134.2 kHz tag. Untagged brown trout (≥ 150 mm) were PIT tagged with a "new" 134.2 kHz tag and given an adipose clip. Carp (≥ 150 mm) were tagged in the dorsal musculature 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. All native fishes were examined for sex, sexual condition, and external parasites.

5. Sample locations were recorded on data sheets and on ortho-photographic maps provided by GCMRC.

Catch rates were calculated for each species and were reported as the catch per unit effort (CPUE) for each gear type. Trammel and hoop net CPUE were calculated as the number of fish per net hour, and seine CPUE were calculated as number of fish per meter$^2$ of backwater area. Trammel and hoop net CPUE were calculated for Reach 3 and seining CPUE were calculated for Reaches 1–11.

Large-bodied native species (humpback chub, flannelmouth sucker, and bluehead sucker) were further analyzed by age groups, including young, juveniles, and adults. Humpback chub and flannelmouth sucker age groups were categorized as follows: young = total length (TL) < 120 mm, juveniles = TL between 120 and 199 mm, and adults = TL > 199 mm. Bluehead sucker age groups were categorized as follows: young = TL < 100 mm, juveniles = TL between 100 and 179 mm, and adults = TL > 179 mm. Humpback chub were analyzed by aggregation as well as by reach.

Catch rates were used to determine changes and trends in the relative abundance of each species captured in 2005. The slope of the mean CPUE for each year from 2002 to 2005 was used to determine the direction of trend and estimate the magnitude of the change in relative abundance for each species.

The coefficient of variation (CV = standard error CPUE/mean CPUE) was calculated for each gear type and species to determine the level of variation in catch rates in 2005. Gear types with highly variable catch rates and therefore high CV values for certain species were assumed to not be useful for estimating changes and trends in relative abundance of those species. A target CV value of 0.10 was established for the monitoring program. This correlates with an ability to detect changes in relative abundance of approximately 75% over 5 years (TRENDS, Gerrodette 1987, alpha = 0.05, beta = 0.20, 2-tailed test, linear rate of change, CV remains constant with abundance, equal sampling intervals). Furthermore, gear types with CV values greater than

0.20 for a certain species were projected to be unable to detect changes in the relative abundance less than 280% over 5 years (TRENDS, Gerrodette 1987, alpha = 0.05, beta = 0.20, 2-tailed test, linear rate of change, CV remains constant with abundance, equal sampling intervals) and therefore assumed to not be particularly useful for 5-year trend monitoring.

Humpback chub catch rate data for hoop and trammel nets in Reach 3 between 2002 and 2005 were combined by gear type and resampled using the Microsoft Excel Add-in Resampling Stats. These data were then bootstrapped (Resampling Stats, 1000 repetitions) to assess the decrease in mean CV values with increased sample size for each gear type, and corresponding increase in the ability to detect changes in relative abundance. These results were summarized by effort days (1 hoop net effort day = 36 samples, 1 trammel net effort day = 10 samples) in increments of 1 effort day up to 12 days, and were summarized for each age group of humpback chub. These CV values provide a more representative estimate of the monitoring program resolution for humpback chub than yearly values because they include the temporal variation in catch rates and may eliminate some environmental factors not related to species abundance that could affect catch rates from year to year.

A mark-and-recapture population estimate was calculated for adult humpback chub in the LCR Inflow Aggregation by using the Chapman-Petersen method (Lockwood and Schneider 2000). The 95% confidence interval (CI) lower and upper limits of the population estimate were calculated using a Poisson distribution (Lockwood and Schneider 2000). All adult humpback chub captured in trammel and hoop nets within the LCR Inflow Aggregation in June 2005 were included in the population estimate. The first sampling efforts within each of the subreaches were combined and considered the marking event, and the second sampling efforts within each of the subreaches were combined and considered the recapture event, with 5 days between subreach sampling events. The designated subreaches and sample schedule are listed in Table 3.

The longitudinal distribution of each species was calculated as the number of fish per river mile. Longitudinal distributions are summarized by age groups for large-bodied native species. The length frequency of each species was calculated as the number of fish per 10 mm TL group. Length frequencies were split by gear type to show the capture bias of size classes for each gear.

## RESULTS

In 2005, one netting trip and one seining trip were completed as scheduled in June and September, respectively. Releases from Glen Canyon Dam followed record of decision[1] flows throughout the two sampling periods (Figure 3). Releases fluctuated between approximately 9,000 and 17,000 cubic feet per second (cfs) daily during the June hoop and trammel net sampling, and flows were steady at 8,000 cfs during the September seining trip.

The longitudinal distribution of samples for each gear type is presented in Figure 4. A total of 121 trammel net samples and 432 hoop net samples were taken in June 2005 (Table 4). The majority of the netting samples (100 trammel nets, 360 hoop nets) were collected in the LCR Inflow Aggregation (RM 57.0–65.4) within Reach 3 (RM 57.0–69.9). Several trammel and hoop

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

net samples were collected in the lower portion of Reach 2 (RM 56.2–56.9) to detect the presence or absence of humpback chub directly upstream of the LCR Inflow Aggregation. Additionally, 21 trammel nets samples and 72 hoop net samples were collected in the upper section of the Lava Chuar-Hance Aggregation between RM 65.7 and RM 68.6 within Reach 3. A total of 213 seine samples were collected in backwaters river-wide in September–October 2005. The majority of seine samples were taken upstream of RM 70 (Reaches 1–3) and downstream of RM 160 (Reaches 8–11); relatively few backwaters were present between RM 70 and RM 160 (Reaches 4–7).

Trammel nets captured a total of 460 fish composed primarily of native species (Table 5), including humpback chub (39% of the total catch), flannelmouth sucker (33% of the total catch), and bluehead sucker (16% of the total catch). Nonnative species captured in trammel nets included rainbow trout (10% of the total catch), black bullhead (1% of the total catch), brown trout (< 1% of the total catch), channel catfish (< 1% of the total catch), and common carp (< 1% of the total catch). Hoop nets captured a total of 821 fish (Table 6), most of which were humpback chub (81% of the total catch). Other native species were less common in hoop nets and included flannelmouth sucker (2% of the total catch), bluehead sucker (1% of the total catch), and speckled dace (< 1% of the total catch). Nonnative species present in hoop nets included fathead minnow (11% of the total catch), rainbow trout (2% of the total catch), black bullhead (< 1% of the total catch), common carp (< 1% of the total catch), and red shiner (< 1% of the total catch).

Humpback chub were captured more frequently in hoop and trammel nets in the LCR Inflow Aggregation than in the Lava Chuar-Hance Aggregation, and none were captured directly upstream of the LCR Inflow Aggregation in the lower section of Reach 2. Furthermore, flannelmouth sucker and rainbow trout were the only species captured in this section with hoop and trammel nets. A total of 382 PIT tags were inserted into native species in June 2005, and 223 native fish were captured that were previously tagged (Table 7).

Backwater seining efforts produced a total of 8,616 fish (Table 8), and samples were dominated by young-of-the-year (YOY) native species, including speckled dace (36% of the total catch), flannelmouth sucker (28% of the total catch), bluehead sucker (5% of the total catch), and humpback chub (3% of the total catch), as well as by fathead minnow (26% of the total catch), a nonnative small-bodied species. Other nonnative species were captured less frequently, including plains killifish (< 1% of the total catch), red shiner (< 1% of the total catch), common carp (< 1% of the total catch), and rainbow trout (< 1% of the total catch).

CPUE indices for trammel nets are presented in Figures 5–7. Figure 5 shows the mean CPUE (± 95% CI) for each species captured in trammel nets in Reach 3. Native species were also summarized by age group (Figure 6), and humpback chub were summarized by age group for each aggregation sampled (Figure 7). An increase in trammel net catch rates in Reach 3 was observed for each native species captured, and 2005 catch rates were considerably higher than those of 2002 (Figure 5). These trends are associated with an increase in adult fish captured in trammel nets for humpback chub, flannelmouth sucker, and bluehead sucker, as well as an increase in juveniles for humpback chub (Figure 6). Furthermore, juvenile and adult humpback chub catch rates have increased in the LCR Inflow, and adult humpback chub were captured in the Lava Chuar-Hance Aggregation in 2005, but were absent from samples taken in 2002 and 2003 (Figure 7).

Two channel catfish were captured in trammel nets in Reach 3 in 2005, but were absent from netting samples in this reach over the three previous years, and black bullhead have been captured over the last two years. Trammel net catch rates of rainbow trout have declined steadily over the last 3 years, and were notably lower in 2005 than in 2002 and 2003 (Figure 5). Brown trout and common carp catch rates have remained fairly consistent over the last 4 years.

CPUE indices for hoop nets are presented in Figures 8–10. Figure 8 represents the mean CPUE (± 95% CI) for each species captured in hoop nets in Reach 3. Large-bodied native species in Reach 3 were also summarized by age group (Figure 9), and humpback chub were summarized by age group for each aggregation sampled (Figure 10). Hoop net catch rates of humpback chub increased greatly in 2005 compared to previous years' monitoring (Figure 8); this increase is attributed to a large increase in young fish and a small increase in juvenile fish (Figure 9). The CPUE of adult humpback chub in hoop nets was not noticeably different from that of previous years. Figure 10 shows that the catch rate of young humpback chub was greater in both aggregations sampled. Other species captured in hoop nets in Reach 3 did not show a large change in catch rates; however, the presence of bluehead sucker (all age groups, Figure 9), common carp, and red shiner is notable since these species were absent from hoop net samples in this reach in the previous three years (Figure 8).

A population estimate was calculated for adult humpback chub in the LCR Inflow Aggregation (Figure 11). The population was estimated at 1,170 individuals in the Colorado River within the LCR Inflow Aggregation in June 2005 (95% CI lower limit = 646, upper limit = 2,340). This estimate is comparable to the 2001 population estimate (Trammel and Valdez 2003), but considerably lower than estimates made in 1991–93 (Valdez and Ryel 1995). A population estimate for humpback chub in the Lava Chuar-Hance Aggregation was not calculated due the lack of recaptures in this aggregation.

Seining CPUE indices are presented in Figures 12–21. Humpback chub were analyzed by reach and age group (Figure 12), as well as by aggregation and age group (Figure 13). Flannelmouth sucker (Figure 14) and bluehead sucker (Figure 15) were analyzed by reach and age group, although juvenile and adult fish were rarely captured in seines. All other species captured in seines in 2005 were not categorized by age group and included speckled dace (Figure 16), common carp (Figure 17), fathead minnow (Figure 18), plains killifish (Figure 19), rainbow trout (Figure 20), and red shiner (Figure 21). Seine CPUE indices were highly variable for all species, and, therefore, trends in relative abundance were not apparent.

The CVs for each gear type were calculated for every species captured in 2005 (Table 9). Hoop nets had highly variable catch rates for the majority of species captured, with the exception of humpback chub (CV = 0.14). All other species captured in hoop nets in Reach 3 had CV values greater than 0.20. Trammel net samples in Reach 3 had the least variation in catches of native species, including humpback chub (CV = 0.15), flannelmouth sucker (CV = 0.13), and bluehead sucker (CV = 0.15). Trammel net catch rates for all other species were highly variable with CV values greater than 0.20. Seining catch rates river-wide were highly variable with CV values greater than 0.20 for all species captured.

The CVs of humpback chub were further analyzed by age group and aggregation for each gear type in 2005 (Table 10). Hoop net samples in the LCR Inflow had the least variation in catch rates for young and juvenile humpback chub (CV = 0.19, respectively) compared to catch rates with other gear types and in other aggregations. Trammel net samples in the LCR Inflow had the least variation in catch rates of adult humpback chub (CV = 0.16) compared to other gear types and aggregations. Seining catch rates were highly variable for all age groups of humpback chub and all aggregations, and samples taken in areas outside of aggregations had the least variation in catch rates of young (CV = 0.34).

Bootstrapped 2002–2005 humpback chub catch rate CV values are presented in Figure 22 for trammel and hoop nets. CV values were much greater than 0.20 for sampling efforts less than 9 days in Reach 3 for both gear types. Interestingly, the 2005 actual CV value for adult humpback chub captured in trammel nets in the LCR Inflow (CV = 0.16) closely matched the resampled and bootstrapped CV value from the entire 2002–2005 dataset for 12 days of sampling in Reach 3 (CV = 0.16). Likewise, 2005 actual CV values for young (CV = 0.19), juvenile (CV = 0.19), and adult humpback chub (CV = 0.20) in hoop nets in the LCR Inflow are similar to resampled and bootstrapped CV values from the entire 2002–2005 dataset for 12 days of sampling (CV young = 0.18, CV juvenile = 0.20, CV adult = 0.18). Contrastingly, the 2005 actual CV value for juvenile humpback chub in trammel nets (CV = 0.28) was lower than the resampled and bootstrapped CV value (CV = 0.36).

The capture locations of each species are presented in Figure 23. Humpback chub, flannelmouth sucker, and bluehead sucker are separated into age groups, and all other species are grouped into a single age group. Large-bodied native and nonnative species, including humpback chub, bluehead sucker, flannelmouth sucker, black bullhead, brown trout, channel catfish, common carp, and rainbow trout were captured in trammel and hoop nets within Reach 3, typically in greater numbers near the confluence of the LCR. The distribution of large-bodied fish outside of Reach 3 cannot be assessed since trammel and hoop nets were not set in other reaches and these fish are rarely captured in seine samples.

YOY flannelmouth sucker, bluehead sucker, and speckled dace were the only fishes captured in backwaters within Reach 1, and were present in relatively low numbers. Seining efforts within Reach 2 produced a high number of YOY flannelmouth sucker and humpback chub (Figure 23). Bluehead sucker and speckled dace were also captured in low numbers within Reach 2. Rainbow trout was the only nonnative species captured with seines in this reach (two individuals caught). YOY bluehead sucker and speckled dace were captured in the greatest numbers in the lower reaches (Reaches 8–11), and bluehead sucker were more numerous in backwaters in 2005 than in any of the previous 3 years of sampling. Small-bodied nonnative species, including fathead minnow, plains killifish, and red shiner were distributed downstream of the LCR confluence and were most numerous in Reaches 3, 4, and 8.

The length frequency distributions of each species captured in trammel nets, hoop nets, and seines in 2005 are shown in Figure 24. Humpback chub ranged between 10 and 480 mm, with a large number of individuals captured between 20 and 120 mm TL in seines and hoop nets. Two nodes are noticeable for adult humpback chub: fish between 200 and 240 mm TL and older fish between 340 and 480 mm TL. Flannelmouth sucker ranged between 10 and 590 mm TL, with the vast majority between 20 and 80 mm TL, captured in seines. Bluehead sucker ranged between 10 and 350 mm, with a YOY cohort captured in seines between 10 and 70 mm TL. All speckled dace were captured in seines and hoop nets and were between 10 and 80 mm TL. Relatively few black bullhead were captured in hoop and trammel nets and ranged between 70 and 310 mm TL. Two brown trout were captured in trammel nets with TLs of 270 and 310 mm. Two channel catfish were captured in trammel nets with TLs of 170 and 210 mm. Most of the common carp that were captured were between 40 and 140 mm TL; one carp was 480 mm TL. All fathead minnow and plains killifish captured were between 10 and 80 mm TL. Rainbow trout were captured in all three gear types and ranged between 40 and 370 mm TL. Red shiner were captured in seines and hoop nets and were between 10 and 70 mm TL.

## DISCUSSION

Focusing trammel and hoop net sampling efforts between Kwagunt and Tanner Rapids in 2005 proved to be an effective and efficient strategy for increasing the mark rate and recapture information of humpback chub in Reach 3. A total of 269 humpback chub > 150 mm TL were captured in hoop and trammel nets, including 112 chub (41%) that had not been previously marked. Furthermore, more humpback chub, flannelmouth sucker, and bluehead sucker were tagged in Reach 3 in June 2005 than over the last 3 years combined. Two days of sampling below Lava Chuar Rapid produced 17 humpback chub > 150 mm TL; however, logistically, this aggregation was considerably more difficult to sample than the LCR Inflow due to the travel distance from camp and because of the need to up-run Lava Chuar Rapid. Although few chub were captured in the Lava Chuar-Hance Aggregation, sampling efforts within this aggregation marked the presence of adult fish for the first time since the monitoring program was implemented (Figure 7).

Sampling the LCR Inflow Aggregation in subreaches allowed the aggregation to be systematically sampled twice within 12 days, which made it possible to calculate a mark-and-recapture population estimate for adult humpback chub. This estimate indicates a declining trend in the adult humpback chub population in the Colorado River within the LCR Inflow Aggregation since the early 1990s and a slight increase in the population since 2001 (Figure 11). Similar results have been documented by open and closed mark-and-recapture population models recently developed by GCMRC for the entire LCR Inflow population (Coggins et al. 2006, GCMRC unpublished data).

Limited data are available about the capture efficiency of humpback chub in trammel and hoop nets, and although it was not possible to calculate the capture probability of each gear type, it was possible to estimate the sampling efficiency of adult humpback chub for 10 days of effort in the LCR Inflow Aggregation. A total of 196 unique adult humpback chub were captured in the LCR Inflow Aggregation during June 2005, and based on the estimated adult population (1170, 95% CI = 646–2340), 10 days of sampling with hoop and trammel nets in the aggregation resulted in the capture of approximately 16.8% of the available adults (95% CI = 8.4–30.3% sampling efficiency). Furthermore, trammel nets captured 142 unique adult fish, or approximately 12.1% of the available adults (95% CI = 6.1–22.0% sampling efficiency), and hoop nets captured 65 unique adult fish, or approximately 5.6% of the available adults (95% CI = 2.8–10.1% sampling efficiency). These data may not be useful for correlating abundance to catch rates of adult humpback chub, but provide information on the amount of effort required to increase mark rates of humpback chub.

