Mechanical Removal of Non-Native Fishes in the Colorado River in Grand Canyon: Update of Winter 2003 Operations and Findings

A Report To The Glen Canyon Dam Adaptive Management Program

By

Lewis Coggins and Michael Yard

Southwest Biological Science Center
Grand Canyon Monitoring and Research Center
U.S. Geological Survey
Flagstaff, Arizona

Draft 7/17/2003

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (CONTINUED)

EXECUTIVE SUMMARY

In December 2002, U.S. Secretary of Interior Norton approved an adaptive management experiment to be conducted in Grand Canyon National Park. This experiment, recommended by the Glen Canyon Dam Adaptive Management Program (GCDAMP) and the Grand Canyon Monitoring and Research Center (GCMRC), began in January 2003 and consists of elements designed to provide a better understanding of both sediment and fisheries resources. As part of the GCDAMP, a key objective is to determine whether certain policy actions are improving humpback chub juvenile survival and recruitment. A central part of the fisheries experiment includes reducing the abundance of non-native fishes in a 9.5-mile reach of the Colorado River near the confluence of the Little Colorado River (LCR; RM 56.2-65.7). This experimental manipulation has been implemented in an attempt to better understand interactions between native and non-native fishes, particularly non-native coldwater salmonids and the federally endangered humpback chub. As a condition of the implementation of this experiment, GCMRC is to provide a report to the Adaptive Management Program every 6 months. This document is the first of these progress reports.

The Grand Canyon Monitoring and Research Center originally proposed a multi-factor experimental design that encompassed 16 years of experimental treatments. The GCDAMP and Secretary Norton approved the first 2 years of this experimental design, and determined that GCMRC and the Technical Work Group of the GCDAMP would determine subsequent year's treatments towards attaining an effective long-term experimental design. Assuming the GCDAMP decides to continue GCMRC's original experimental design, a total of 24 mechanical removal trips will be conducted during 2003 – 2006. To date, three of these trips have been conducted: January (1/15/03-1/30/03), February (2/12/03-2/28/03), and March (3/9/03 – 3/24/03). As this study is in it's early stages with much data collection and analysis yet to be completed, this document is essentially a progress report rather than a rigorous treatment of all the study objectives. Therefore, the reader is cautioned to interpret the results as preliminary, recognizing that only 1/8th of the field collection effort is complete. Activities and results associated with three separate efforts will be addressed in this report:

1) mechanical removal of non-native fish within the removal reach (56.2 RM - 65.7 RM),
2) monitoring fish relative abundance within the Control Reach (44 RM – 52 RM), and
3) monitoring native fish relative abundance within the removal reach downstream of the LCR confluence (63.7 RM – 64.2 RM).

The additional analyses required for assessing rainbow trout and brown trout diet is not yet complete, therefore, forthcoming results will be reported under separate cover.

INTRODUCTION

Purpose

In December 2002, U.S. Secretary of Interior Norton approved an adaptive management experiment to be conducted in Grand Canyon National Park. This experiment, recommended by the Glen Canyon Dam Adaptive Management Program (GCDAMP) and the Grand Canyon Monitoring and Research Center (GCMRC), began in January 2003 and consists of elements designed to provide a better understanding of both sediment and fisheries resources. As part of the GCDAMP, a key objective is to determine whether certain policy actions are improving humpback chub juvenile survival and recruitment. A central part of the fisheries experiment includes reducing the abundance of non-native fishes in a 9.5-mile reach of the Colorado River near the confluence of the Little Colorado River (LCR; RM 56.2-65.7). This experimental manipulation has been implemented in an attempt to better understand interactions between native and non-native fishes, particularly non-native coldwater salmonids and the federally endangered humpback chub. As a condition of the implementation of this experiment, GCMRC is to provide a report to the Adaptive Management Program every 6 months. This document is the first of these progress reports.

Background

Recent analyses of historical humpback chub data suggest that the overall abundance of the Little Colorado River (LCR) population is in decline as a result of a chronic recruitment decline (Coggins et al. 2003). Of paramount importance in conserving this population of federally endangered humpback chub is determining the factors contributing to this recruitment decline and implementing management actions designed to minimize the effect of those factors. We have identified a list of likely factors that could be acting either singly or in combination. These factors include: 1) Colorado and Little Colorado River hydrology, 2) infestation of juvenile humpback chub by asian tapeworm, 3) predation by or competition with warm-water native cyprinids and catastomids and non-native cyprinids and ictalurids within the LCR, and 4) predation by or competition with cold-water non-native salmonids within the Colorado River.

The body of evidence available to evaluate specific hypotheses varies among the postulated factors. For instance, beginning in August 1991 the operation of Glen Canyon Dam was changed to reflect the so-called “interim operating criteria”. This hydrology, and subsequent Record of Decision flows that continue to present, can be generally characterized as having less severe daily flow fluctuations than the previous 28 years of load-following hydrology. Temporally, this major change in Colorado River hydrology correlates closely to the decline in humpback chub recruitment. Additionally, it is possible that the initial decline in humpback chub recruitment in 1992 was caused by the nearly continuous flooding in the LCR that occurred during summer 1992 through early winter 1993, particularly during the early summer time period when larval humpback chub emerge (Robinson et al. 1998). It is also possible that the high infestation rate of juvenile humpback chub by the introduced parasite asian tapeworm is a causative factor.

Humpback chub infected with asian tapeworm were first found during 1990, and infestation rates during 2001 exceeded 90% (Anindo Choudury, pers. comm.). Finally, predation and competition by fishes either within the LCR or in the Colorado River may be driving the humpback chub recruitment trend. Although robust relative abundance data does not exist for non-native fishes within the LCR, there has been a large increase in the abundance of non-native salmonids in the Colorado River near the confluence of the LCR (Coggins et al. 2003).

While it is difficult to determine which factors are most responsible for the humpback chub recruitment decline, a likely significant factor is negative interactions (predation and competition) with non-native fish. Interaction with non-native fish is implicated in the decline and extinction of native fishes throughout the Colorado River basin (Tyus and Saunders, III 2000 and references therein). Indeed, the National Park Service is beginning removal of non-native fishes in Bright Angel Creek and contemplating the removal of non-native fishes in other tributaries in Grand Canyon. Though these efforts may ultimately lead to improvements in the native fish community in Grand Canyon, they are essentially management actions that do little to answer the question of whether or not non-native fishes are having a negative impact on native fishes in Grand Canyon. These actions simply assume we already know the answer to this important question. Additionally, removal of non-natives fishes in tributaries quite distant (> 20 miles) may not significantly improve the recruitment dynamics of the LCR population of humpback chub, even if interactions with non-native fishes are detrimental at a population scale.

This study is different from the Bright Angel Creek non-native removal effort in several important ways. First, our primary objective is to experimentally evaluate the relationship between the abundance of non-native fishes and the recruitment dynamics of the LCR humpback chub population. Second, this experiment focuses on a specific geographic area where non-native fishes and juvenile humpback chub are known to interact. Third, this study has several components that specifically focus on characterizing the diet of non-native fishes to provide a better understanding of both predatory interactions and possible competitory interactions through diet overlap. Finally, by conducting this work in the mainstem Colorado River, we are also obtaining information relative to the efficiency of removal efforts in a large river system and the movement dynamics of non-native fishes.