Trammel net catch rate indices in Reach 3 show an increasing trend in relative abundance for native species since 2002 and a decreasing trend for rainbow trout (Figures 5–7). Humpback chub and flannelmouth sucker catch rates have increased annually since 2002, and bluehead sucker catch rates have increased in this reach for the first time since the monitoring program was implemented. The increase in catch rates of these three species is attributed to an increase in the capture of adult fish (Figure 6); however, an increase in juvenile humpback chub in trammel nets is notable. The increases in adult native fish catch rates may be explained by an increased abundance of these species or by increased mainstem habitation by adult fish from the LCR. These results are complicated by the fact that increased effort was applied in 2005, although the increasing trends are consistent from 2002 to 2005 for humpback chub and flannelmouth sucker. Trammel net catch rate indices do not show a change in relative abundance for nonnative species other than rainbow trout.

Hoop net catch rate indices show an increasing trend in humpback chub relative abundance, with a particularly large increase in 2005 (Figure 8). Unlike trammel net indices, increased hoop net catch rates of humpback chub are not associated with an increase in adult fish, but rather young fish (Figure 9). 2005 hoop net catch rates of adult humpback chub actually decreased from the previous two years. Juvenile humpback chub showed a slight increase in catch rates for hoop nets, similar to trammel nets, and was more apparent in the LCR Inflow Aggregation than in the Lava Chuar-Hance Aggregation (Figure 10). The increase in young humpback chub catch rate in hoop nets was apparent in both aggregations sampled (Figure 10). No trends in hoop net catch rates were apparent for other species, although it was noted that bluehead sucker, common carp, and red shiner were present in hoop net samples in Reach 3 for the first time this year. Similar to trammel nets, hoop net indices are complicated by the fact that unequal effort was applied to Reach 3 in 2005. Additionally, catch rates of young humpback chub in hoop nets may be influenced by flooding of the LCR, and spring 2005 had several flood events greater than 2,000 cfs (USGS 2006) prior to hoop net sampling.

Seining catch rate indices were highly variably for all species captured (Figures 12–21). Trends in seining catch rates of young native and small-bodied nonnative species were indeterminable due to the large variance associated with this gear type, and these data suggest that seining efforts may not be useful for determining trends in species' relative abundances.

Although seining data may not be able to detect changes in relative abundance, river-wide seining efforts provide presence or absence data for young native and small-bodied nonnative species, as well as provide indication of native fish spawning locations (Figure 23). For example, 2002–2005 seining efforts have documented the absence of fathead minnow, plains killifish, and red shiner upstream of the LCR confluence and suggest that these species are introduced into the Colorado River via the LCR. Additionally, the presence of a large number of YOY humpback chub and flannelmouth sucker in Reach 2 between RM 35 and 52 are evidence that mainstem spawning of these two species occurred in this reach of river. Furthermore, seine samples in Reach 2 were dominated by native species (99.9%) with a total of two rainbow trout being the only nonnative species captured in this reach. These data indicate that Reach 2 may be important for mainstem native fish rearing.

Increased trammel and hoop catch rates of native species, and increased numbers of young native fish in seine samples in Reach 2, suggest that some native species are benefiting from changes that have occurred in the ecosystem over the last 4 years. These changes include increased mean temperatures in the Colorado River (Hueftle 2005, Vernieu et al. 2005) and the decreased abundance of rainbow trout in Reach 3 due to mechanical removal efforts (Gloss and Coggins 2005, GCMRC unpublished data). Since these changes have occurred simultaneously, it is not possible to determine which factor is more beneficial to native fish; however, future monitoring efforts may provide some indication of which factor is more advantageous to native species if either river temperatures were decreased due to increased reservoir elevation in Lake Powell or nonnative species removal efforts were discontinued and trout populations increased.

CV values (Table 9) indicate that trammel nets may not be useful for monitoring relative abundance trends for fishes other than humpback chub, flannelmouth sucker, and bluehead sucker in Reach 3 due to the high variance in catch rates associated with other species. Trammel nets are not likely to be able to monitor changes in relative abundance of native species less than 146% over 5 years in this reach at 2005 effort levels (TRENDS, Gerrodette 1987, alpha = 0.05, beta = 0.20, 2-tailed test, linear rate of change, CV remains constant with abundance, equal sampling intervals). CV values indicate that hoop nets may only be useful for monitoring young, juvenile, and adult humpback chub in the LCR Inflow Aggregation at 2005 effort levels (Table 10); however, hoop nets are only likely to detect changes in relative abundance greater than 286% over 5 years (TRENDS, Gerrodette 1987, alpha = 0.05, beta = 0.20, 2-tailed test, linear rate of change, CV remains constant with abundance, equal sampling intervals). Despite the low resolution in catch rate indices, increases in catch rates over the last 4 years were detected for young and juvenile humpback chub in hoop nets, and juvenile and adult humpback chub in trammel nets in Reach 3, indicating an increase in relative abundance. Furthermore, more subtle changes may be detected over a longer period. For example, 2005 CV values indicated that a 73% change in the relative abundance of native species in trammel nets in Reach 3 over 10 years may be detected, and a 143% change may be detected for humpback chub in hoop nets over 10 years (TRENDS, Gerrodette 1987).

Concentrating netting efforts in Reach 3 provides less variation in catch rates and therefore a greater ability to detect relative abundance trends (Figure 22). Nine days of sampling are necessary to achieve a CV value less than 0.20 for adult humpback chub in trammel nets, and 11 days of sampling are necessary to obtain CV values less than 0.20 for all age groups of humpback chub in hoop nets. Other species catch rates in Reach 3 are more variable than humpback chub, and greater effort would be required to achieve CV values less than 0.20.

Although concentrated netting effort in Reach 3 in 2005 improved trend detection resolution for native species, it did not provide any information on fishes outside of this reach. For example, increased catch rates were detected for humpback chub in Reach 3 for both hoop and trammel nets; however, 2005 sampling provided no information on humpback chub in aggregations outside of Reach 3 or the presence of humpback chub outside of known aggregations. The distribution of nonnative species outside of Reach 3 was only measurable for young native and small-bodied species within backwaters (Figure 23). Therefore, 2005 data did not provide accurate distribution data for juvenile and adult native species or large-bodied nonnative species, which have been shown to be distributed over a much greater range in the past.

The length frequency distributions show a cohort of YOY native and small-bodied nonnative species captured in backwaters, suggesting that increased river temperatures, steady fall flows, or both had a positive impact on native fish rearing, as well as on warm-water small-bodied species such as fathead minnow and plains killifish (Figure 24). The presence of a large number of YOY humpback chub in Reach 2 suggests that mainstem spawning occurred in this reach, either by adult fish at the 30-mile Aggregation, adult fish that moved up from the LCR Inflow Aggregation into Reach 2, an unknown aggregation of adults between RM 35 and 50, or a combination of these aggregations. Additionally, a relatively high number of young humpback chub between 50 and 120 mm TL were captured in hoop nets along shorelines in Reach 3, and a juvenile and young adult cohort was detected in trammel nets between 180 and 250 mm TL. Humpback chub between 100 and 200 mm TL have been relatively rare in previous years, and 2005 age structure data suggests that the survival of young and juvenile humpback chub may have increased over the last couple of years, which may lead to improved recruitment to adulthood.

## CONCLUSIONS AND RECOMMENDATIONS

Catch rates for trammel nets, hoop nets, and seines were more variable than the target variation level established during the design of the monitoring program (CV = 0.10), and indices did not have the resolution to detect changes in relative abundance at target levels (75% change over 5 years). None-the-less, CPUE indices for trammel and hoop nets were able to detect increasing trends in native species catch rates, including juvenile and adult humpback chub in trammel nets, and young and juvenile humpback chub in hoop nets. Seining data were highly variable for all species, and seining efforts are not likely to provide relative abundance trend information but do provide river-wide distribution data for YOY and small-bodied species in backwaters. Trend detection can be improved by concentrating efforts in areas where species are more abundant, such as humpback chub in the LCR Inflow Aggregation, although river-wide distributional information is compromised.

Power analyses suggest that a minimum of 11 days of sampling are required to lower variability in humpback chub catch rates in the LCR Inflow to near target levels (CV < 0.20). Concentrating sampling efforts within the LCR Inflow Aggregation allowed for an absolute abundance estimate of humpback chub in the Colorado River within the aggregation, which may be just as valuable as relative abundance estimates. It is important to consider that native fish populations may experience drastic changes in population size and distribution associated with changes in the ecosystem, that current monitoring efforts may detect large changes in relative abundance and distribution, and that trend detection resolution improves with increased study duration. It is therefore important that long-term monitoring methods be standardized and sampling efforts occur consistently each year in order to determine relative abundance trend direction and magnitude, as well as determine impacts to native fish populations from changes in the Colorado River ecosystem such as increased river temperatures, nonnative species invasion, or changes in the food base. A combination of river-wide, aggregation, and intensive LCR Inflow Aggregation netting may be ideal for monitoring humpback chub in the Colorado River, although it is likely that three netting trips would be required per year, and managers must compromise between the cost of increased sampling efforts and native fish trend detection resolution.

It is recommended that sampling occur within all aggregations in 2006, as well as within longitudinal reaches, similar to 2002–2004 in order to detect changes in the relative abundance of humpback chub in aggregations other than the LCR Inflow, as well as gain presence and absence data for humpback chub in areas outside of known aggregations. Furthermore, sampling within Reach 2 in 2006, particularly between RM 35 and 50, may provide information on mainstem spawning of humpback chub, mainly the origin of the spawning adult fish, provided adult fish are captured that have been previously marked. Lastly, river-wide netting efforts may detect the invasion of nonnative species that are not susceptible to other methods of sampling. For example, if crayfish were to be introduced to the Colorado River via flooding in the LCR drainage, hoop nets would be more likely to detect the presence of this species than other gears, since crayfish are likely to pursue the bait.

## REFERENCES


Coggins, L.G., W.E. Pine, C.J. Walters, D.R. VanHaverbeke, D. Ward, and H.C. Johnstone. 2006. Abundance trends and status of the Little Colorado River population of humpback chub. North American Journal of Fisheries Management 26:233–245.

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

Gloss, S.P. and L.G. Coggins. 2005. Fishes of Grand Canyon. Chapter 2 in Gloss, S.P., J.E. Lovich, and T.S. Melis. (eds). 2005. The state of the Colorado River ecosystem in Grand Canyon. U.S. Geological Survey Circular 1282, 220 p.

Hueftle, S. 2005. Downstream water quality effects of drops in Lake Powell elevation, 2003. Presentation at the Colorado River Ecosystem Science Symposium. October 28–30, 2003. Tucson, Arizona. Available at: www.gcmrc.gov.

Lockwood, R.N., and J.C. Schneider. 2000. Stream fish population estimates by mark-and-recapture and depletion methods. Chapter 7 in Schneider, J. C. (ed.). 2000. Manual of fisheries surveys methods II: with periodic updates. Michigan Department of Natural Resources, Fisheries Special Report 25, Ann Arbor.

Trammel, M.T., and R.A. Valdez. 2003. Native fish monitoring activities in the Colorado River within Grand Canyon during 2001. Final Report to the Grand Canyon Monitoring and Research Center, Flagstaff, Arizona. SWCA Environmental Consultants, Flagstaff, Arizona.

U.S. Geological Survey. 2006. USGS, Water Resources of the United States, NWISWeb Data for the Nation. Available at: http://nwis.waterdata.usgs.gov/nwis/discharge/?site_no=09402000.

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

Vernieu, W.S., S.J. Hueftle, and S.P. Gloss. 2005. Water quality in Lake Powell and the Colorado River. Chapter 4 in Gloss, S.P., J.E. Lovich, and T.S. Melis. (eds). 2005. The state of the Colorado River ecosystem in Grand Canyon. U.S. Geological Survey Circular 1282, 220 p.

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

Ward, D.L., and R.S. Rogers. 2006. In Review. Grand Canyon long-term nonnative fish monitoring, 2005. Draft Report to Grand Canyon Monitoring and Research Center, Flagstaff, Arizona. Arizona Game and Fish Department, Phoenix, Arizona.

# TABLES

**Table 1.** Status and Relative Abundance of Fish Species Occurring in the Colorado River within Grand Canyon from Lees Ferry to Diamond Creek

| Common name | Abbreviation | Scientific Name | Status | Relative Abundance |
|---|---|---|---|---|
| Black bullhead | BBH | *Ictalurus melas* | NN | R |
| Bluegill sunfish | BGS | *Lepomis macrochirus* | NN | R |
| Bluehead sucker | BHS | *Catostomus discobolus* | N | C |
| 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 |
| Flannelmouth sucker | FMS | *Catostomus latipinnis* | N | C |
| Golden shiner | GSH | *Notemigonus crysoleucas* | NN | R |
| Green sunfish | GSF | *Lepomis cyanellus* | NN | R |
| Humpback chub | HBC | *Gila cypha* | N, E | LC |
| 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 |
| Speckled dace | SPD | *Rhinichthys osculus* | N | C |
| Striped bass | STB | *Morone saxatilis* | NN | R |
| Threadfin shad | TFS | *Dorosoma petenense* | NN | R |
| Walleye | WAL | *Stizostedion vitreum* | NN | R |

Adapted from Valdez and Ryel (1995).
Status: N=native; NN=nonnative; E=endangered.
Relative abundance: A=abundant; C=common; LC=locally common; R=rare.

**Table 2.** Reach and Aggregation River Mile Designations

| Reach | River Miles |
|---|---|
| 1 | 0.0–30.9 |
| 2 | 31.0–56.9 |
| 3 | 57.0–69.9 |
| 4 | 70.0–79.9 |
| 5 | 80.0–109.9 |
| 6 | 110.0–129.9 |
| 7 | 130.0–159.9 |
| 8 | 160.0–179.9 |
| 9 | 180.0–199.9 |
| 10 | 200.0–219.9 |
| 11 | 220.0–225.7 |
| **Aggregation** | **River Miles** |
| 30-mile | 29.8–31.3 |
| Little Colorado River Inflow | 57.0–65.4 |
| Lava Chuar-Hance | 65.7–76.3 |
| Bright Angel Creek Inflow | 83.8–92.2 |
| Shinumo Creek Inflow | 108.1–108.6 |
| Stephen Aisle | 114.9–120.1 |
| Middle Granite Gorge | 126.1–129.0 |
| Havasu Creek Inflow | 155.8–156.7 |
| Pumpkin Spring | 212.5–213.2 |

**Table 3.** 2005 Sampling Locations of Trammel and Hoop Nets in the Colorado River, Grand Canyon, within Reaches 2 (RM 31.0–56.9) and 3 (RM 57.0–69.9)

| Date | Boat A | | Boat B | |
|---|---|---|---|---|
| | Hoop reach (RM, Side) | Trammel reach (RM, Side) | Hoop reach (RM, Side) | Trammel reach (RM, Side) |
| 6/12/2005 | 57.6–60.4, Left | 56.2–57.8, Left | 58.8–60.6, Right | 56.7–58.2, Right |
| 6/13/2005 | 60.8–61.2, Left | 58.1–59.6, Left | 60.7–62.2, Right | 58.7–60.1, Right |
| 6/14/2005 | 63.0–63.8, Left | 60.2–61.9, Left | 62.4–64.0, Right | 60.7–61.6, Right |
| 6/15/2005 | 64.2–65.3, Left | 62.6–63.7, Left | 64.1–65.0, Right | 62.5–63.7, Right |
| 6/16/2005 | 66.6–68.5, Left | 64.4–65.3, Left | 66.9–68.5, Right | 64.2–65.0, Right |
| 6/17/2005 | 56.2–58.2, Left | 66.8–68.5, Left | 56.9–57.8, Right | 66.9–68.5, Right |
| 6/18/2005 | 58.3–59.5, Right | 56.7–57.4, Right | 58.4–59.6, Left | 56.2–57.8, Left |
| 6/19/2005 | 60.1–61.3, Right | 60.1–61.1, Right | 59.7–60.4, Left | 58.1–59.3, Left |
| 6/20/2005 | 61.2–62.7, Right | 58.2–59.3, Right | 61.0–61.8, Left | 59.4–60.7, Left |
| 6/21/2005 | 63.1–64.9, Right | 61.8–62.6, Right | 62.7–63.5, Left | 61.2–62.7, Left |
| 6/22/2005 | 66.3–68.5, Right | 63.1–64.5, Right | 68.1–68.6, Left | 63.0–64.2, Left |
| 6/23/2005 | 56.9–57.9, Right | 66.8–68.5, Right | 56.2–57.8, Left | 66.8–68.5, Left |