Objectives

To develop an understanding of the interactions between humpback chub and rainbow and brown trout, this study includes the following classes of objectives: 1) effect of adult rainbow trout and brown trout in the LCR inflow reach on the population dynamics of the LCR humpback chub population, 2) rainbow trout and brown trout diet analysis and predation, and 3) efficacy of mechanical removal of adult rainbow trout and brown trout from the LCR Inflow reach. Sub-objectives are listed below:

Effect of Adult Rainbow Trout and Brown Trout in the LCR Inflow Reach on the Population Dynamics of the LCR Humpback Chub Population

1. Evaluate the relationship between adult rainbow trout and brown trout abundance in the LCR inflow reach and juvenile humpback chub survival/retention rate in the LCR inflow reach.
2. Evaluate the relationship between adult rainbow trout and brown trout abundance in the LCR inflow reach and recruitment to the LCR humpback chub population.

Rainbow and Brown Trout Diet Analysis and Predation

1. Estimate the instantaneous proportion of adult rainbow trout and brown trout residing in the LCR Inflow reach that are piscivorous.
2. Determine relationship between adult rainbow trout and brown trout total length and likelihood of piscivory.
3. Estimate the relationship between adult rainbow trout and brown trout total length and gape.
4. Estimate the relationship between adult rainbow trout and brown trout total length and prey body depth.
5. Estimate adult rainbow trout and brown trout diet composition.

Efficacy of Mechanical Removal of Adult Rainbow Trout and Brown Trout from the LCR Inflow Reach

1. Estimate abundance of adult rainbow trout and brown trout in the LCR Inflow reach prior to each removal event.
2. Estimate changes in adult rainbow trout and brown trout size composition in response to removal events.
3. Determine trout immigration rate (Seasonal and Annual) into the LCR Inflow reach between removal events.
4. Estimate gear efficiency as a function of boat type, turbidity, season, and dominant habitat type.

Progress to Date

The Grand Canyon Monitoring and Research Center originally proposed a multi-factor experimental design that encompassed 16 years of experimental treatments. The GCDAMP and Secretary Norton approved the first 2 years of this experimental design, and determined that GCMRC and the Technical Work Group of the GCDAMP would determine subsequent year's treatments towards attaining an effective long-term experimental design. Assuming the GCDAMP decides to continue GCMRC's original experimental design, a total of 24 mechanical removal trips will be conducted during 2003 – 2006. To date, three of these trips have been conducted: January (1/15/03-1/30/03), February (2/12/03-2/28/03), and March (3/9/03 – 3/24/03). As this study is in it's early stages with much data collection and analysis yet to be completed, this document is essentially a progress report rather than a rigorous treatment of all the study objectives. Therefore, the reader is cautioned to interpret the results as preliminary, recognizing that only 1/8th of the field collection effort is complete. Activities and results associated with three separate efforts will be addressed in this report:

4) mechanical removal of non-native fish within the removal reach (56.2 RM - 65.7 RM),
5) monitoring fish relative abundance within the Control Reach (44 RM – 52 RM), and
6) monitoring native fish relative abundance within the removal reach downstream of the LCR confluence (63.7 RM – 64.2 RM).

The additional analysis required for assessing rainbow trout and brown trout diet is not yet complete, therefore, forthcoming results will be reported under separate cover.

METHODS

Mechanical Removal of Non-Native Fish

Study Area and Design

The LCR Inflow reach is recognized for having the highest abundance of adult and juvenile humpback chub in the Colorado River mainstem (Valdez and Ryel 1995). Within the LCR Inflow reach, we designate the removal reach as between 56.2 RM - 65.7 RM (Figure 1). The removal reach is stratified into 6 river reaches: A-F. Reaches A and B are the right and left shore reaches from Kwagunt Rapid (RM 56.2) to Science Beach (RM 61.5). Reaches C and D are the right and left shore river reaches between RM 61.5 to RM 62.1 and include the LCR confluence and the mixing zone below the LCR. Reaches E and F are the right and left shore reaches downstream of the LCR confluence (RM 62.1 to Lava Chuar Rapid RM 65.7). We stratified the study area into these 6 reaches in order to control for the affect of the LCR discharge into the Mainstem Colorado River. Reaches A and B are unaffected by the tributary and reaches E and F are believed to be of sufficient distance downstream of the mixing zone to be affected uniformly throughout. Reaches C and D include the LCR confluence and will be differentially affected by LCR discharge throughout their lengths. Within river reaches A-B and E-F, the shoreline is divided into 500m sites. The number of sites within each river reach is as follows: A=19, B=19, E=13, and F=14 (13 shoreline sites and one island site). Reaches C and D constitute single sites.

During each trip, aerial photographs were used to mark the boundaries of the 500m sites within reaches A-B and E-F (Figure 1). The boundaries were marked by hanging lengths of pvc pipe wrapped with reflective tape. Over the course of 10 nights, all sample units within reaches A-B, E-F, and C were electrofished 5 times in order to construct depletion abundance estimates. Reach D, encompassing the LCR confluence, was not electrofished during any of the trips due to concerns about high water conductivity, possibly high native fish abundance, and cultural significance. Electrofishing began following dusk each day.

A total of 4 electrofishing boats of two types each were utilized in the removal. The boat types are: 1) 15’ Achilles sport boat (rubber hull) and 2) 15’ Osprey sport boat (aluminum hull). Power output was standardized such that each boat was producing an electric field of equivalent power. Within the removal reach, a rubber boat and an aluminum boat were always used above the LCR and 1 of each was always used below the LCR. The 4 boat drivers were randomly assigned to a particular reach/depletion run within each trip. The underlying purpose for the random assignment is to control for systematic bias that might exist among different electrofishing boat operators.

Fish Handling Procedures

During removal operations, qualified personnel identified fish to species; a fish key was available when necessary. Fish were then separated into two storage containers as either native- or non-native fish. Salmonids and other non-native fish were euthanized according to procedures detailed in the study operational plan (Coggins et al 2002). Native fish caught during the electrofishing run were separated and placed in a separate container of fresh water. Native fish were processed and released alive by qualified boat personnel. Standard fishery measurements were collected on all native fish encountered according to protocols detailed in the study operational plan (Coggins et al 2002). To avoid recapture in subsequent sampling sites, native fish were transported to the upper extent of the electrofished section.

Fish Processing and Disposal

During each trip, a fish processing station was established at the base camp to process and collect data on all euthanized fish. Procedures for data collection, stomach preservation, and fish disposal are detailed in the study operational plan (Coggins et al 2002). All euthanized fish were delivered to representatives of the Hualapai Nation for use as fertilizer at the end of each trip.

Data Analysis

Abundance of selected non-native fishes within the removal reach was estimated using methods pioneered by Leslie and Davis (1939). Contemporary descriptions of the derivation and use of depletion approaches can be found in many standard textbooks addressing fisheries stock assessment or estimation of animal abundance (e.g. Seber 1982, Hilborn and Walters 1992, Quinn and Deriso 1999.

Monitoring Fish Relative Abundance Within the Control Reach

To determine if differences in fish population characteristics (e.g., relative abundance, size structure, etc.) in the removal reach is a function of environmental influences/fluctuating flow treatments and not the mechanical removal, a control area was established (44 RM – 52 RM; Figure 2) and divided into 60 500 m sites occurring on both sides of the river. During each trip, 24 randomly selected sites within the control reach were sampled to estimate the relative abundance and size structure of native and non-native fishes inhabiting this reach. All fish collection and handling procedures were as described above for the removal reach except no fish were euthanized within the control reach. Additionally, each captured rainbow and brown trout greater than or equal to 200 mm in total length was fitted with a floy tag between the dorsal fin pterygiophores near the posterior insertion of the fin. Recaptures of these tagged fish are used to assess movement and possibly future absolute abundance estimates.

Monitoring Native Fish Relative Abundance Within the Removal Reach

Mini-hoopnets were used to estimate the relative abundance (catch-rate) of humpback chub at the standardized sites downstream of the LCR confluence. Set locations corresponded to the standardized locations established by Gorman and Coggins (2000; Figure 3). Owing to the large fluctuations in discharge, only 24 of the 30 standardized locations were sampled during the January-March trips. The nets were deployed for three nights during the removal operations when electrofishing activities were not being conducted within the sites that were occupied by the nets. The nets were deployed between 1100 and 1300 hours and retrieved the following day during the same timeframe.

RESULTS AND DISCUSSION

Mechanical Removal of Non-Native Fish

Total Sampling Effort and Catch

A total of 21,304 minutes (355 hours) of electrofishing effort was expended during the three removal trips (Table 1). Total effort within each trip ranged from a low during the March trip of 6,759 min (112.6 hrs) to a high during January of 7,422 min (123.7 hrs). The total catch resulting from electrofishing in the removal reach was 7,573 fish (Table 2). The numerically dominant species was rainbow trout with a combined catch over the three trips of 6,703 (89%). Catches of the remaining non-native fishes combined represented about 4% of the total catch with brown trout (130 fish) and common carp (135 fish) being the dominant species. Native fishes constituted 7% of the total catch: flannelmouth sucker (430 fish), humpback chub (65 fish), bluehead sucker (37 fish) and speckled dace (17 fish). Small numbers of other non-native fishes were also present (Table 2).

Depletion Abundance Estimates

Depletion abundance estimates were attempted for rainbow trout, brown trout, and common carp at three geographic scales: 1) upstream of the LCR confluence, 2) downstream of the LCR confluence, and 3) within the entire removal reach. The sum of the upstream and downstream estimates do not necessarily equal the total reach estimate because the estimators are independent and based on stratified or pooled data.

Rainbow trout. In general the rainbow trout depletion data displayed a declining and strongly linear pattern expected in depletion type experiments for each of the geographic scales (Figure 4). Rainbow trout abundance at the beginning of January was estimated as 6,499 throughout the removal reach (Table 3). Approximately 21% of the rainbow trout were in the downstream reach (1,416 fish) and the remaining proportion in the upstream reach (5,221 fish). A total of 3,606 rainbow trout were removed during the January trip resulting in an ending abundance of 2,893 and an overall removal efficiency of 55%. Initial rainbow trout abundance during the February trip was estimated as 2,935 fish. Initial abundance estimates in the upstream and downstream sections suggest that rainbow trout were in similar geographic distribution during February as compared to January with approximately 22% of the rainbow trout found below the LCR confluence. Comparison of the final abundance in January with the initial abundance in February at all three geographic scales suggests minimal net immigration into the removal reach. In total during February, 1,898 rainbow trout were removed resulting in an ending total abundance estimate of 1,037 fish and a removal efficiency of 65%. The March estimate of initial rainbow trout abundance within the entire reach was 1,978 fish, suggesting an overall net immigration of 941 rainbow trout since the end of the February trip. However, comparing the final abundance during February with the initial March abundance in both the downstream and upstream sections shows virtually no net immigration in the downstream reach, but nearly a doubling of abundance in the upstream reach. Additionally, examining the estimates of initial rainbow trout abundance during March suggests that only 15% of the total abundance was below the LCR confluence. These two observations combined suggest that there may have been immigration between February and March, but it appears to have occurred only within the upstream reach. A total of 1,196 rainbow trout were removed during March resulting in a final abundance estimate of 782 fish and a removal efficiency of 60%. Lastly, the distribution of abundance following the March trip suggests that approximately 8% of the rainbow trout abundance is concentrated below the LCR confluence (66 fish) with nearly 92% residing in the upstream section (687 fish).

Brown trout. Brown trout depletion abundance estimates relative to those for rainbow trout are somewhat problematic (Figure 5). In general one can see that the relationship between cumulative catch and CPUE is not always strongly linear nor even negative. The latter situation of a positive slope results in nonsensical negative abundance estimates. However, there is a systematic and large reduction in both catch rate (CPUE) and total removals from January to February, and to a lesser degree from February to March (Table 3). Overall, the removal efficiency estimates range between a low of 26% in February to a high of 65% in January. This variability is indicative of differences in catchability between and within sampling months, suggestive of differences in immigration rates or shoreline habitat use.

Common carp. Estimation performance using the common carp depletion removal data is generally better than brown trout but not as good as rainbow trout as evidenced by model fit and consistency (Figure 6 and Table 3). For data collected during both January and March, abundance estimates for common carp in the upstream section were not possible owing to a pattern of increasing catch through the depletion passes. However, the estimators of abundance for both the total reach and the downstream reach consistently produced positive estimates. For the total removal area, the January final estimate is identical to the February initial estimate, suggesting reasonably good performance, low net immigration, and perhaps a bit of luck. Catch-rate estimates and total removals declined between January and February in the downstream section and in total, but increased slightly within the upstream section. Removal efficiencies appear higher for common carp than for either brown trout or rainbow trout ranging from 67% to 92%.

Length Frequency Distributions For Select Species Within the Removal Reach

The distribution of rainbow trout lengths captured within the control reach is strongly bimodal suggesting a juvenile mode of 130 mm total length (TL) in January growing to approximately 180 mm TL in March (Figure 7). Additionally, an adult mode is present in January – March of between 330 mm and 350 mm TL. Appealing to the Lee's Ferry literature, the smaller of these modes likely include fish between 1 and 2 years of age and the larger mode likely includes fish aged 2 and older (McKinney and Speas 2001). Comparing the length frequency distributions between January, February, and March, one can clearly see the effect of removal, particularly on fish in the larger mode. We conducted depletion estimators on these 2 modes separately and estimated that the removal process was only about 65% as effective on fish in the lower mode compared to the upper mode, likely explaining the apparent difference in depletion rates between the two modes among trips.

Brown trout length frequency distribution indicates a juvenile mode near 150 mm TL and an adult mode near 270 mm TL (Figure 8). However, the distribution of adult length frequencies is highly left skewed with the suggestion of another mode centered near 350 mm TL. Additionally, there were 5 individuals captured over 500 mm TL, and 2 over 650 mm TL. The largest fish encountered during the three trips was a brown trout measuring 775mm TL.

No distinctive modes in the length frequency distribution existed for common carp (Figure 9). Lengths range from <120mm TL to the largest individual at 735 mm TL.

Flannelmouth sucker was the second most abundant fish captured in the removal reach (Table 2). A large juvenile mode is apparent in the length frequency distribution centered at 135mm (Figure 10). Growth analysis would indicate that these fish are between 1 and 2 years of age (Scott Rogers, AGFD, pers. comm.). Additionally, there is a mode centered near 520 mm TL corresponding to adult fish.

Humpback chub captured in the removal reach ranged from approximately 50 mm to 446 mm TL (Figure 11). The majority (61%) of humpback chub captured were less than 200 mm.

Monitoring Fish Relative Abundance Within the Control Reach

Total Sampling Effort and Catch

Among three trips, a total of 1813 min (30 hours) of electrofishing effort was expended in the control reach (Table 4). Effort ranged between 589 min (9.8 hrs) in March to 629 min (10.5 hrs) in February. The catch among the three trips totaled 1906 fish (Table 5). As in the removal reach, rainbow trout (1882) was the largest constituent (~99%) with brown trout (20 fish), common carp (1 fish), and flannelmouth sucker (3 fish) combined making up approximately 1% of the total catch.