**Table 4.** Sampling Effort within the Colorado River, Grand Canyon, during the 2005 Native Fish Monitoring Trips

| Reach | Trammel Net Effort | | | Hoop Net Effort | | | Seine Effort | | |
|---|---|---|---|---|---|---|---|---|---|
| | # Samples | Mean (hrs) | SE (hrs) | # Samples | Mean (hrs) | SE (hrs) | # Samples | Mean ($m^2$) | SE ($m^2$) |
| 1 | 0 | - | - | 0 | - | - | 25 | 45.5 | 7.0 |
| 2 | 6 | 5.94 | 0.09 | 12 | 19.81 | 0.15 | 44 | 58.2 | 6.8 |
| 3 | 115 | 5.78 | 0.07 | 420 | 22.39 | 0.06 | 20 | 56.6 | 9.0 |
| 4 | 0 | - | - | 0 | - | - | 7 | 30.9 | 7.8 |
| 5 | 0 | - | - | 0 | - | - | 7 | 28.5 | 7.1 |
| 6 | 0 | - | - | 0 | - | - | 14 | 40.7 | 7.1 |
| 7 | 0 | - | - | 0 | - | - | 7 | 27.4 | 8.0 |
| 8 | 0 | - | - | 0 | - | - | 26 | 35.1 | 6.6 |
| 9 | 0 | - | - | 0 | - | - | 30 | 31.5 | 4.1 |
| 10 | 0 | - | - | 0 | - | - | 29 | 39.9 | 6.9 |
| 11 | 0 | - | - | 0 | - | - | 4 | 27.5 | 4.9 |

**Table 5.** Numbers of Fish Captured with Trammel Nets in the Colorado River, Grand Canyon, in 2005

| Reach | HBC | FMS | BHS | BBH | BNT | CCF | CRP | RBT |
|---|---|---|---|---|---|---|---|---|
| 1 | - | - | - | - | - | - | - | - |
| 2 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 4 |
| 3 | 178 | 149 | 73 | 5 | 2 | 2 | 1 | 42 |
| 4 | - | - | - | - | - | - | - | - |
| 5 | - | - | - | - | - | - | - | - |
| 6 | - | - | - | - | - | - | - | - |
| 7 | - | - | - | - | - | - | - | - |
| 8 | - | - | - | - | - | - | - | - |
| 9 | - | - | - | - | - | - | - | - |
| 10 | - | - | - | - | - | - | - | - |
| 11 | - | - | - | - | - | - | - | - |
| **Aggregation** | **HBC** | **FMS** | **BHS** | **BBH** | **BNT** | **CCF** | **CRP** | **RBT** |
| 30-Mile | - | - | - | - | - | - | - | - |
| LCR Inflow | 165 | 134 | 56 | 5 | 1 | 2 | 0 | 37 |
| Lava Chuar-Hance | 13 | 15 | 17 | 0 | 1 | 0 | 1 | 5 |
| BAC Inflow | - | - | - | - | - | - | - | - |
| SHI Inflow | - | - | - | - | - | - | - | - |
| Stephen Aisle | - | - | - | - | - | - | - | - |
| Middle Granite Gorge | - | - | - | - | - | - | - | - |
| HAV Inflow | - | - | - | - | - | - | - | - |
| Pumpkin Spring | - | - | - | - | - | - | - | - |
| Outside of Aggregations | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 4 |

**Table 6.** Numbers of fish captured with hoop nets in the Colorado River, Grand Canyon, in 2005

| Reach | HBC | FMS | BHS | SPD | BBH | CRP | FHM | RBT | RSH |
|---|---|---|---|---|---|---|---|---|---|
| 1 | - | - | - | - | - | - | - | - | - |
| 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 7 | 0 |
| 3 | 669 | 16 | 8 | 6 | 5 | 4 | 92 | 10 | 3 |
| 4 | - | - | - | - | - | - | - | - | - |
| 5 | - | - | - | - | - | - | - | - | - |
| 6 | - | - | - | - | - | - | - | - | - |
| 7 | - | - | - | - | - | - | - | - | - |
| 8 | - | - | - | - | - | - | - | - | - |
| 9 | - | - | - | - | - | - | - | - | - |
| 10 | - | - | - | - | - | - | - | - | - |
| 11 | - | - | - | - | - | - | - | - | - |
| **Aggregation** | **HBC** | **FMS** | **BHS** | **SPD** | **BBH** | **CRP** | **FHM** | **RBT** | **RSH** |
| 30-Mile | - | - | - | - | - | - | - | - | - |
| LCR Inflow | 577 | 15 | 7 | 6 | 4 | 4 | 77 | 10 | 1 |
| Lava Chuar-Hance | 92 | 1 | 1 | 0 | 1 | 0 | 15 | 0 | 2 |
| BAC Inflow | - | - | - | - | - | - | - | - | - |
| SHI Inflow | - | - | - | - | - | - | - | - | - |
| Stephen Aisle | - | - | - | - | - | - | - | - | - |
| Middle Granite Gorge | - | - | - | - | - | - | - | - | - |
| HAV Inflow | - | - | - | - | - | - | - | - | - |
| Pumpkin Spring | - | - | - | - | - | - | - | - | - |
| Outside of Aggregations | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 7 | 0 |

**Table 7.** Mark and Recapture Summary for SWCA Native Fish Monitoring in the Colorado River, Grand Canyon, in 2005

| Species | Data | Total |
|---|---|---|
| BHS | Count of NEW PIT TAGS | 72 |
| | Count of TAG RECAP | 5 |
| FMS | Count of NEW PIT TAGS | 117 |
| | Count of TAG RECAP | 61 |
| HBC | Count of NEW PIT TAGS | 193 |
| | Count of TAG RECAP | 157 |
| **Total Count of NEW PIT TAGS** | | **382** |
| **Total Count of TAG RECAP** | | **223** |

**Table 8.** Numbers of Fish Captured with Seines in the Colorado River, Grand Canyon, in 2005

| Reach | HBC | FMS | BHS | SPD | CRP | FHM | PKF | RBT | RSH |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 17 | 24 | 20 | 0 | 0 | 0 | 1 | 0 |
| 2 | 231 | 1,185 | 1 | 48 | 0 | 0 | 0 | 1 | 0 |
| 3 | 6 | 196 | 17 | 47 | 0 | 447 | 38 | 0 | 3 |
| 4 | 17 | 76 | 29 | 17 | 0 | 395 | 17 | 0 | 3 |
| 5 | 0 | 19 | 20 | 52 | 0 | 109 | 1 | 0 | 0 |
| 6 | 9 | 157 | 27 | 253 | 0 | 151 | 4 | 0 | 0 |
| 7 | 3 | 68 | 7 | 377 | 0 | 137 | 2 | 0 | 0 |
| 8 | 15 | 295 | 109 | 595 | 0 | 546 | 8 | 0 | 3 |
| 9 | 1 | 289 | 127 | 1,008 | 3 | 158 | 2 | 0 | 0 |
| 10 | 4 | 148 | 111 | 682 | 2 | 272 | 4 | 0 | 0 |
| 11 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| **Aggregation** | **HBC** | **FMS** | **BHS** | **SPD** | **CRP** | **FHM** | **PKF** | **RBT** | **RSH** |
| 30-mile | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| LCR Inflow | 5 | 190 | 14 | 46 | 0 | 420 | 37 | 0 | 3 |
| Lava Chuar | 15 | 70 | 9 | 12 | 0 | 285 | 6 | 0 | 2 |
| BAC Inflow | 0 | 5 | 16 | 16 | 0 | 71 | 1 | 0 | 0 |
| Stephen | 6 | 114 | 14 | 197 | 0 | 111 | 1 | 0 | 0 |
| MGG | 0 | 2 | 0 | 3 | 0 | 8 | 0 | 0 | 0 |
| HAV Inflow | 0 | 1 | 0 | 1 | 0 | 20 | 0 | 0 | 0 |
| Pumpkin | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| Outside | 260 | 2,069 | 419 | 2,824 | 5 | 1,300 | 31 | 1 | 4 |

**Table 9.** Coefficients of Variation by Species for Hoop Net, Trammels Net, and Seine Samples in the Colorado River, Grand Canyon, in 2005

| Gear Type | HBC | FMS | BHS | SPD | BBH | BNT | CCF | CRP | FHM | PKF | RBT | RSH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hoop Nets (Reach 3) | 0.14 | 0.27 | 0.35 | 0.47 | 0.45 | - | - | 0.50 | 0.36 | - | 0.34 | 0.58 |
| Trammel Nets (Reach 3) | 0.15 | 0.13 | 0.15 | - | 0.44 | 0.70 | 0.70 | 1.00 | - | - | 0.20 | - |
| Seine (Reaches 1–11) | 0.31 | 0.25 | 0.26 | 0.24 | - | - | - | 0.78 | 0.21 | 0.36 | 0.71 | 0.40 |

**Table 10.** Coefficients of Variation of Humpback Chub by Age Group and Aggregation for Hoop Net, Trammel Net, and Seine Samples in the Colorado River, Grand Canyon, in 2005*

| Age Class | Gear Type | 30-mile | LCR Inflow | Lava Chuar-Hance | Bright Angel Creek Inflow | Shinumo Creek Inflow | Stephen Aisle | Middle Granite Gorge | Havasu Creek Inflow | Pumpkin Spring | Outside of Aggregations |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Young | Hoop | - | 0.19 | 0.29 | - | - | - | - | - | - | - |
| | Trammel | - | NA | NA | - | - | - | - | - | - | - |
| | Seine | NA | 0.62 | 0.92 | NA | - | 0.68 | NA | NA | NA | 0.34 |
| Juvenile | Hoop | - | 0.19 | 0.31 | - | - | - | - | - | - | - |
| | Trammel | - | 0.28 | 0.75 | - | - | - | - | - | - | - |
| | Seine | NA | NA | NA | NA | - | NA | NA | NA | NA | NA |
| Adult | Hoop | - | 0.20 | 1.00 | - | - | - | - | - | - | - |
| | Trammel | - | 0.16 | 0.34 | - | - | - | - | - | - | - |
| | Seine | NA | NA | NA | NA | - | NA | NA | NA | NA | NA |
| All Ages | Hoop | - | 0.16 | 0.26 | - | - | - | - | - | - | - |
| | Trammel | - | 0.15 | 0.34 | - | - | - | - | - | - | - |
| | Seine | NA | 0.62 | 0.92 | NA | - | 0.68 | NA | NA | NA | 0.34 |

*Aggregations that were not samples are denoted by "-", and aggregations that were sampled but no HBC were captured are denoted by "NA".