Trends in Relative Abundance

Due to the small sample sizes, little can be said of the relative abundance of brown trout, common carp, and flannelmouth sucker other than their abundance is very small relative to rainbow trout within the control reach. However, the relative abundance of rainbow trout appeared to be nearly constant between January and February and then doubled between February and March (Table 4 and Figure 12). Since it is unlikely that the rainbow trout population within the control reach doubled between February and March (29 days elapsed time), it is likely that something else changed the electrofishing efficiency (catchability). Recent research by the Arizona Game and Fish department has suggested that turbidity and electrofishing catchability are inversely correlated within the range of low to moderate turbidity (Dave Speas, pers. comm.). The turbidity data (optical transmission) collected by USGS instrumentation at the 30-mile site partially supports this contention (Figure 12; unpublished data provided by D. Topping, USGS WRD). We suspect that the increase in catch rate in March may be more a result of increased catchability associated with an increase in turbidity than an increase in rainbow trout abundance.

Length Frequency Distribution for Rainbow Trout Captured in the Control Reach

The length frequency distribution of rainbow trout captured within the removal reach is similar to that observed in the removal reach (Figure 13). The only notable difference between the two charts is that the modal size of the juvenile fish within the control reach appears to be approximately 10 mm smaller than in the removal reach. Additionally, the modal size of the adult fish in the control reach appears to be approximately 20 mm smaller than in the removal reach.

Movement of Floy Tagged Fish

During control reach sampling, a total of 1,323 rainbow trout were marked with floy tags. To date, a total of 11 of these fish have been captured outside the control reach (Table 6). Of these 11, 8 have been captured downstream in the removal reach and 3 have been captured in the Lee’s Ferry reach. Of the 3 fish recaptured in the Lees Ferry reach, 1 was recaptured just downstream of Glen Canyon Dam by Arizona Game and Fish Personnel conducting routine monitoring, 1 was recaptured by an angler at an unspecified location and date (during May) within the Lee’s Ferry reach, and the last was recaptured by an angler near mile 0 within the Lee's Ferry reach (Bill Persons, AGFD, pers. comm.). Of the fish recaptured in the removal reach, the most notable one was captured on January 25th with a partially swallowed juvenile flannelmouth sucker.

Monitoring Native Fish Relative Abundance Within the Removal Reach

<u>Total Sampling Effort and Catch</u>

A total of 5,318 hours of hoopnet sampling was conducted at the standardized locations downstream of the LCR confluence during January, February, and March (Table 7). Effort ranged from a low in March of 1,734 hrs to a high in January of 1,833 hrs. A total of 114 fish were captured during hoopnet sampling including: humpback chub (86 fish), rainbow trout (16 fish), flannelmouth sucker (7 fish), bluehead sucker (2 fish), brown trout (2 fish), and fathead minnow (1 fish; Table 8).

<u>Trends in Relative Abundance</u>

Over three sampling occasions, relative abundance (catch rate) of humpback chub increased and relative abundance of rainbow trout decreased (Table 7 and Figure 14). The decreasing pattern in rainbow trout abundance is likely the result of the mechanical removal operations. However, the trend in humpback chub is more difficult to interpret. One possibility is that as a result of the removal operations, juvenile humpback chub are either experiencing a higher survival rate or utilizing near-shore habitat more frequently. Alternatively, there were 2 very small freshets on February 22 and March 8 in the LCR between the February and March sampling trips (Figure 14). It is possible that the increased catch rate observed in March is a result of those freshets causing juvenile humpback chub to move into the mainstem Colorado resulting in a higher relative abundance. Sampling during July, August, and September should help resolve these alternative hypotheses.

<u>Length Frequency Distribution for Humpback Chub Captured During Hoopnet Monitoring</u>

A total of 86 humpback chub were captured during hoopnet monitoring ranging in size from 60mm TL to 200 mm TL (Figure 15). Exactly half the fish captured were between 50 mm and 100 mm TL and half were between 100 mm and 200 mm TL.

LITERATURE CITED

Coggins, L., M. Yard, and C. Paukert. 2002. Piscivory by Non-Native Salmonids in the Colorado River and an Evaluation of the Efficacy of Mechanical Removal of Non-Native Salmonids. USGS, Grand Canyon Monitoring and Research Center, Flagstaff, AZ.

Coggins, L.G. Jr., C. Walters, C. Paukert, and S. Gloss. 2003. An overview of status and trend information for the Grand Canyon population of the humpback chub, Gila cypha. Report to the Glen Canyon Dam Adaptive Management Work Group Ad Hoc Committee on humpback chub. Grand Canyon Monitoring and Research Center. Flagstaff, Arizona. 23 pp.

Gorman, O.T., and L. Coggins. 2000. Status and trends of native and non-native fishes of the Colorado River in Grand Canyon 1990-2000. Final Report, USFWS, Flagstaff, AZ.

Hilborn, R. and C.J. Walters. 1992. Quantitative fisheries stock assessment: choice, dynamics, and uncertainty. Chapman and Hall, New York. 570 pp.

Leslie, P.H. and D.H.S. Davis. 1939. An attempt to determine the absolute number of rats on a given area. J. Anim. Ecol. 8:94-113.

McKinney, T and D.W. Speas. 2001. Observations of size-related asymmetries in diet and energy intake of rainbow trout in a regulated river. Environmental Biology of Fishes. 61:435-444.

Quinn, T.J., II and R.B. Deriso. 1999. Quantitative Fish Dynamics. Oxford University Press. New York. 542 pp.

Robinson, A.T., R.W. Clarkson and R. E. Forrest. 1998. Dispersal of larval fishes in a regulated river tributary. Transactions of the American Fisheries Society 127:772-786.

Seber, G.A.F. 1982. The Estimation of Animal Abundance, 2nd edition. Griffin, London. 654 pp.

Tyus, H.M and J.F. Saunders, III. 2000. Nonnative fish control and endangered fish recovery: lessons from the Colorado River. Fisheries. 25(9): 17-24.

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. 286 pp.

ACKNOWLEDGEMENTS

We would like to acknowledge the support and wisdom of the members of the Glen Canyon Dam Adaptive Management Program in promoting this important research. Additionally a host of exceptionally dedicated boatman, field biologists and technicians, and volunteers have made this arduous task possible. Our sincere thanks go to the following people without whom this work would not have been possible: Fritz, Park, Brian, Dave, Melanie, Lynn, Courtney, Yael, Brent, Steve, Erika, Ted, Nelson, Laura, Ally, Pete, Stewart, Jimmy, Todd, Josh, Danny, Aaron, Scotty, John, Emily, Dick, J.P., Craig, and Ron.

Table 1 Total electrofishing effort (minutes) expended by location, depletion pass, and month within the removal reach, January – March, 2003.

Month	Depletion Pass	Downstream [a]	Upstream [b]	Total [c]
January	1	628	930	1,559
	2	630	885	1,515
	3	644	862	1,506
	4	602	843	1,445
	5	587	811	1,398
	Total	**3,092**	**4,331**	**7,422**
February	1	644	767	1,411
	2	648	812	1,460
	3	644	862	1,506
	4	641	803	1,444
	5	533	770	1,302
	Total	**3,110**	**4,014**	**7,124**
March	1	658	756	1,414
	2	582	806	1,388
	3	550	773	1,323
	4	554	764	1,318
	5	516	800	1,316
	Total	**2,859**	**3,900**	**6,759**
Grand Total		***9,060***	***12,245***	***21,304***

[a] Reaches C, E, and F, downstream of the Little Colorado River Confluence.
[b] Reaches A and B, upstream of the Little Colorado River Confluence.
[c] Reaches A,B,C,E,and F.

Table 2 Total catch by species and month within the removal reach, January – March, 2003.

Removal Reach Electrofishing

	Species												
Month	Bluehead Sucker	Brown Trout	Channel Catfish	Common Carp	Fathead Minnow	Flannelmouth Sucker	Humpback Chub	Plains Killifish	Rainbow Trout	Red Shiner	Speckled Dace	Unidentified Sucker	Yellow Bulhead
January	8	86	0	80	17	185	26	1	3609	0	7	2	0
February	18	24	0	33	21	156	26	0	1898	1	2	0	0
March	11	20	1	22	8	89	13	1	1196	1	8	0	3
Total	**37**	**130**	**1**	**135**	**46**	**430**	**65**	**2**	**6703**	**2**	**17**	**2**	**3**

Table 3 Depletion abundance estimates, catch rate, and removal efficiency by species, month, and location within the removal reach, January – March, 2003.

		Downstream [a]					Upstream [b]					Total [c]				
Species	Month	Initial Abund. [e]	Removal	Final Abund. [f]	CPUE [d]	Removal Efficiency	Initial Abund.	Removal	Final Abund.	CPUE	Removal Efficiency	Initial Abund.	Removal	Final Abund.	CPUE	Removal Efficiency
Rainbow Trout	January	1416	732	684	0.24	52%	5221	2874	2347	0.66	55%	6499	3606	2893	0.49	55%
	February	649	339	310	0.11	52%	2282	1559	723	0.39	68%	2935	1898	1037	0.27	65%
	March	301	235	66	0.08	78%	1648	961	687	0.25	58%	1978	1196	782	0.18	60%
Brown Trout	January	[g]	24	[g]	0.0078	[h]	79	63	16	0.0145	80%	135	87	48	0.0117	65%
	February	84	12	72	0.0039	14%	[g]	12	[g]	0.003	[h]	91	24	67	0.003	26%
	March	14	11	3	0.0038	77%	[g]	9	[g]	0.002	[h]	39	20	19	0.003	52%
Common Carp	January	94	65	29	0.0210	69%	[g]	15	[g]	0.0035	[h]	119	80	39	0.011	67%
	February	14	13	1	0.0042	92%	26	20	6	0.0050	77%	39	33	6	0.005	85%
	March	18	15	3	0.0052	82%	[g]	7	[g]	0.0018	[h]	33	22	11	0.003	67%

[a] Reaches C, E and F, downstream of the Little Colorado River Confluence.
[b] Reaches A and B, upstream of the Little Colorado River Confluence.
[c] Reaches A,B,C,E,and F.
[d] Catch rate in fish/minute.
[e] Initial Abundance; abundance at the beginning of a trip.
[f] Final Abundance; abundance at the end of a trip = Initial Abundance - Removal
[g] Procedure produced a negative abundance estimate.
[h] Efficiency not estimable due to a negative abundance estimate.

Table 4 Electrofishing effort and catch rate by species and month within the control reach, January – March, 2003.

Month	Effort (minutes)	Brown Trout		Common Carp		Flannelmouth Sucker		Rainbow Trout	
		CPUE[a]	SE[b]	CPUE	SE	CPUE	SE	CPUE	SE
January	595	0.02	0.006	0.001	0.001	0.002	0.002	0.77	0.08
February	629	0.01	0.005	0	--	0.001	0.001	0.89	0.08
March	589	0.01	0.005	0	--	0.002	0.002	1.70	0.13

[a] Catch per unit effort (fish/minute)
[b] Standard error of CPUE

Table 5 Total catch by species and month within the control reach, January – March, 2003.

Control Reach Electofishing

	Species												
Month	Bluehead Sucker	Brown Trout	Channel Catfish	Common Carp	Fathead Minnow	Flannelmouth Sucker	Humpback Chub	Plains Killifish	Rainbow Trout	Red Shiner	Speckled Dace	Unidentified Sucker	Yellow Bulhead
January	0	9	0	1	0	1	0	0	446	0	0	0	0
February	0	6	0		0	1	0	0	549	0	0	0	0
March	0	5	0		0	1	0	0	887	0	0	0	0
Total	**0**	**20**	**0**	**1**	**0**	**3**	**0**	**0**	**1882**	**0**	**0**	**0**	**0**

Table 6 Capture and recapture history for 11 rainbow trout tagged within the control reach and recaptured outside the control reach.

Tag Location	Recapture Location	Tag Date	Recapture Date	Distance Moved	Elapsed Time
46 mile	61.5 mile	1/15/2003	1/25/2003	15.5 miles	10 days
50 mile	57.5 mile	2/13/2003	2/16/2003	7.5 miles	3 days
48.5 mile	65.7 mile	2/13/2003	2/23/2003	17.2 miles	10 days
49 mile	56.2 mile	2/13/2003	2/16/2003	7.2 miles	3 days
50 mile	56.2 mile	2/13/2003	3/5/2003	6.2 miles	20 days
46.5 mile	58.5 mile	1/16/2003	3/12/2003	12 miles	55 days
51.1 mile	59.5 mile	3/10/2003	3/18/2003	8.4 miles	8 days
41 mile	59.5 mile	3/10/2003	3/18/2003	18.5 miles	8 days
48 mile	-14.5 mile	1/15/2003	4/29/2003	62.5 miles	104 days
48.2 mile	Lees Ferry Reach	2/13/2003	May	>48.2 miles	>71 days
45 mile	0 mile	2/12/2003	6/14/2003	45 miles	122 days

Table 7 Hoopnet effort and catch rate by species and month within the removal reach, January – March, 2003.

Month	Effort (hrs)	Bluehead Sucker CPUE [a]	SE [b]	Brown Trout CPUE	SE	Fathead Minnow CPUE	SE	Flannelmouth Sucker CPUE	SE	Humpback Chub CPUE	SE	Rainbow Trout CPUE	SE
January	1,833	0	0	0.001	0.001	0.001	0.001	0.002	0.001	0.009	0.002	0.006	0.002
February	1,751	0.001	0.001	0	0	0	0	0.002	0.001	0.012	0.003	0.002	0.001
March	1,734	0	0	0	0	0	0	0.001	0.001	0.027	0.005	0.001	0.001

[a] Catch per unit effort (fish/hour).
[b] Standard error of CPUE.

Table 8 Total catch by species and month during hoopnet monitoring within the removal reach, January – March, 2003.

Hoopnet Monitoring

	Species					
Month	Bluehead Sucker	Brown Trout	Fathead Minnow	Flannelmouth Sucker	Humpback Chub	Rainbow Trout
January		2	1	3	17	11
February	2			3	22	3
March				1	47	2
Total	**2**	**2**	**1**	**7**	**86**	**16**