# FIGURES

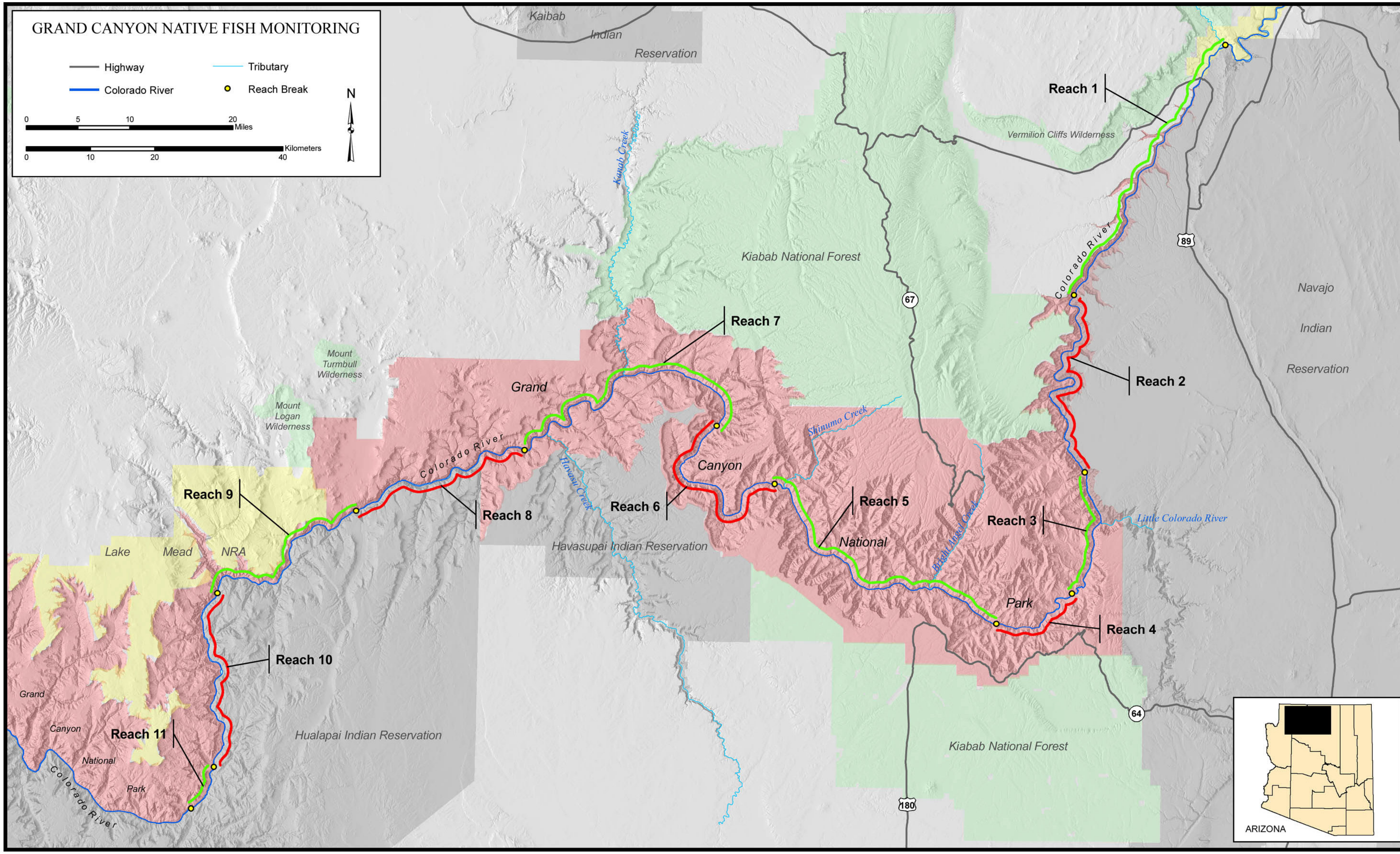


**Figure 1.** Colorado River reach designations in Grand Canyon.

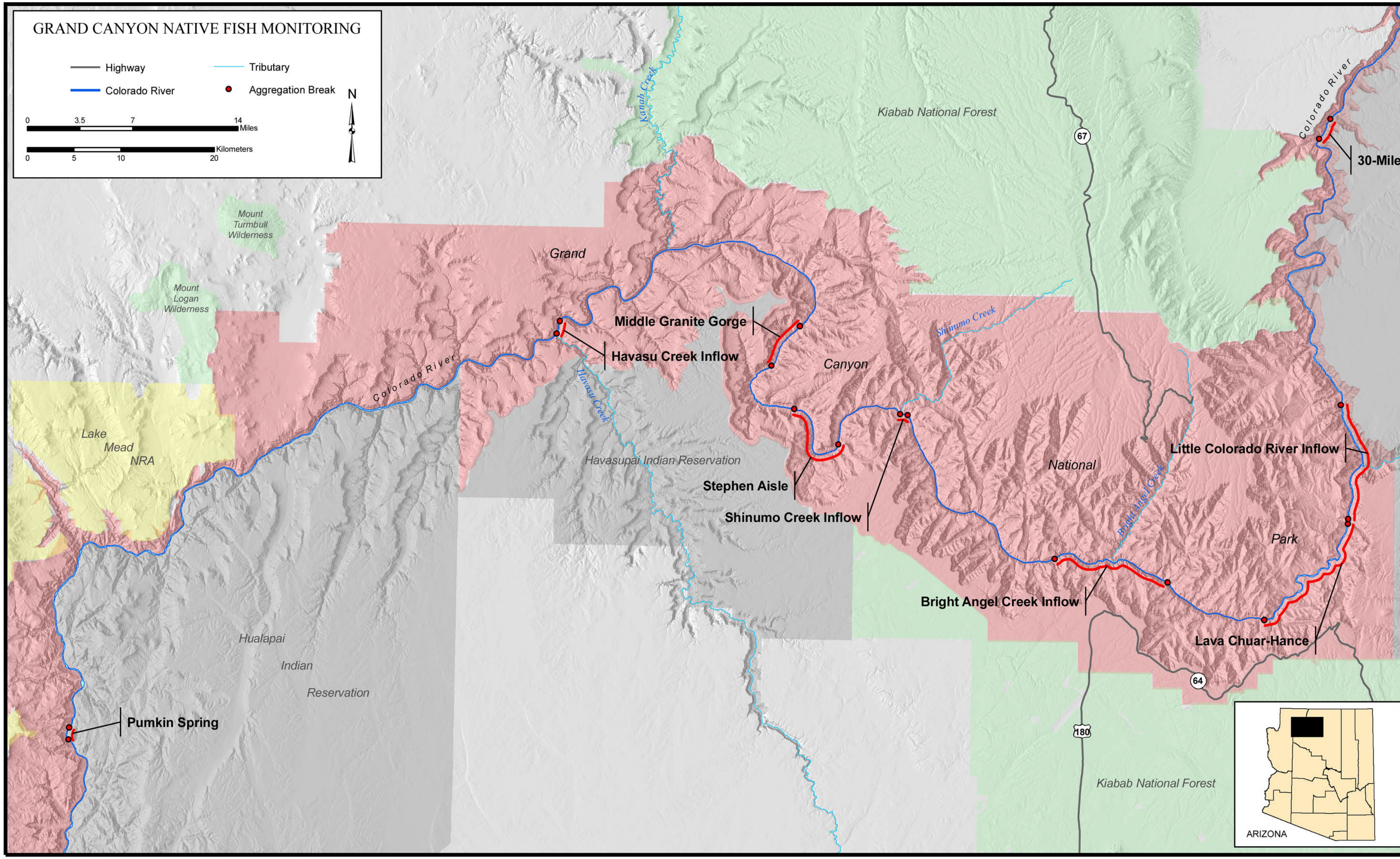


**Figure 2.** Humpback chub aggregations in Grand Canyon.

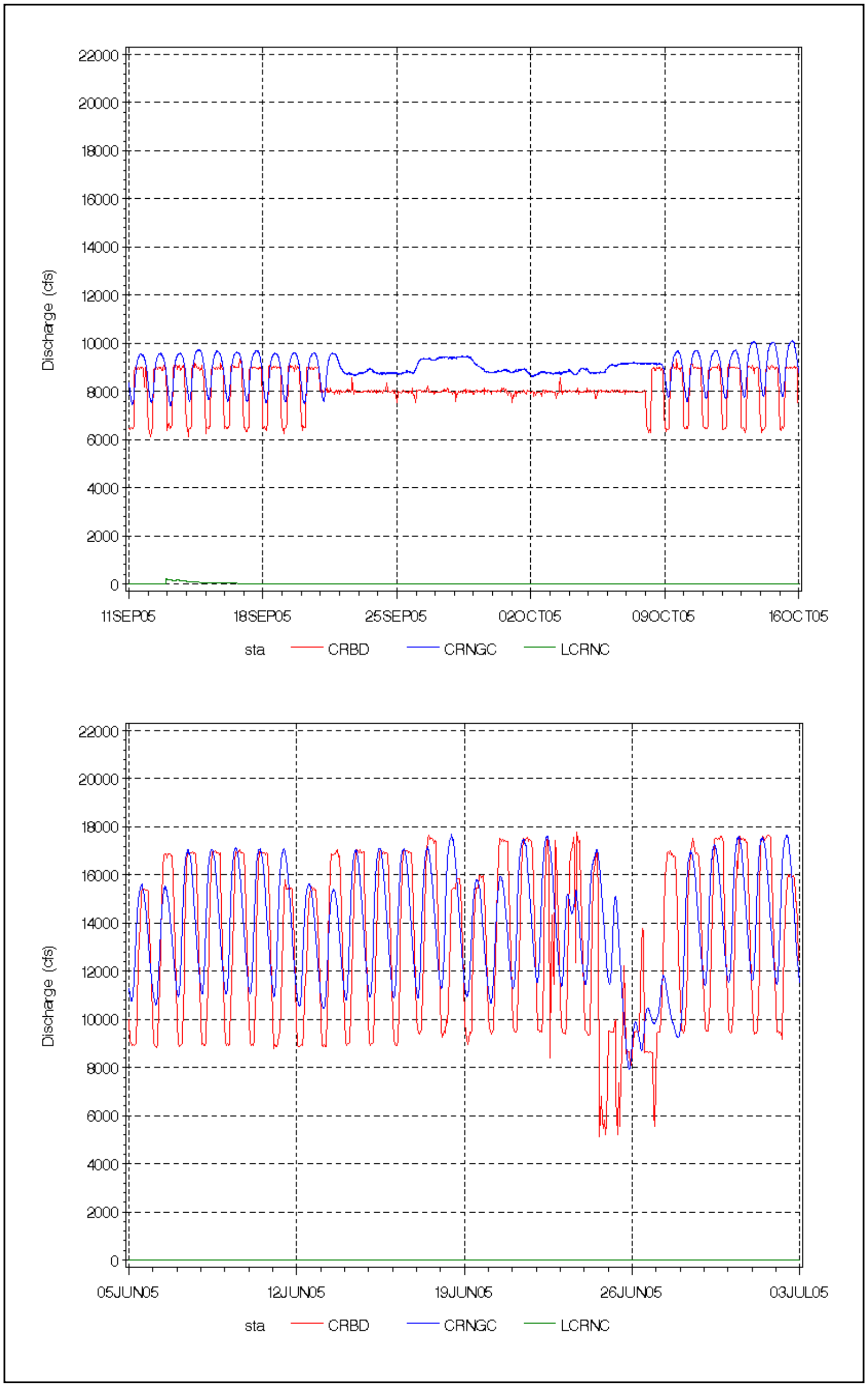


**Figure 3.** Hydrographs for the Colorado River below Glen Canyon Dam (CRBD), the Colorado River near Phantom Ranch (CRNGC), and the Little Colorado River near Cameron (LCRNC) during the 2005 native fish monitoring trips (Trip 1: June 11–27, 2005 and Trip 2: Sep. 22–Oct. 7, 2005). SOURCE: USGS GCMRC 2005.

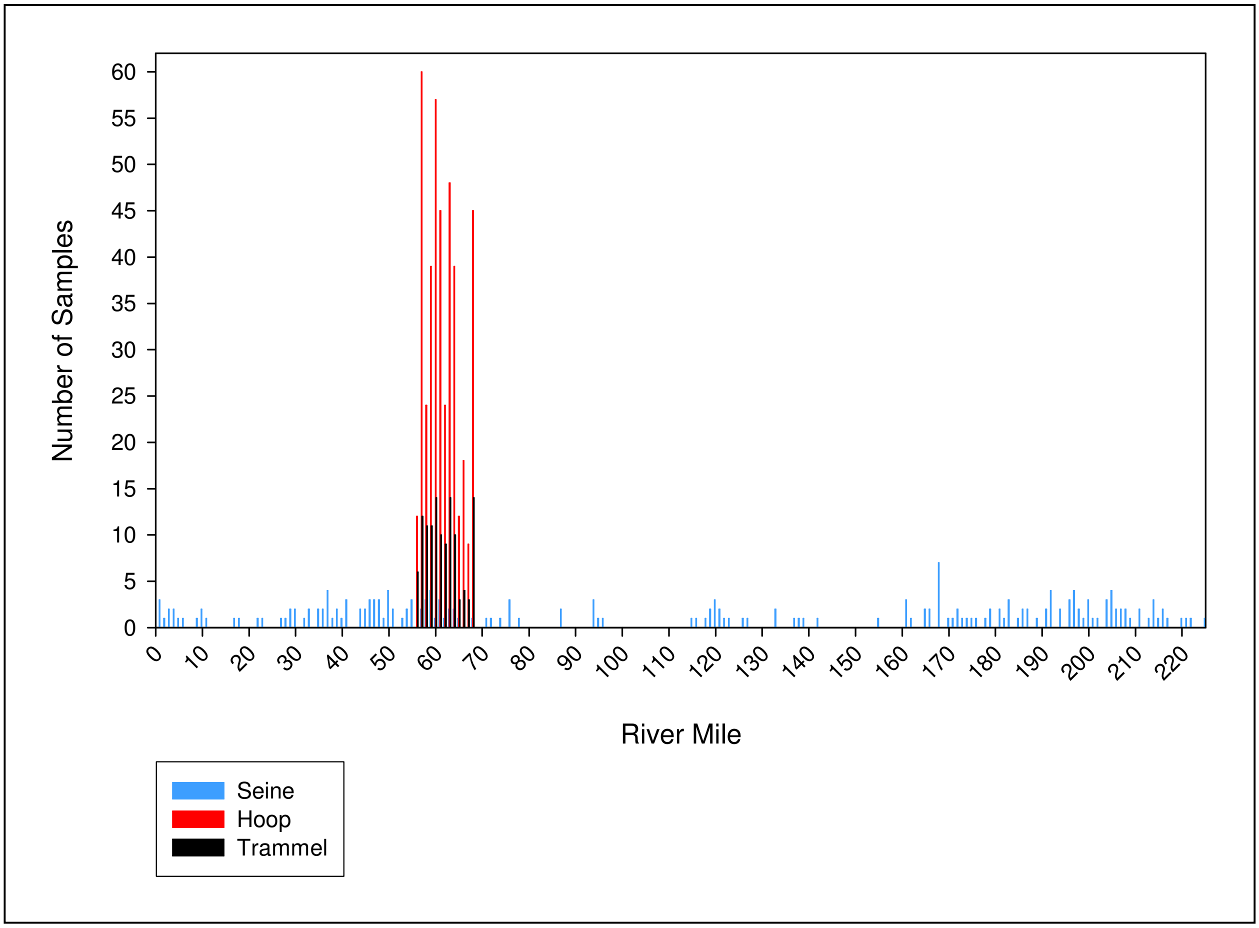


**Figure 4.** Distribution of netting samples taken in the Colorado River, Grand Canyon, in 2005.

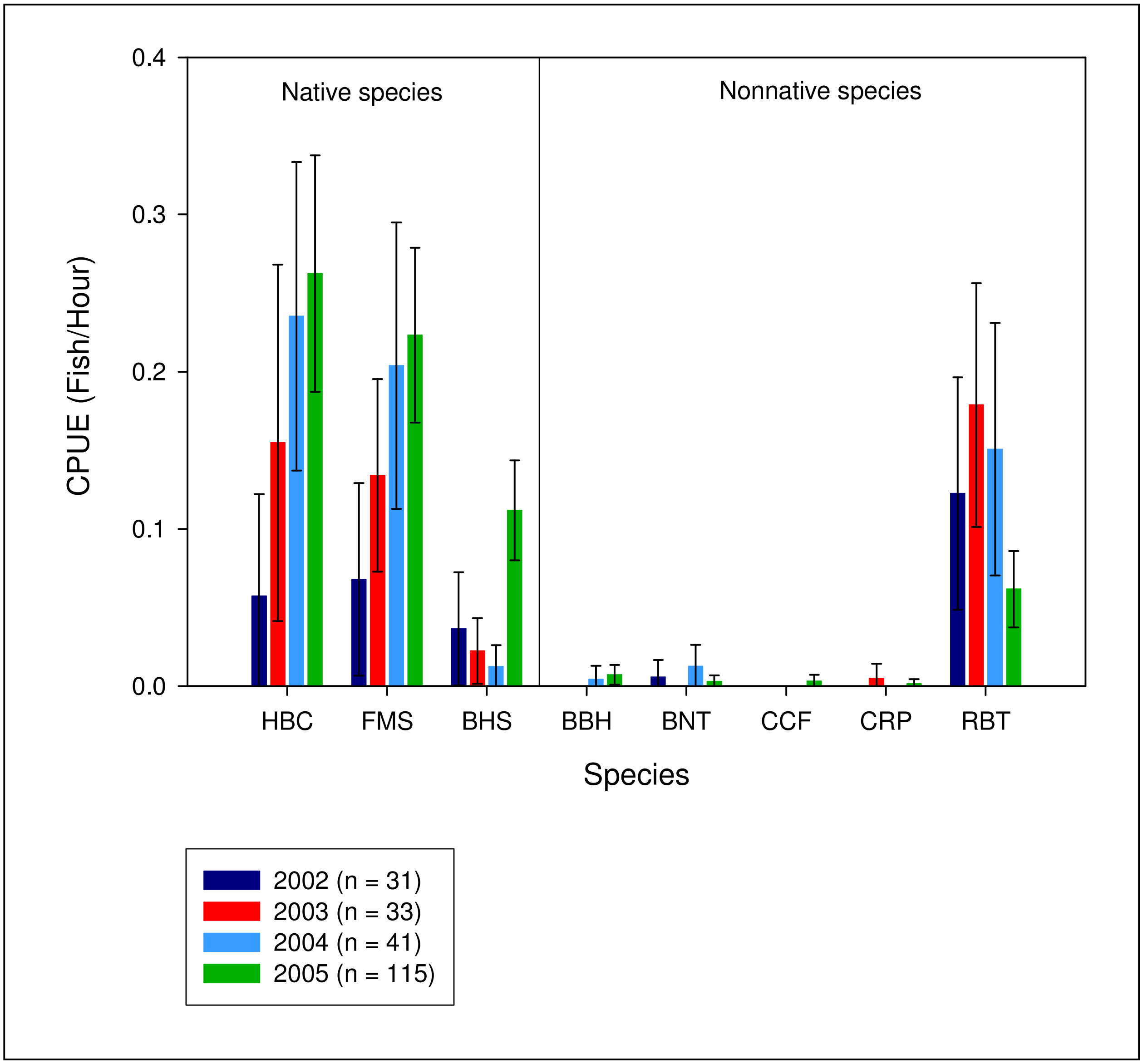


**Figure 5.** Trammel net catch per unit effort (CPUE, ± 95% CI) in Reach 3. HBC = humpback chub, FMS = flannelmouth sucker, BHS = bluehead sucker, BBH = black bullhead, BNT = brown trout, CCF = channel catfish, CRP = common carp, and RBT = rainbow trout.