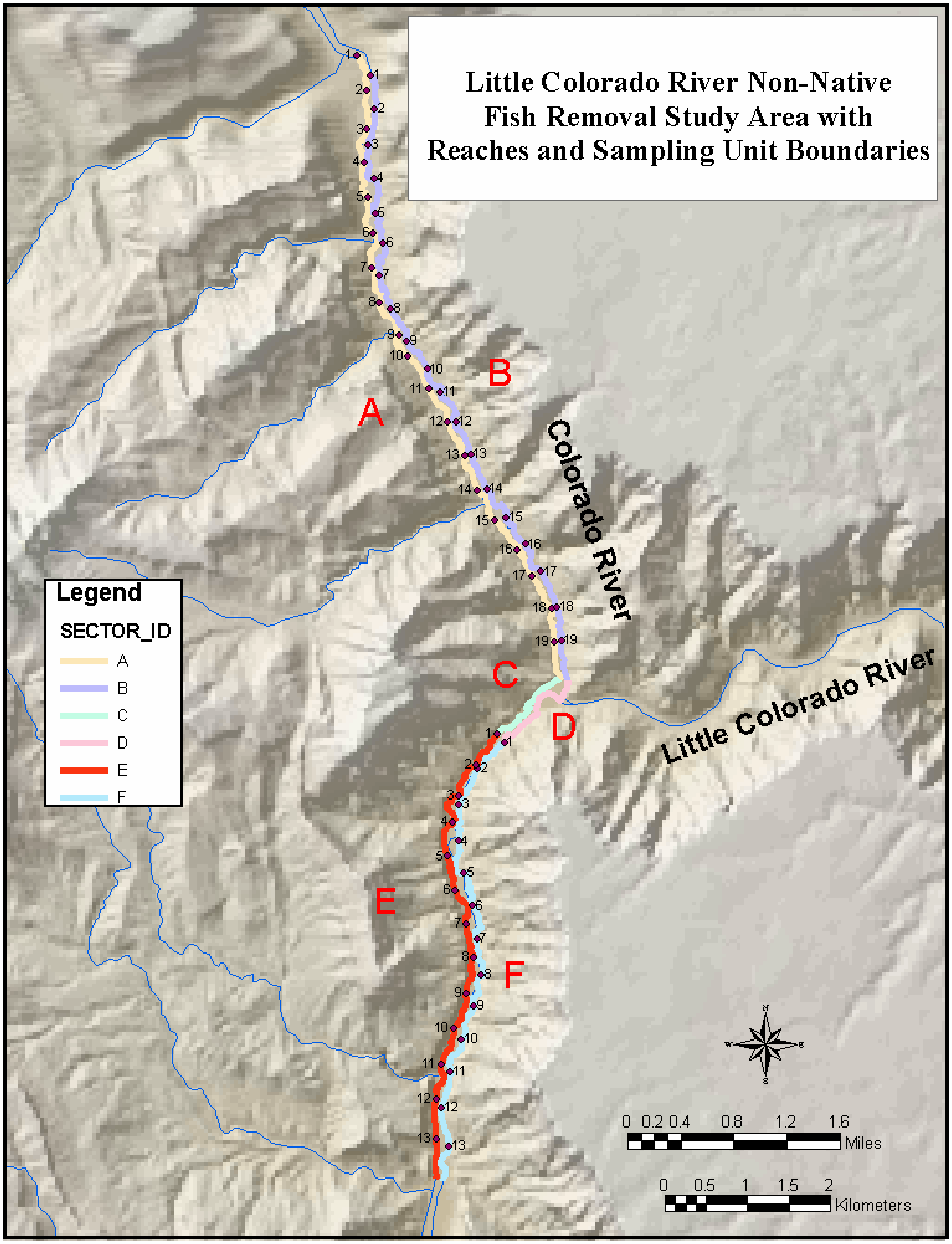

Figure 1. Mechanical removal reach in the Colorado River near the confluence of the Little Colorado River, Grand Canyon, Arizona. Six study reaches are identified (A-F).

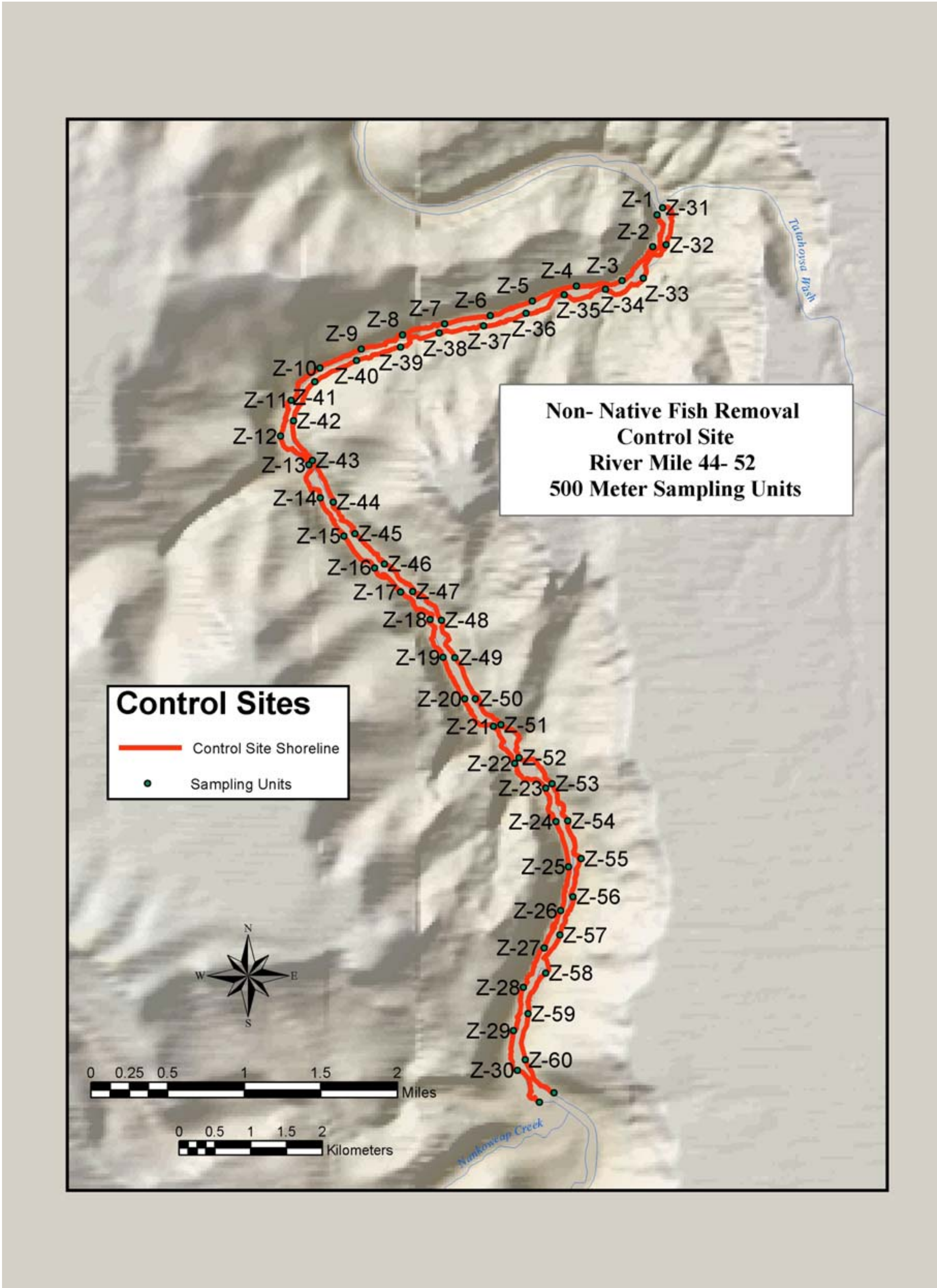

Figure 2 Control Reach in the Colorado River, RM 44-52, Grand Canyon, Arizona. Randomly selected 500 m sites were electrofished from this area each sampling trip; however, no fish were removed.

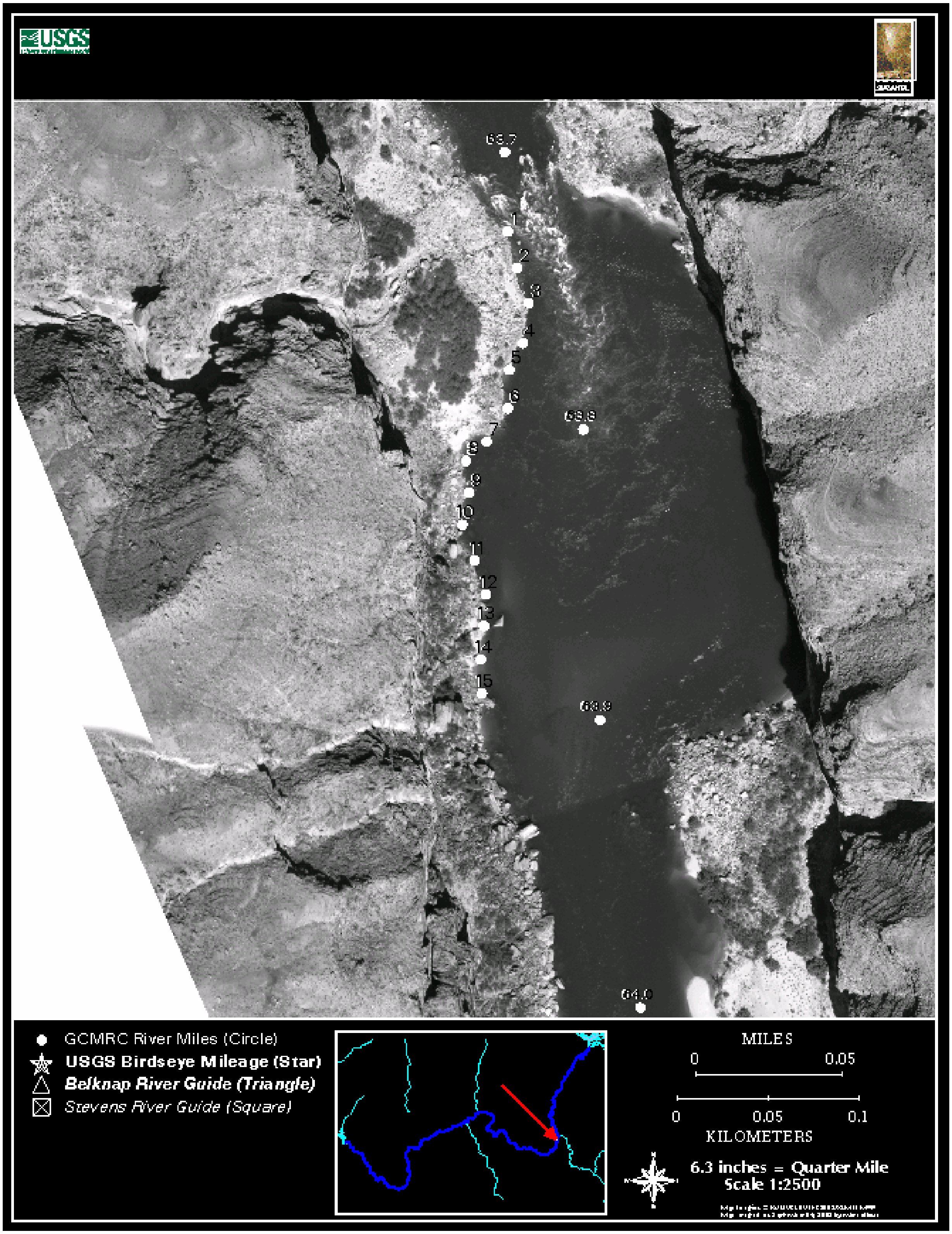

Figure 3a Hoopnet locations (stations 1-15) for native fish relative abundance monitoring in the Colorado River below the Little Colorado River confluence, Grand Canyon, Arizona.

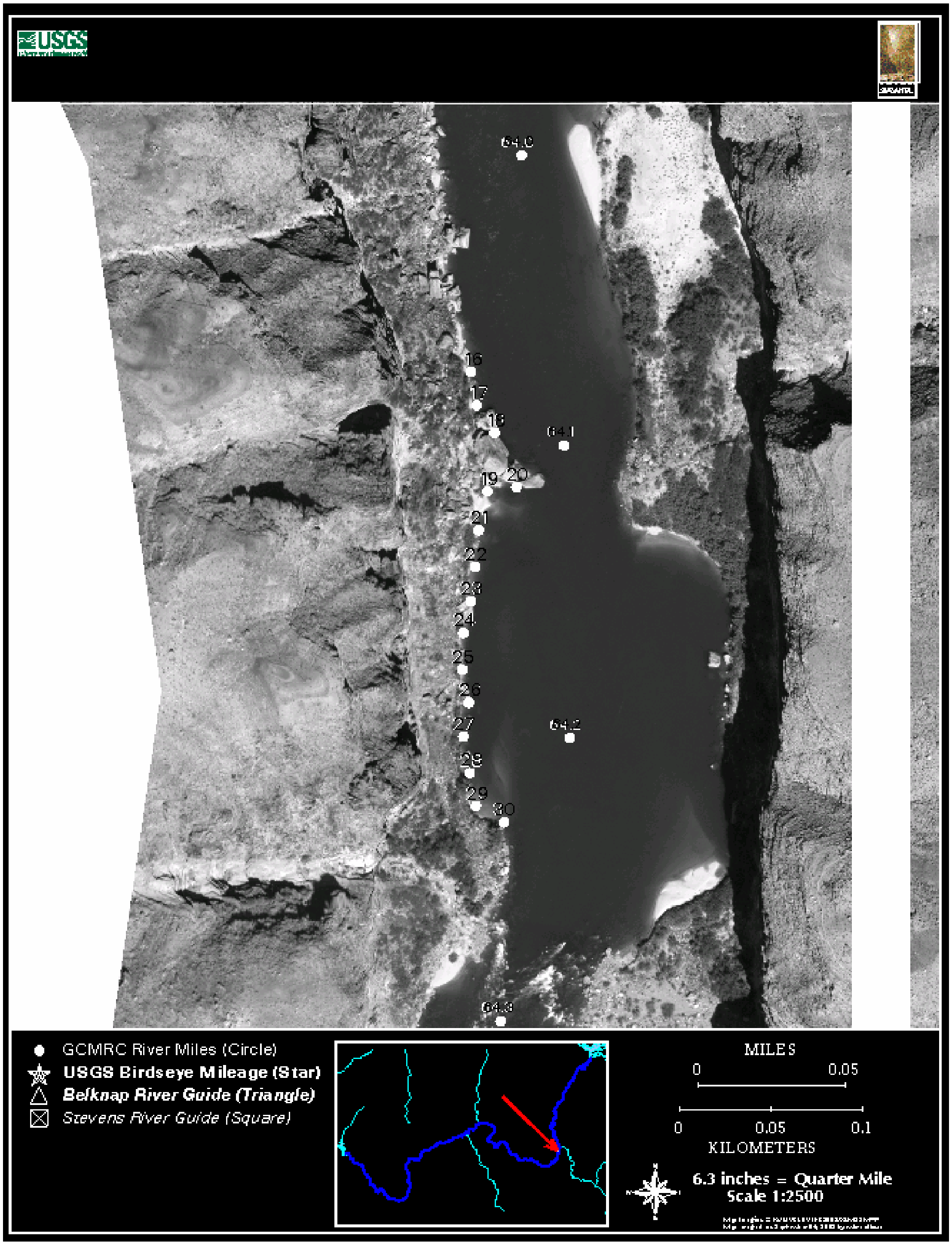

Figure 3b Hoopnet locations (stations 16-30) for native fish relative abundance monitoring in the Colorado River below the Little Colorado River confluence, Grand Canyon, Arizona.