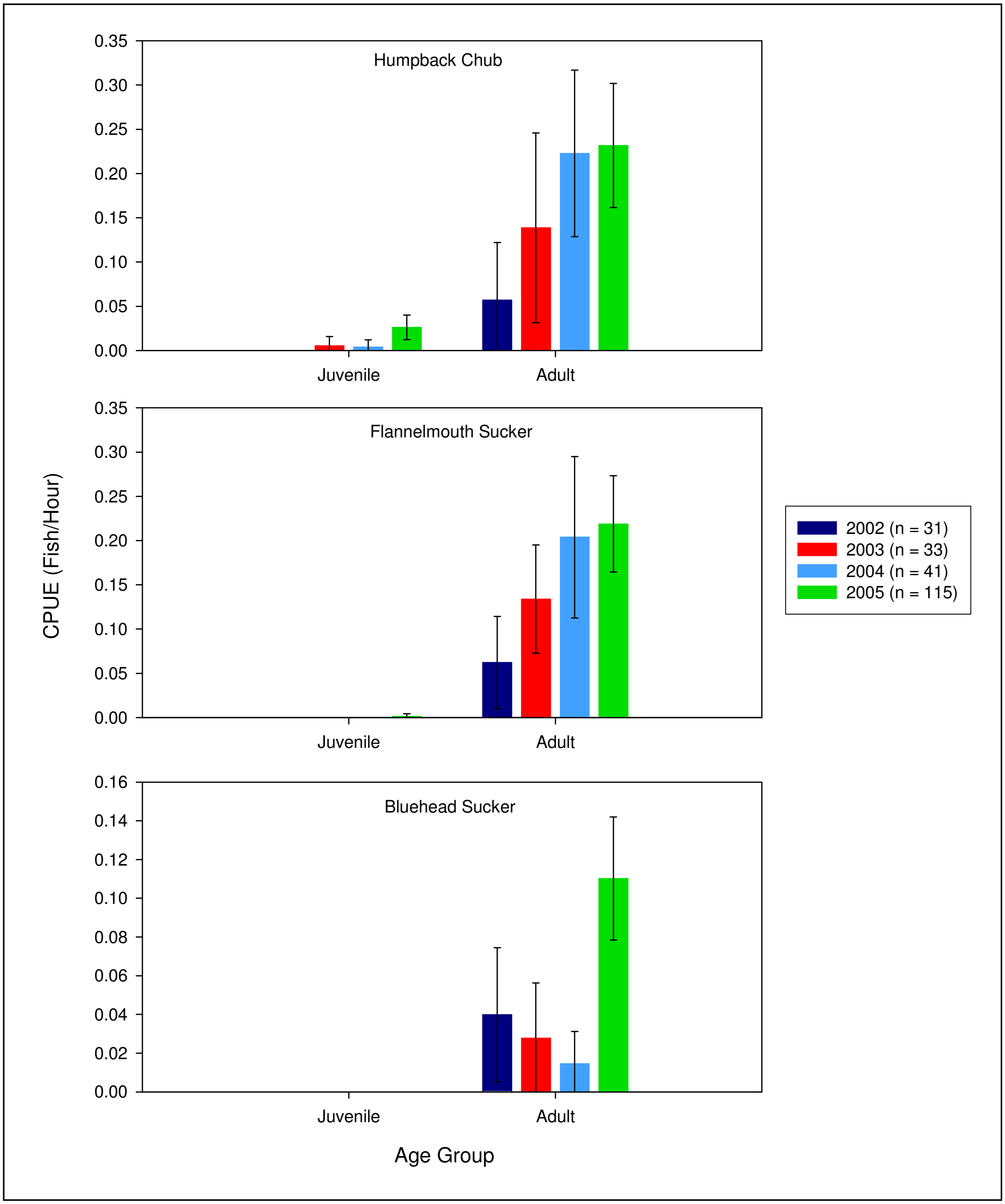


**Figure 6.** Trammel net catch per unit effort (CPUE, ± 95% CI) of native species by age group in Reach 3.

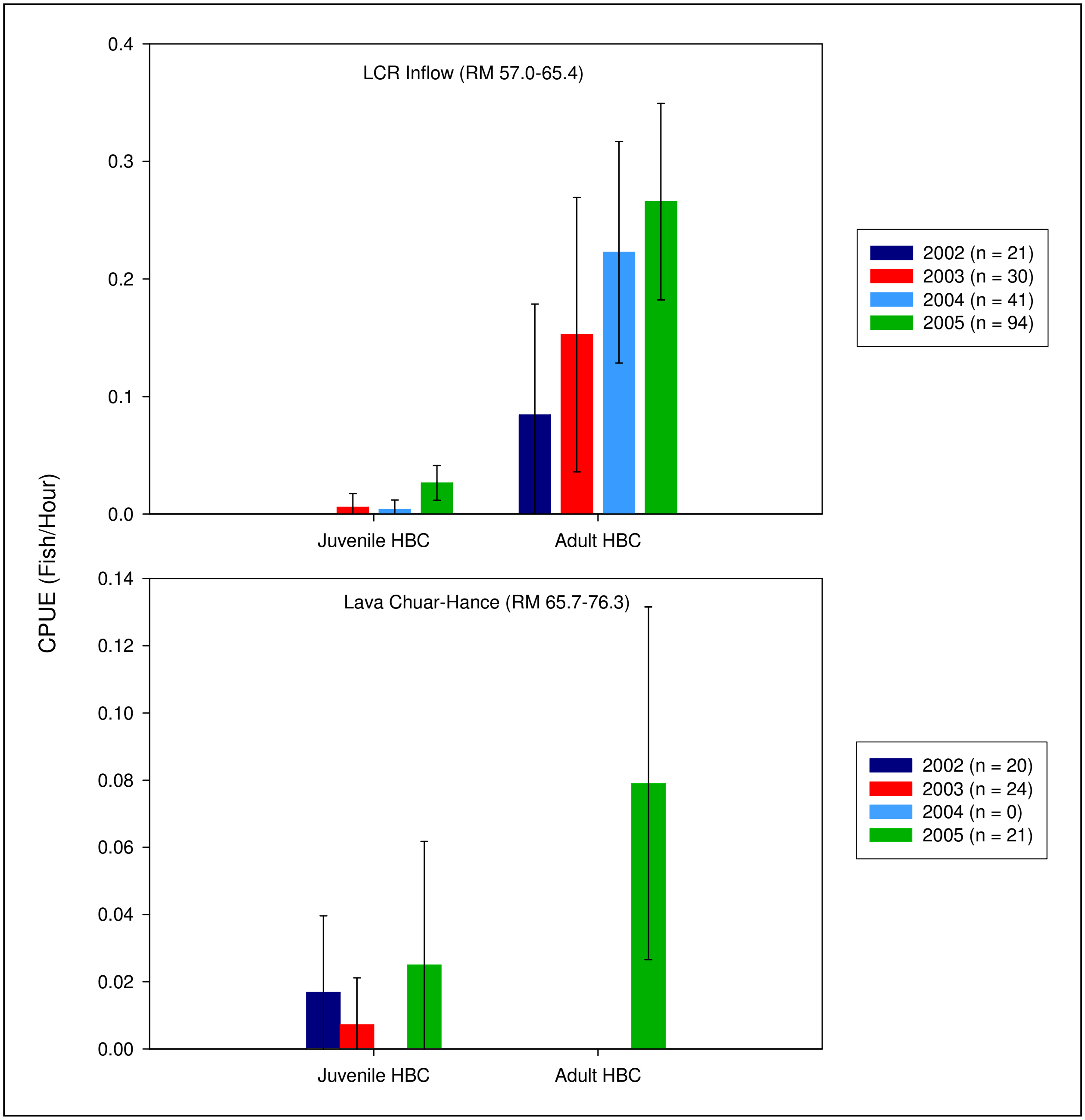


**Figure 7.** Trammel net catch per unit effort (CPUE, ± 95% CI) of humpback chub in the LCR Inflow and Lava Chuar-Hance Aggregations.

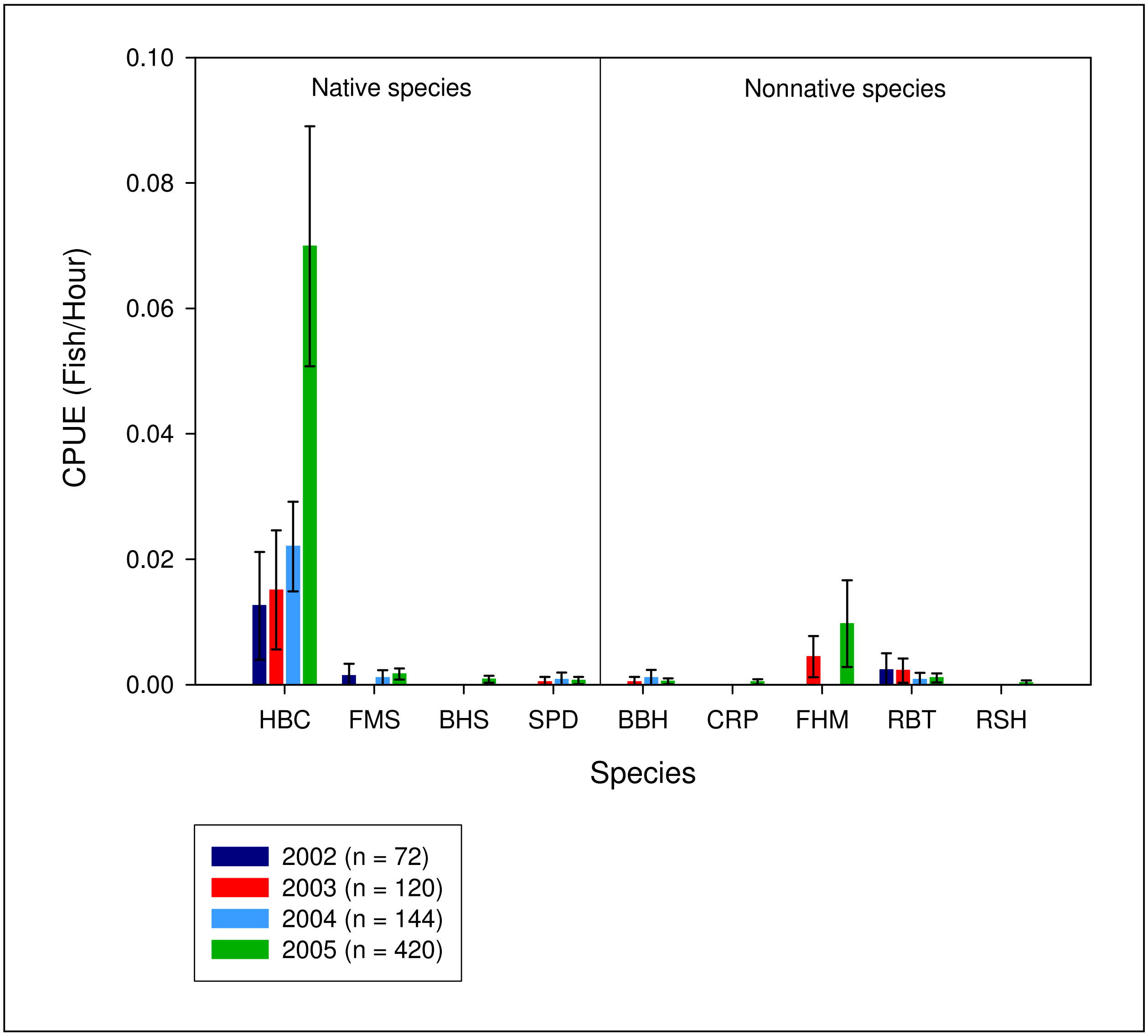


**Figure 8.** Hoop net catch per unit effort (CPUE, ± 95% CI) in Reach 3. HBC = humpback chub, FMS = flannelmouth sucker, BHS = bluehead sucker, SPD = speckled dace, BBH = black bullhead, CRP = common carp, FHM = fathead minnow, RBT = rainbow trout, and RSH = red shiner.

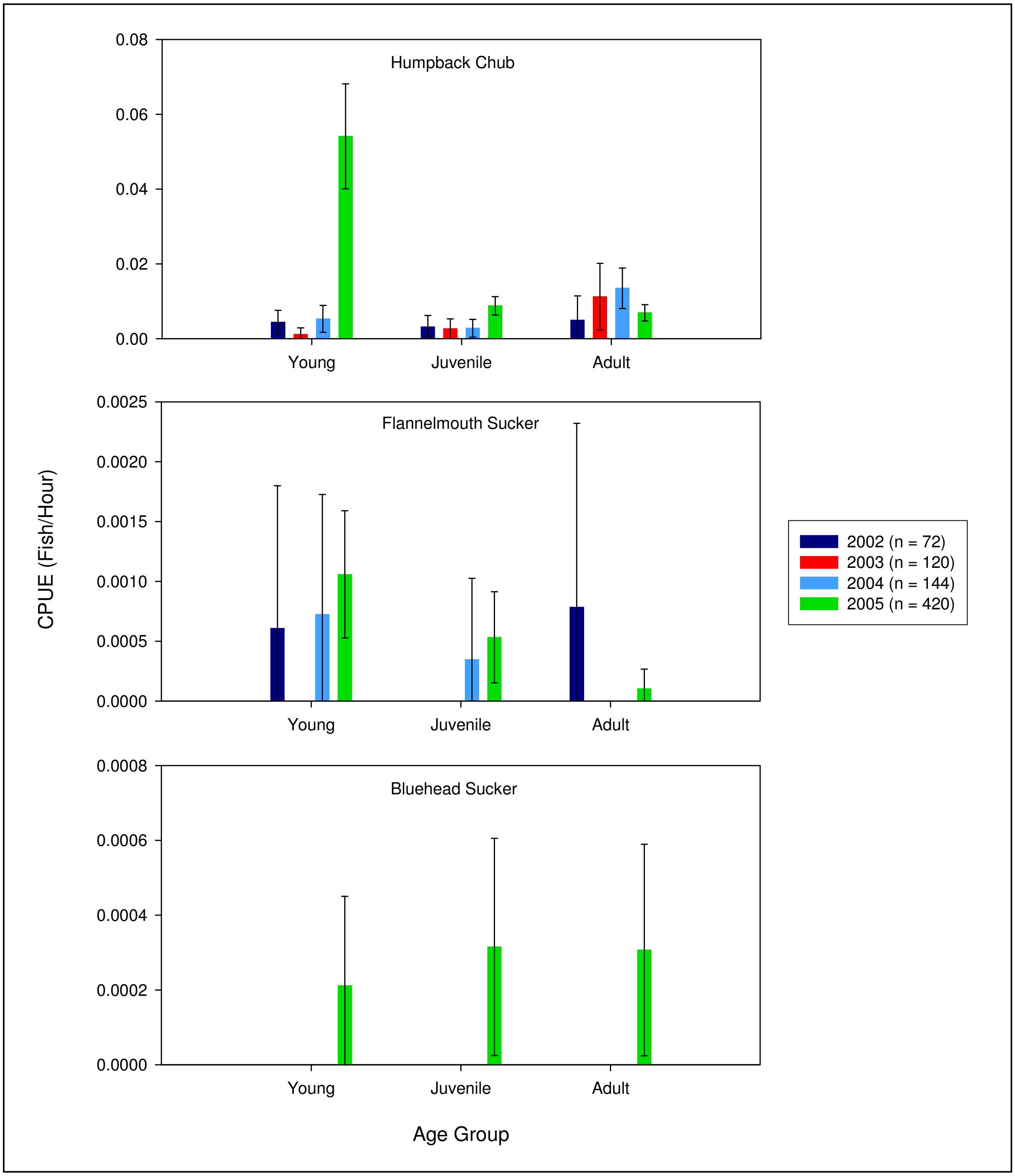


**Figure 9.** Hoop net catch per unit effort (CPUE, ± 95% CI) of native species by age group in Reach 3.

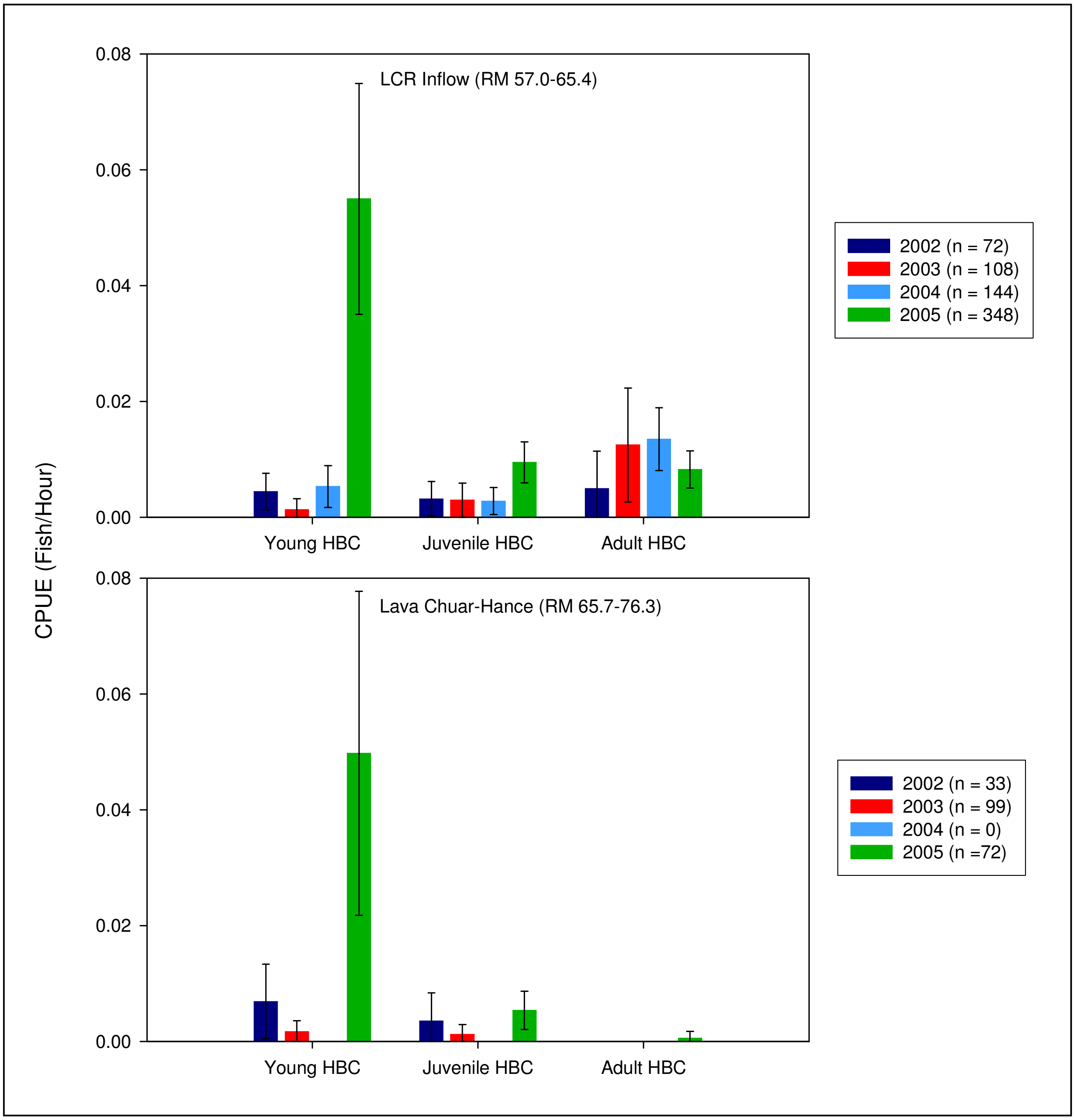


**Figure 10.** Hoop net catch per unit effort (CPUE, ± 95% CI) of humpback chub in the LCR Inflow and Lava Chuar-Hance Aggregations.

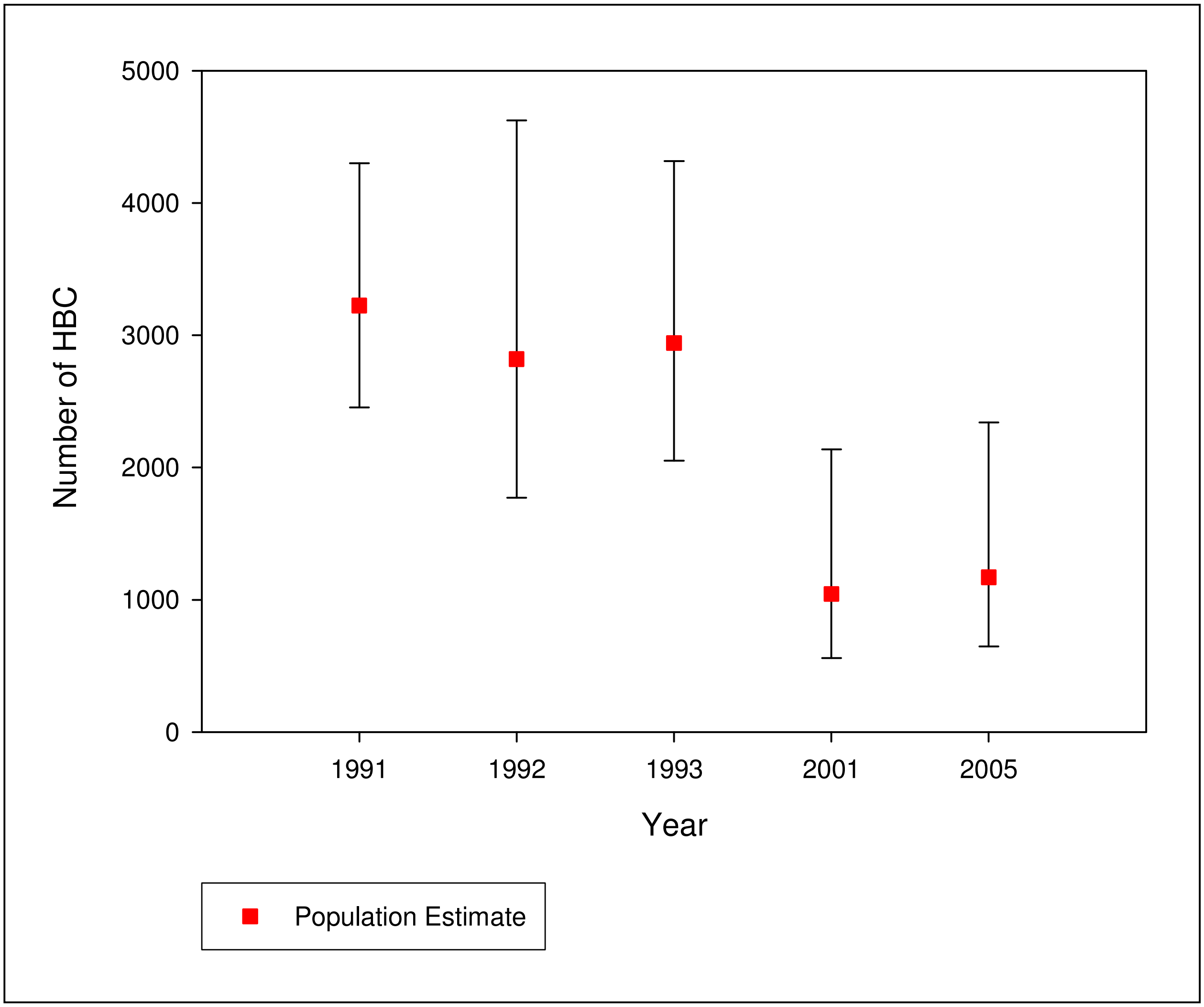


**Figure 11.** Population estimates of adult humpback chub (TL > 199mm, ± 95% CI) in the Colorado River within the LCR Inflow Aggregation. Population estimates for 1991–93 were completed by Bio/West (Valdez and Ryel 1995) using the Schnabel method, and 2001 (Trammell and Valdez 2003) and 2005 population estimates were completed by SWCA using the Chapman-Petersen method.

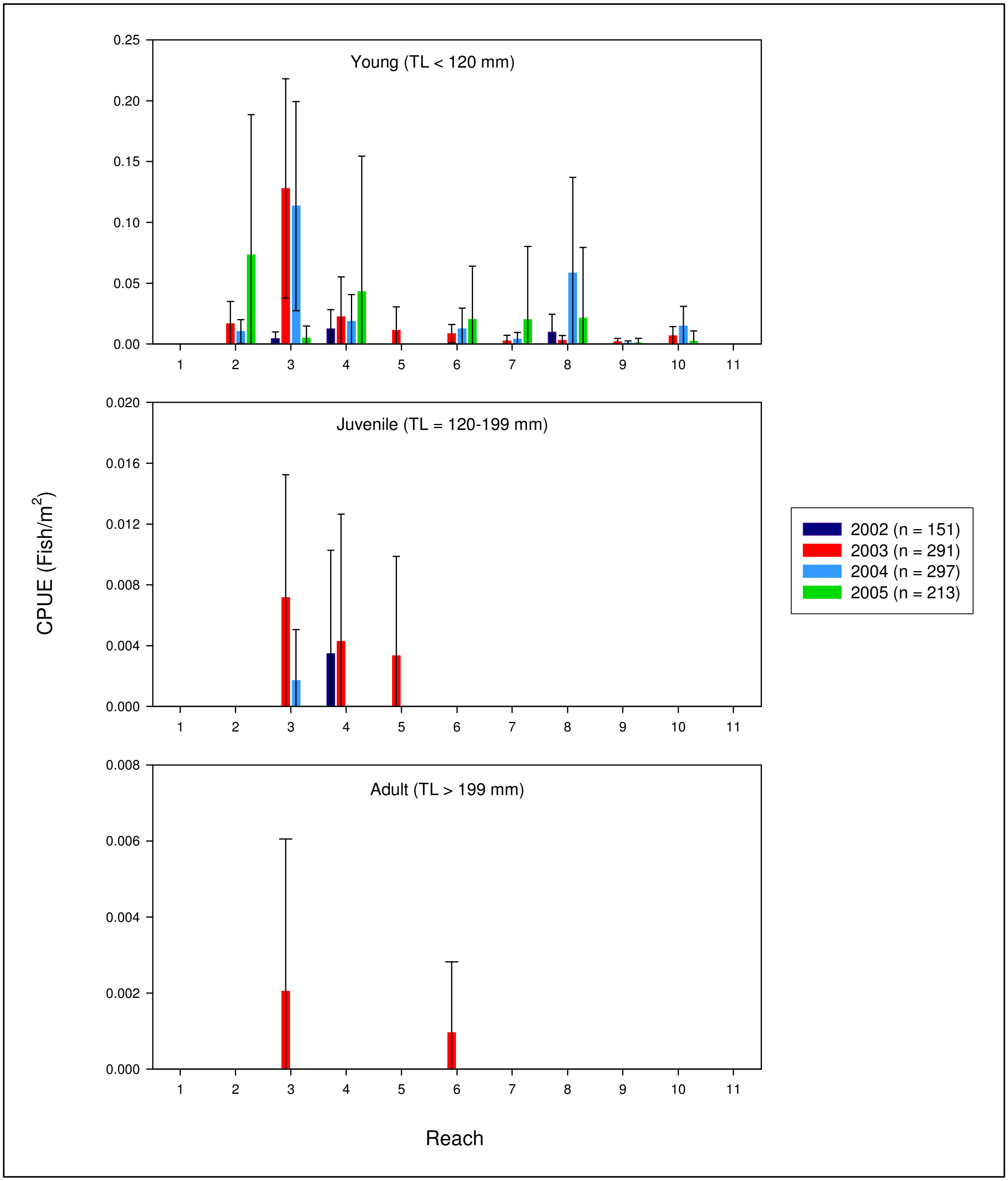


**Figure 12.** Seine catch per unit effort (CPUE, ± 95% CI) of humpback chub by age group and reach.

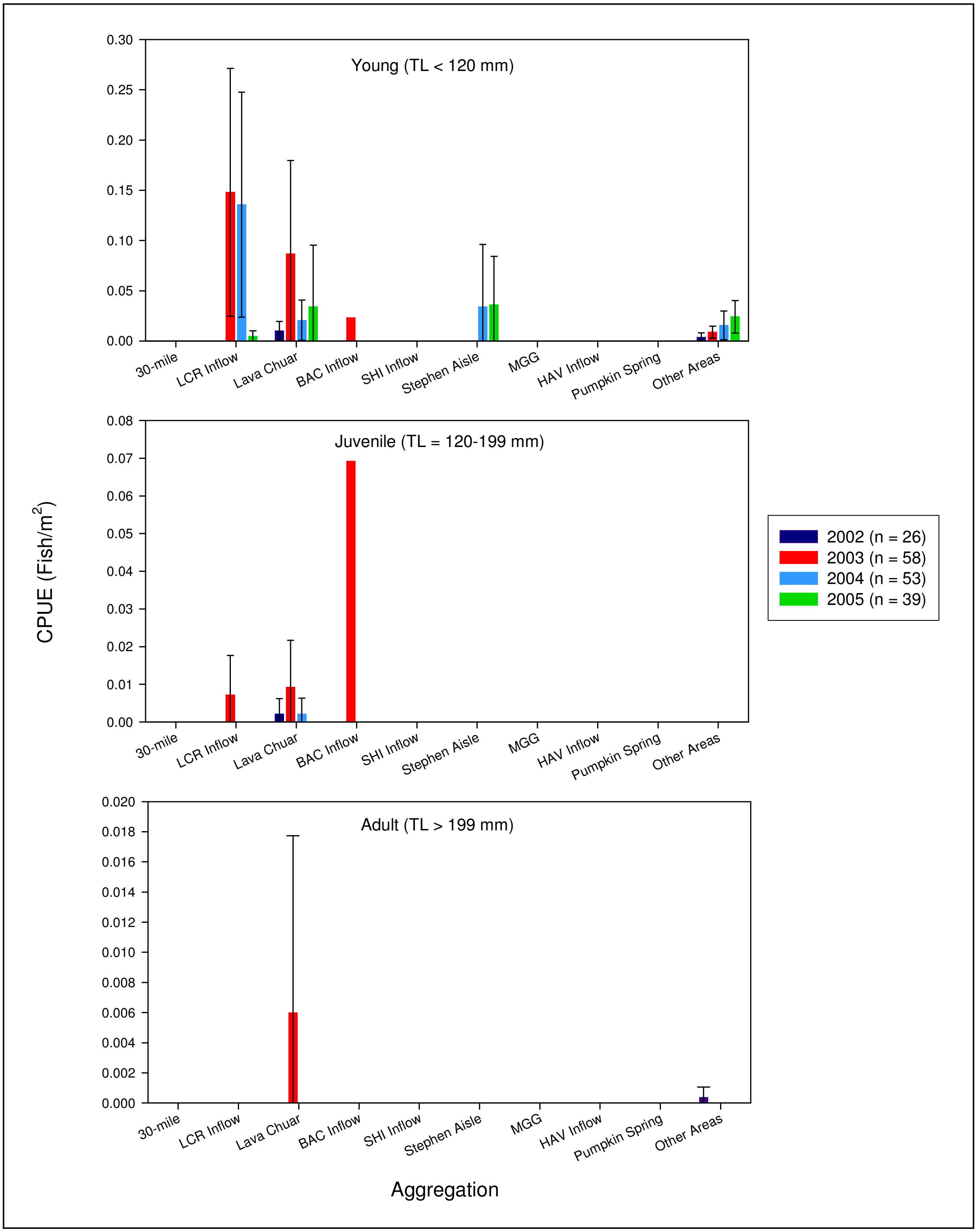


**Figure 13.** Seine catch per unit effort (CPUE, ± 95% CI) of humpback chub by age group and aggregation.

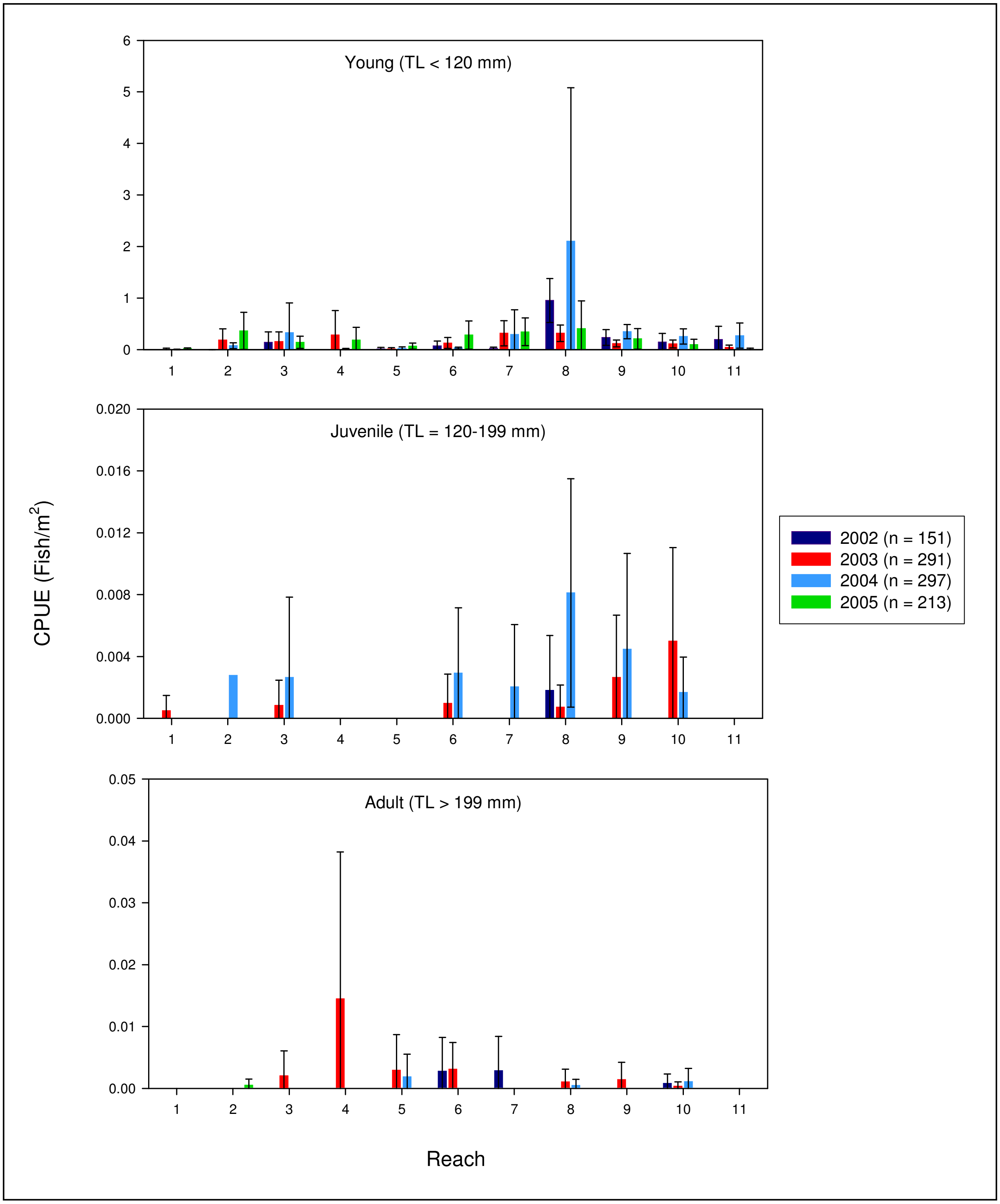


**Figure 14.** Seine catch per unit effort (CPUE, ± 95% CI) of flannelmouth sucker by age group and reach.

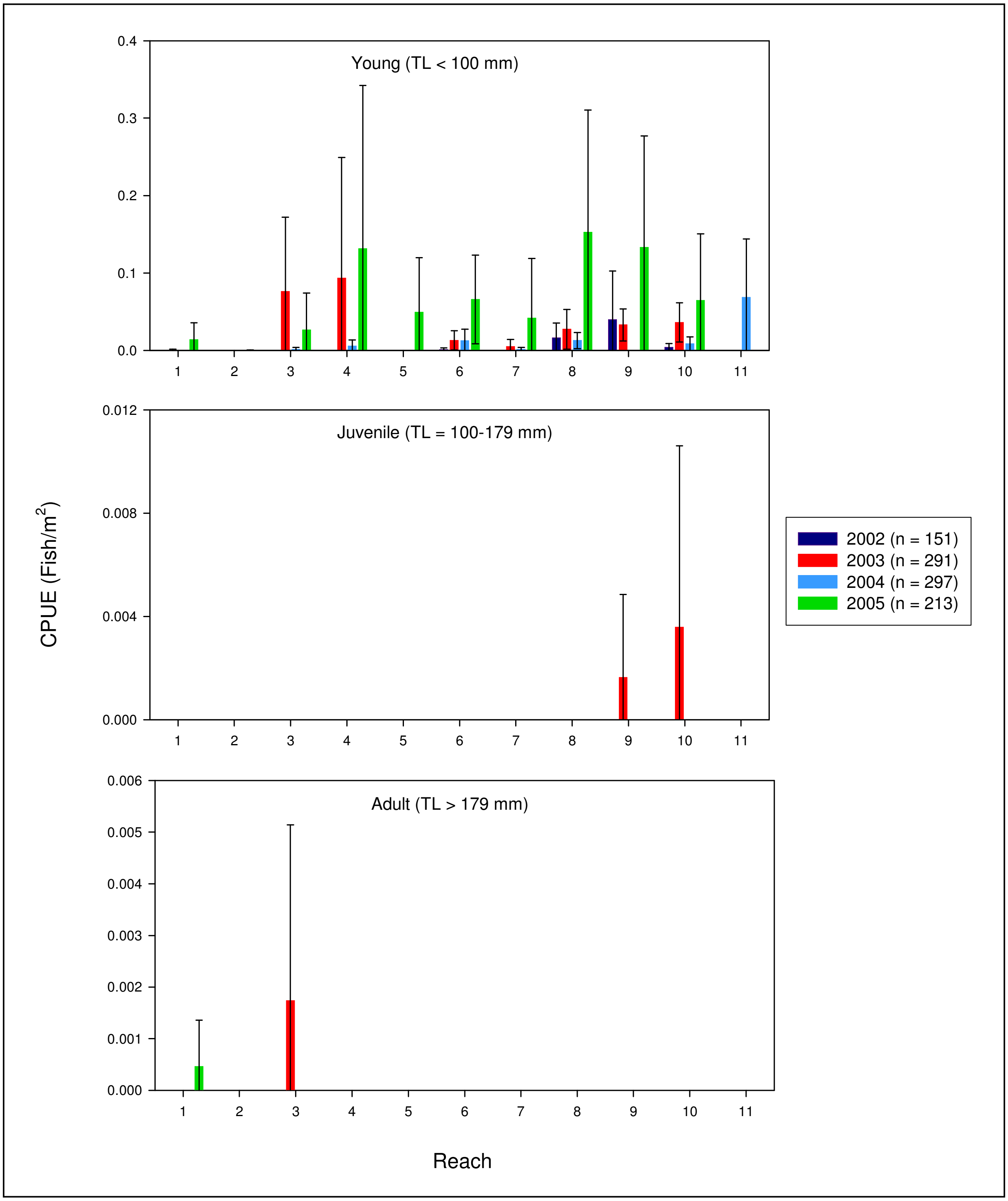


**Figure 15.** Seine catch per unit effort (CPUE, ± 95% CI) of bluehead sucker by age group and reach.

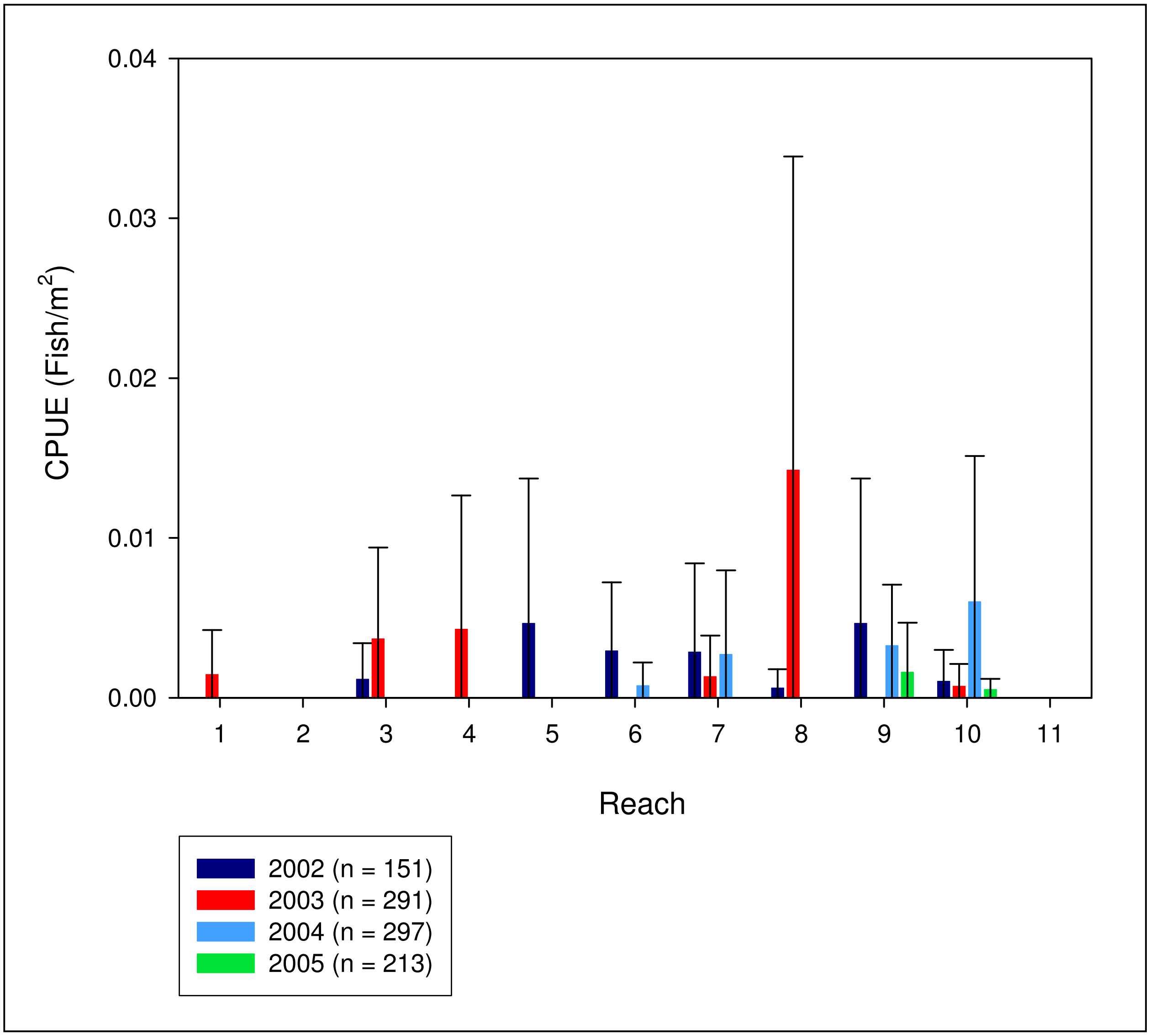


**Figure 16.** Seine catch per unit effort (CPUE, ± 95% CI) of speckled dace by reach.

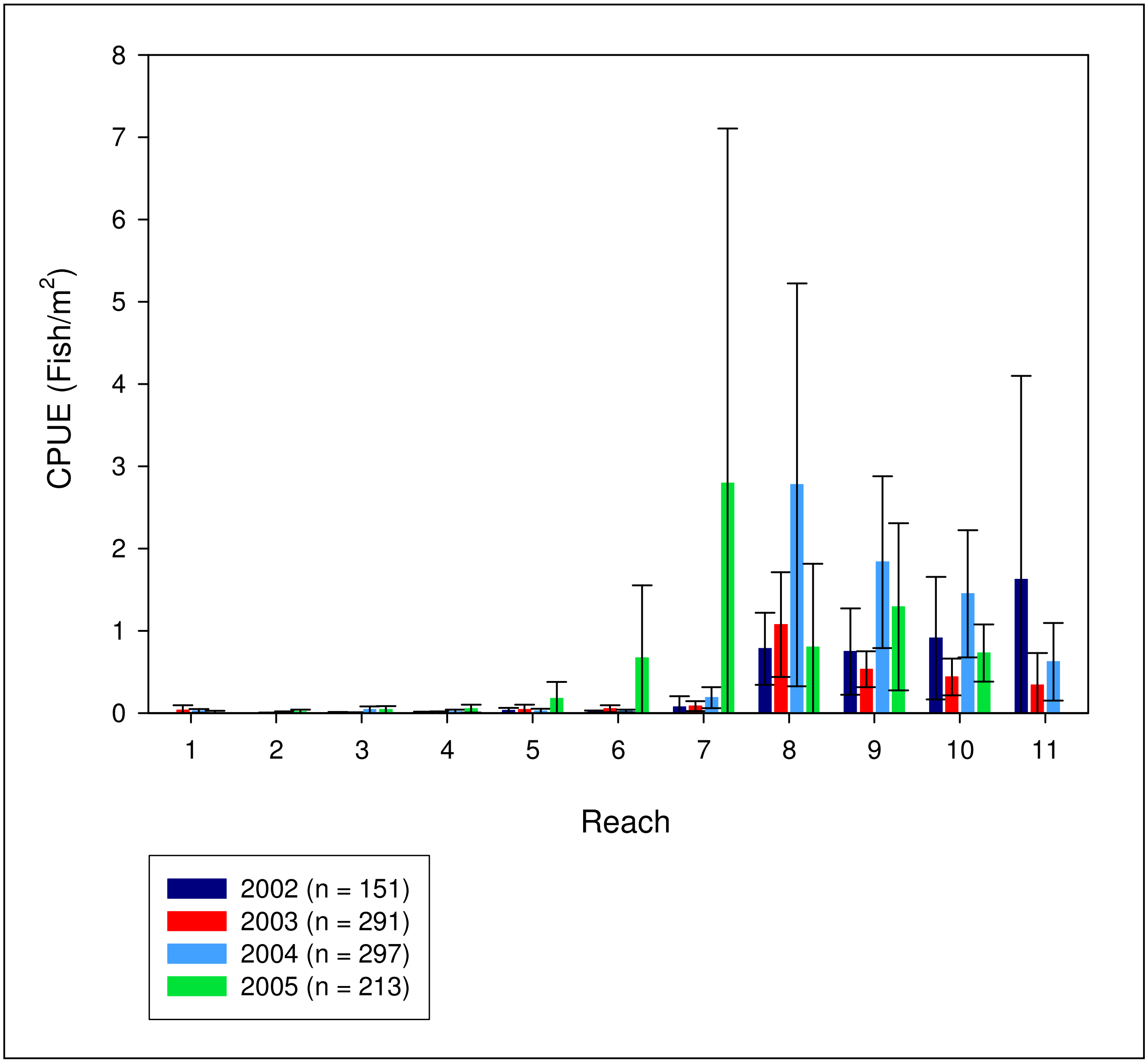


**Figure 17.** Seine catch per unit effort (CPUE, ± 95% CI) of common carp by reach.

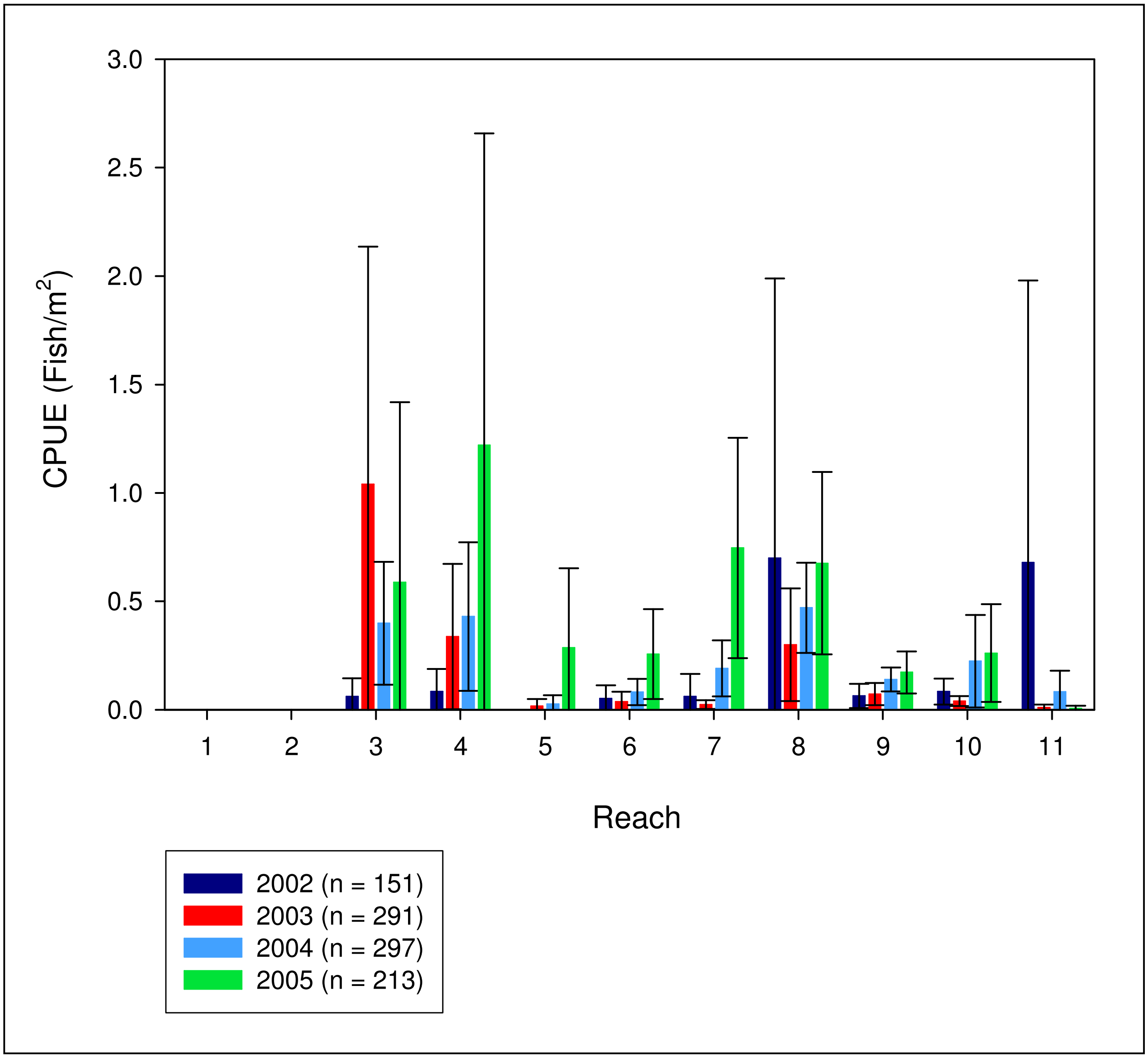


**Figure 18.** Seine catch per unit effort (CPUE, ± 95% CI) of fathead minnow by reach.

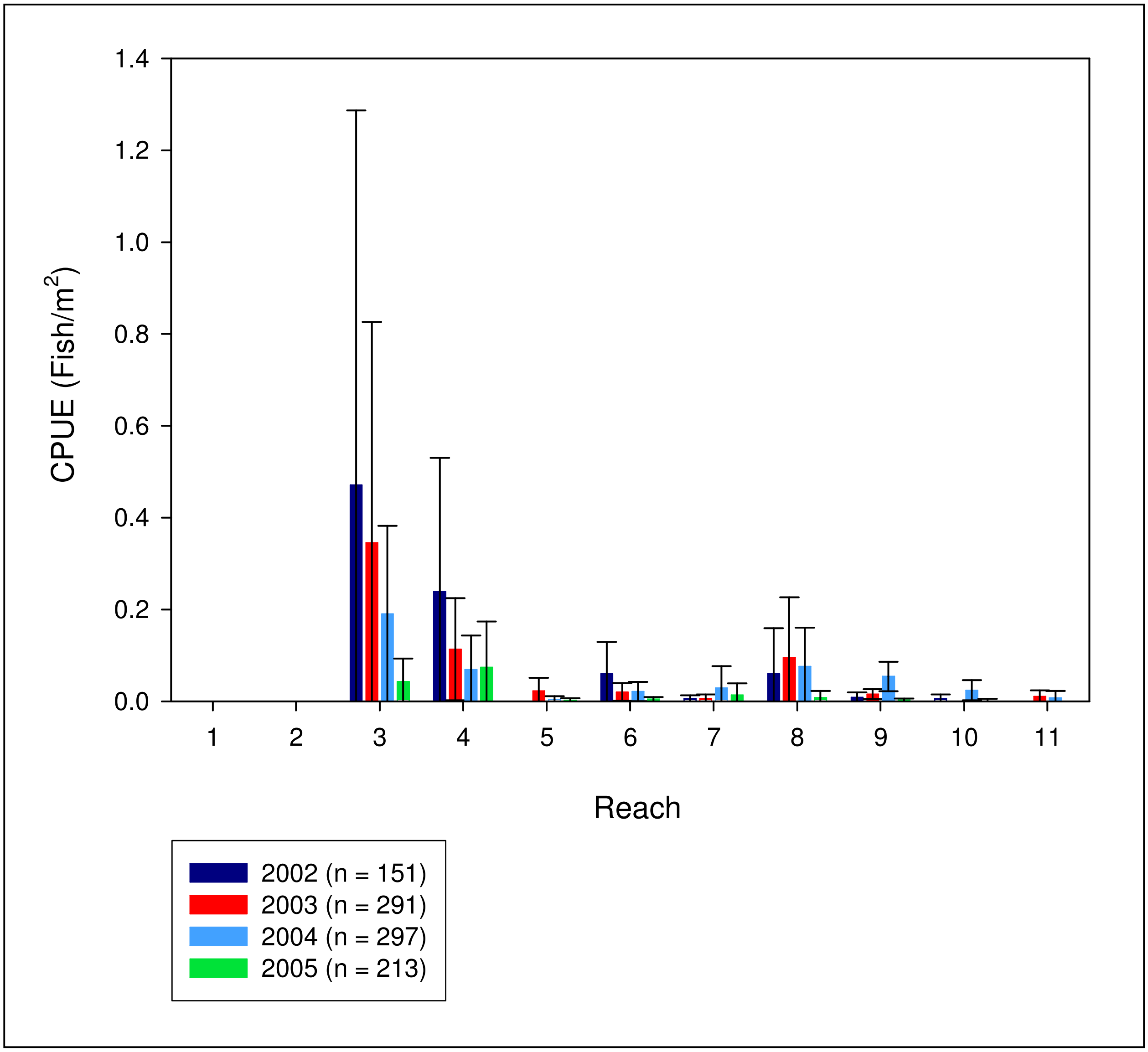


**Figure 19.** Seine catch per unit effort (CPUE, ± 95% CI) of plains killifish by reach.

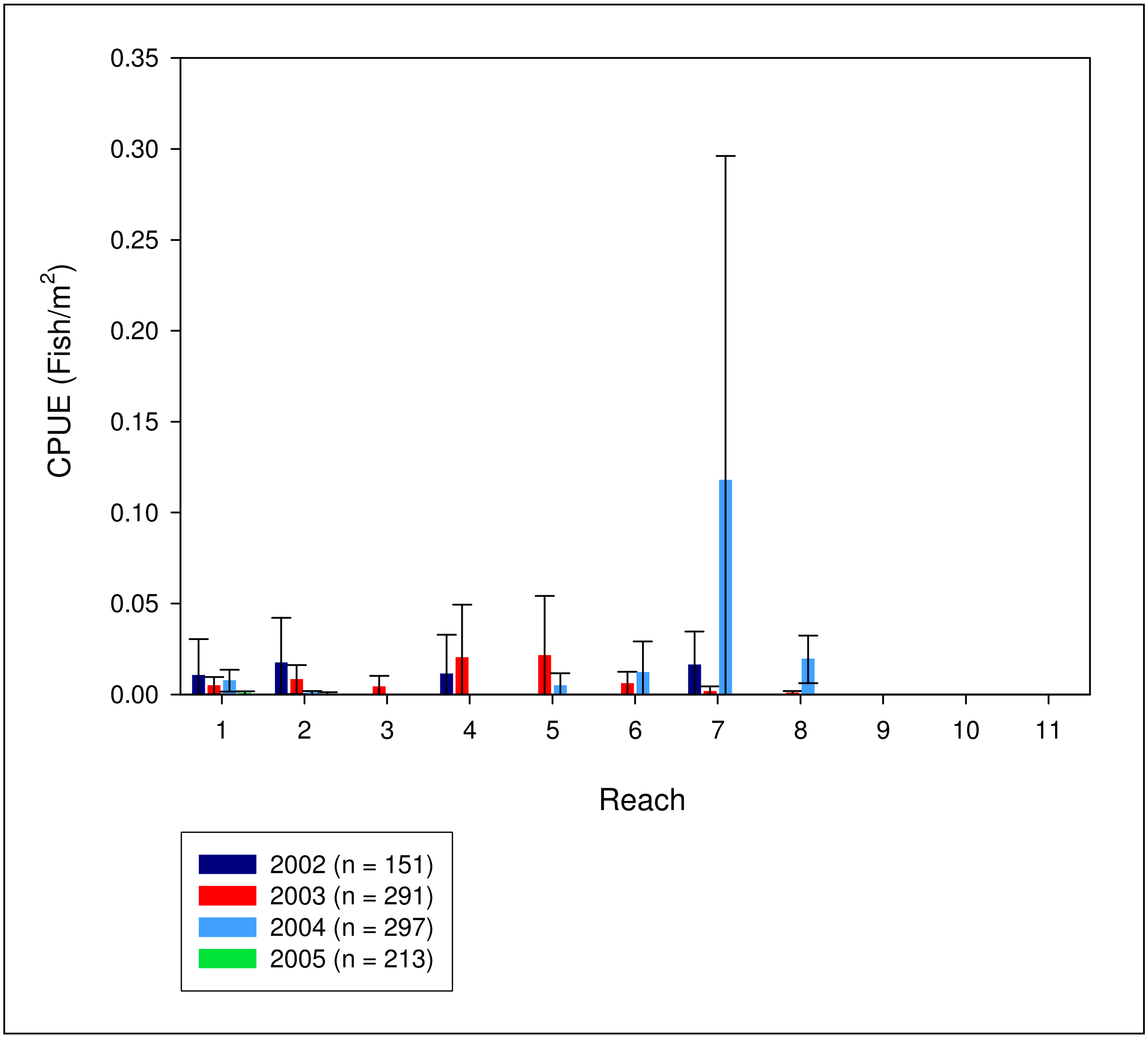


**Figure 20.** Seine catch per unit effort (CPUE, ± 95% CI) of rainbow trout by reach.

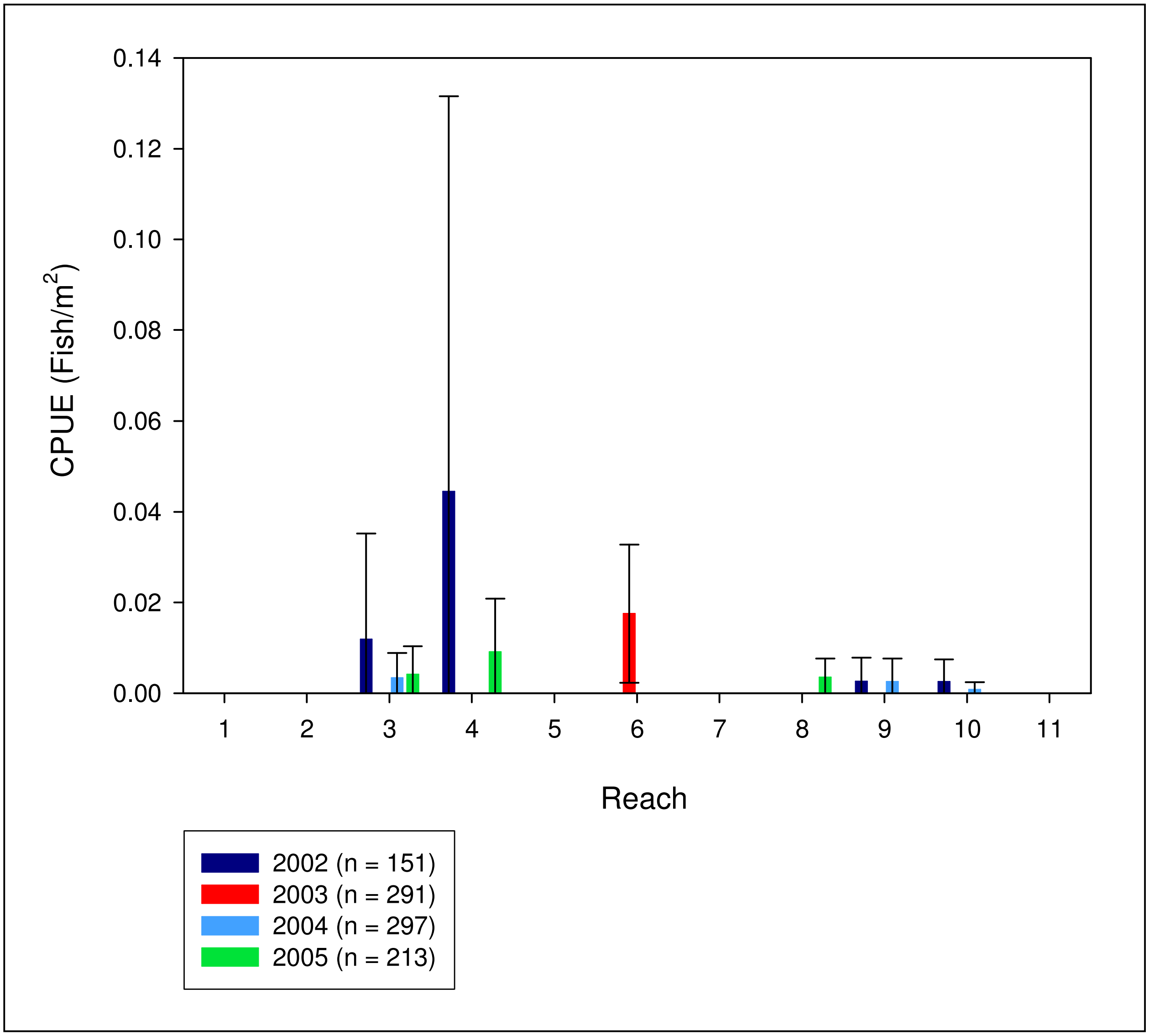


**Figure 21.** Seine catch per unit effort (CPUE, ± 95% CI) of red shiner by reach.

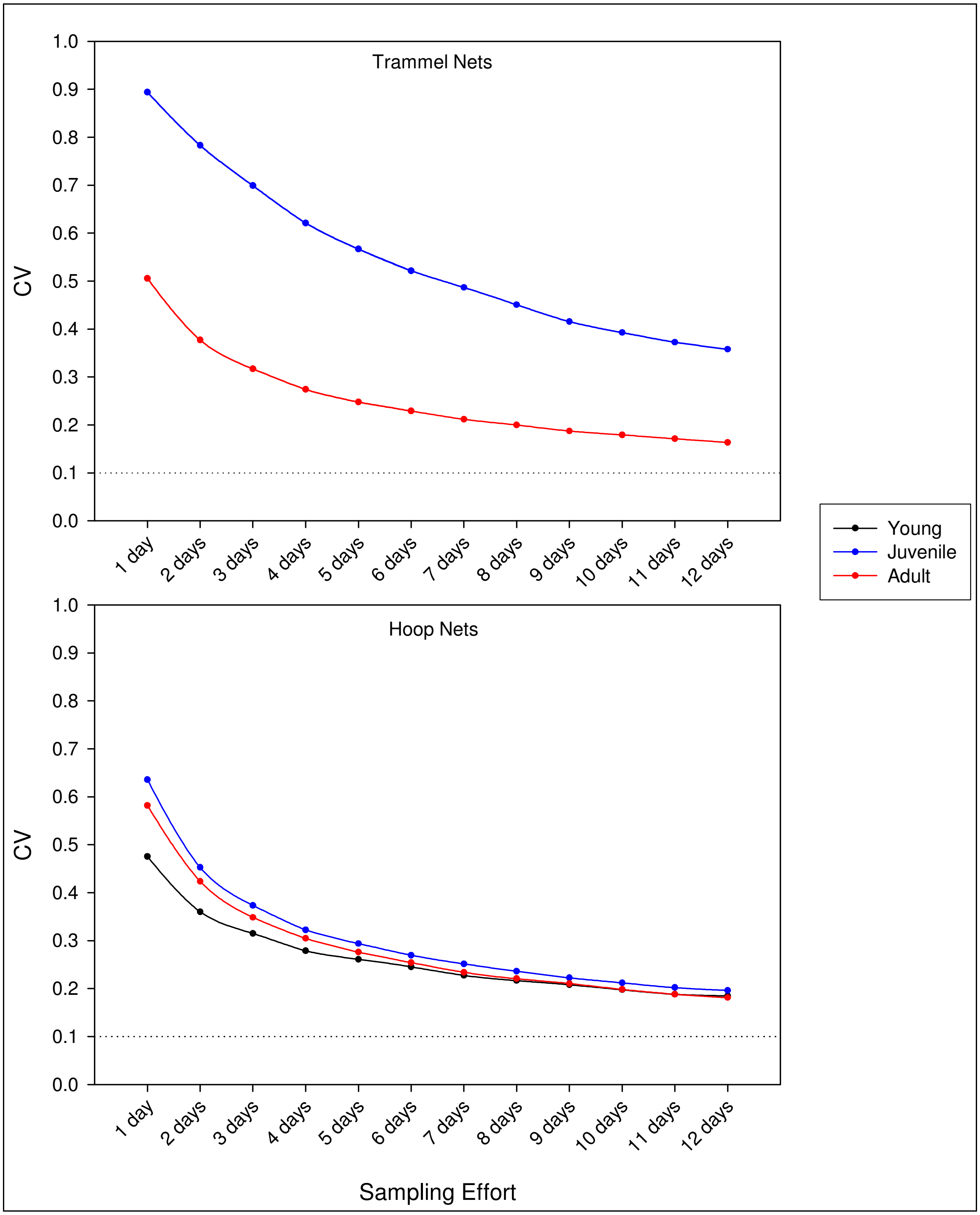


**Figure 22.** 2002–2005 resampled and bootstrapped (1000 repetitions) CV values for humpback chub (HBC) in Reach 3.

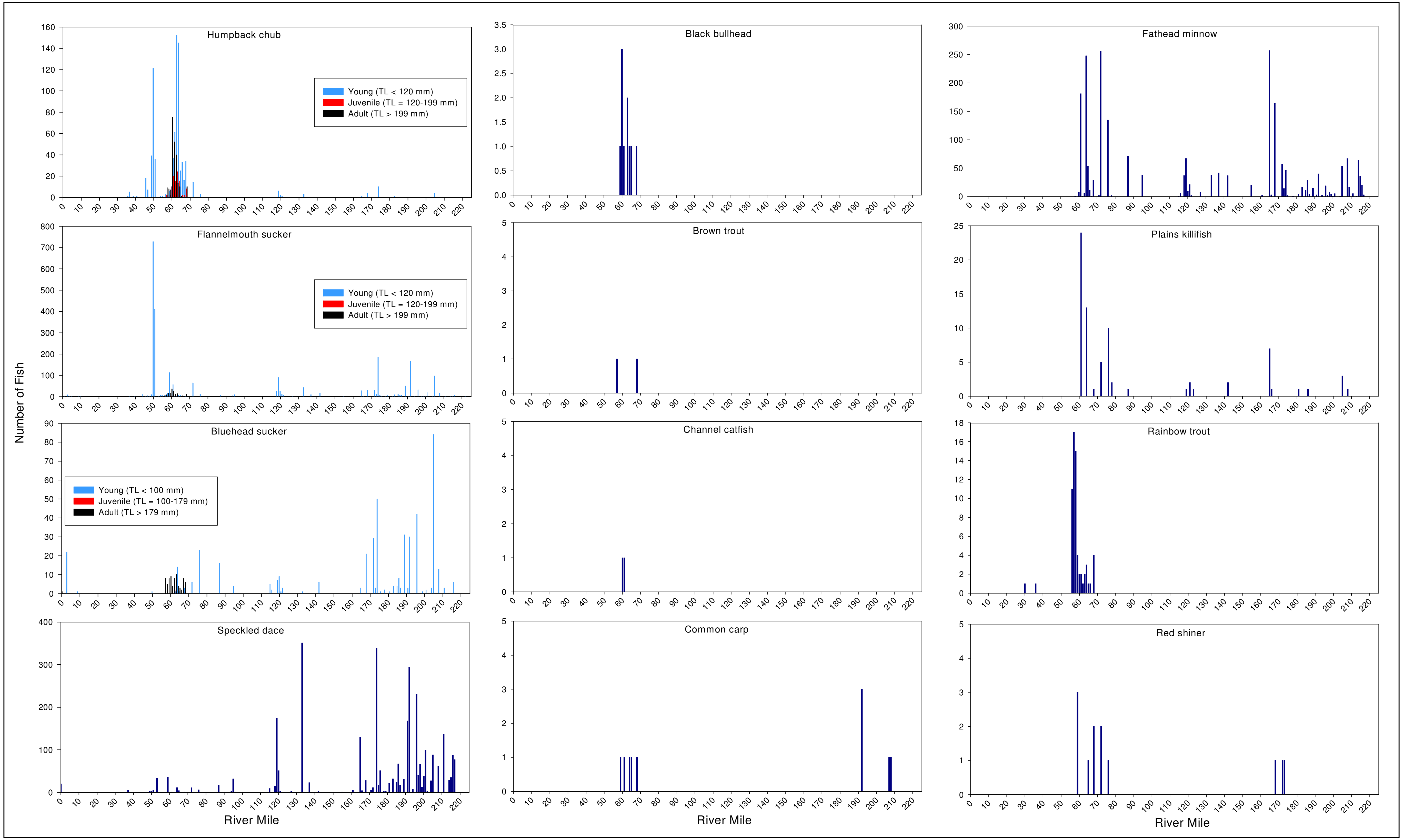


**Figure 23.** Longitudinal distribution of species captured with trammel nets, hoop nets, and seines in the Colorado River, Grand Canyon, in 2005.

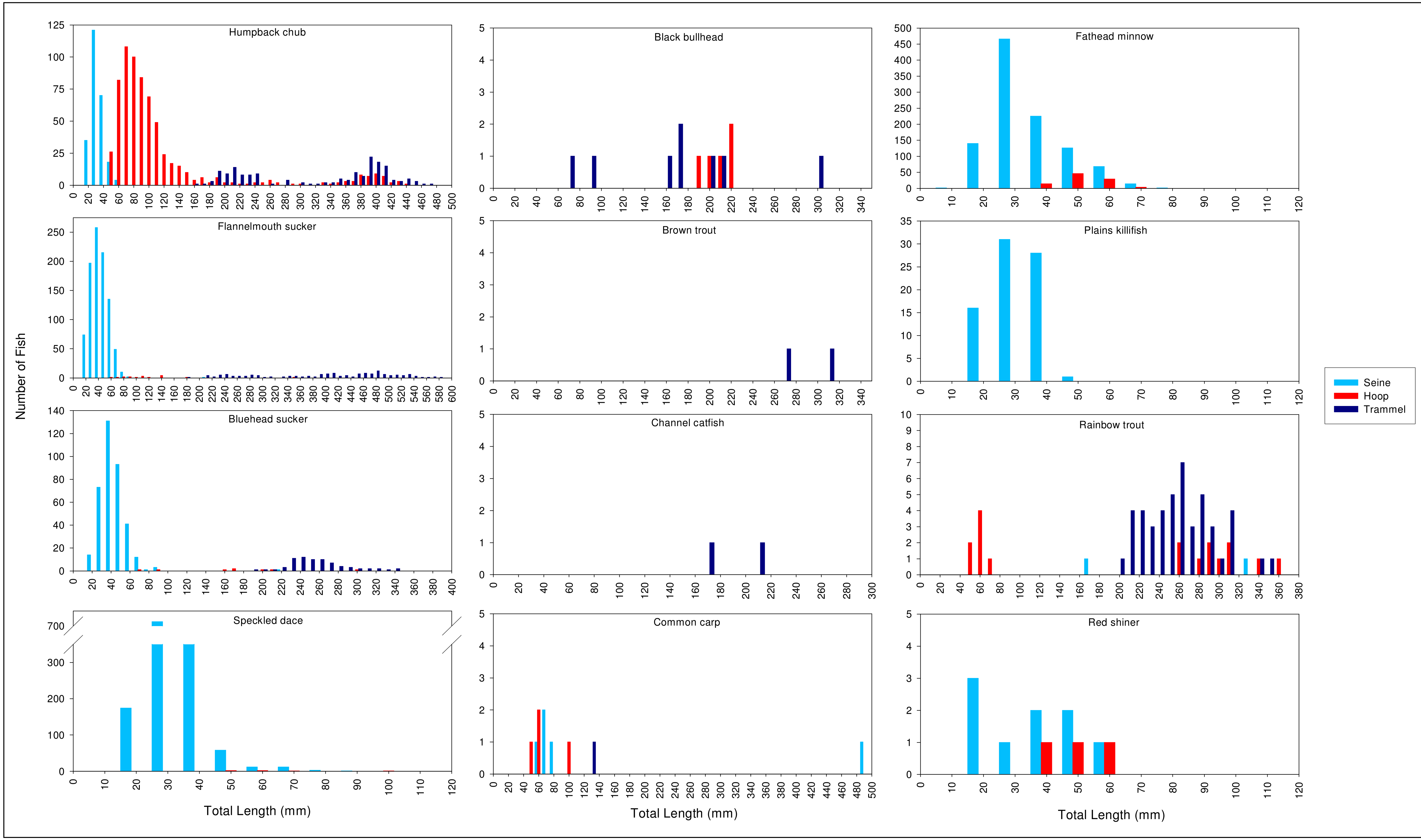


**Figure 24.** Length frequency distribution of species captured in trammel nets, hoop nets, and seines in the Colorado River, Grand Canyon, in 2005.