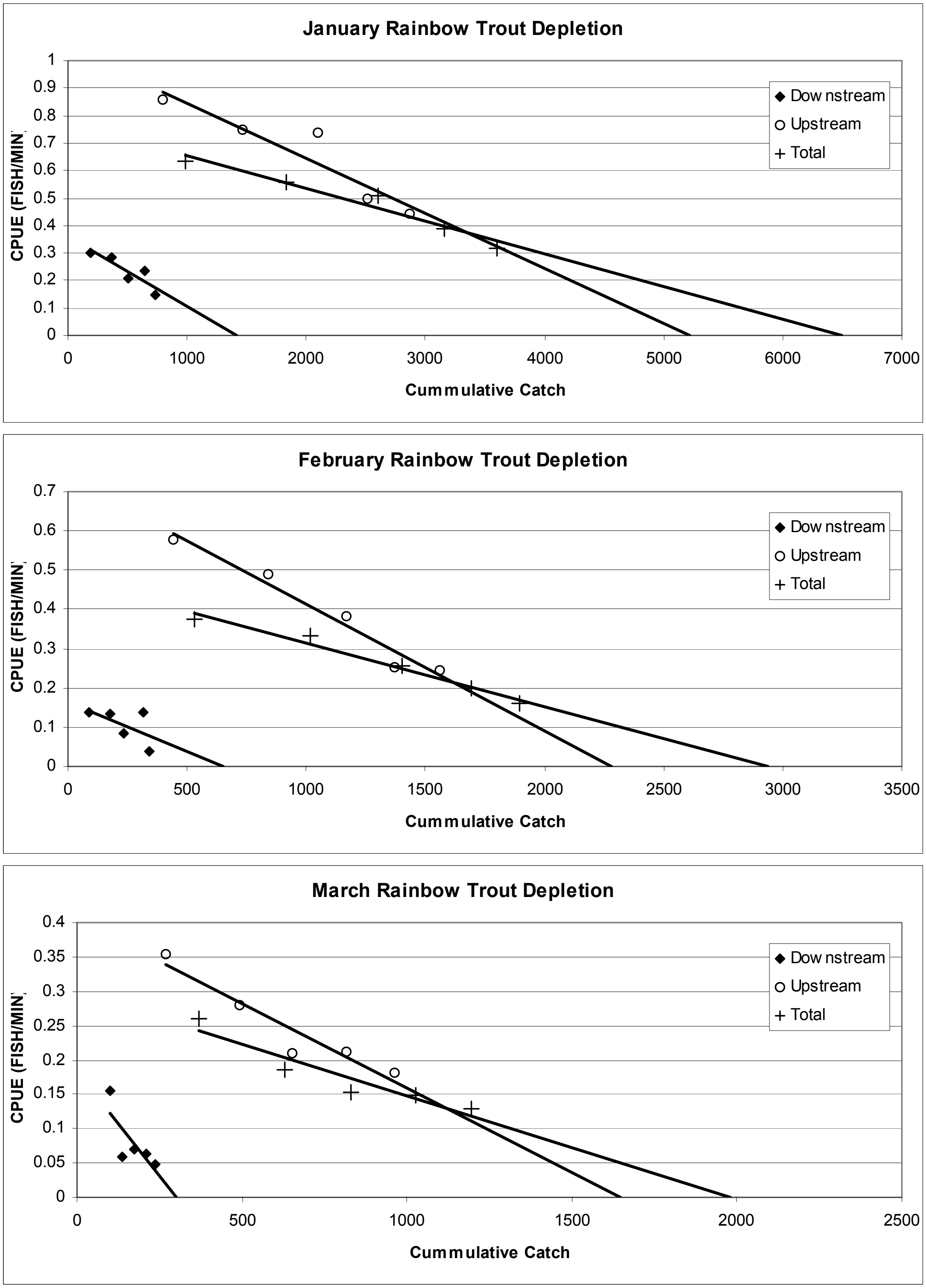

Figure 4 Simple linear regressions for rainbow trout removal data by month and location, January – March 2003. X-axis intercepts represent initial abundance estimates.

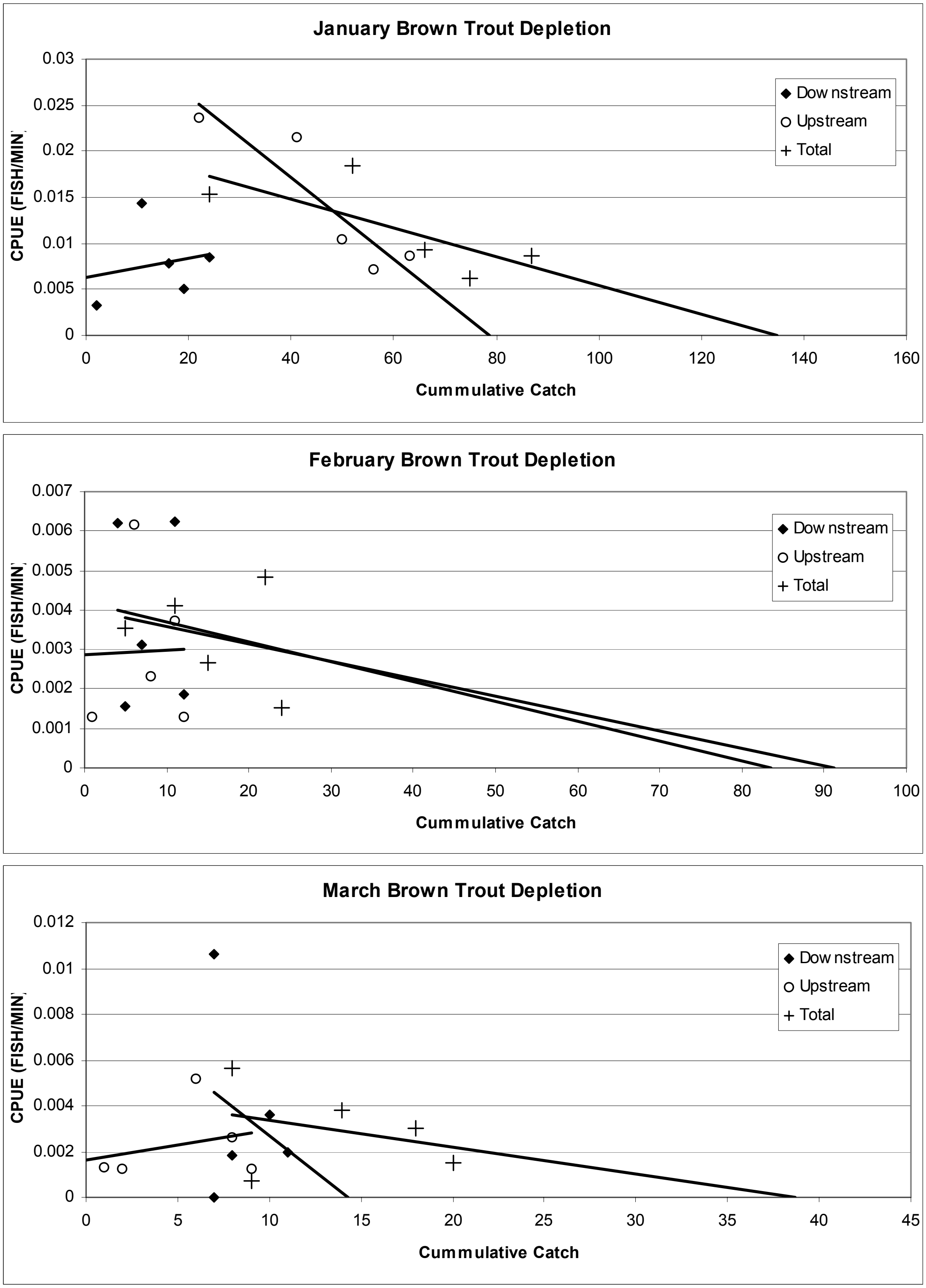

Figure 5 Simple linear regressions for brown trout removal data by month and location, January – March 2003. X-axis intercepts represent initial abundance estimates.

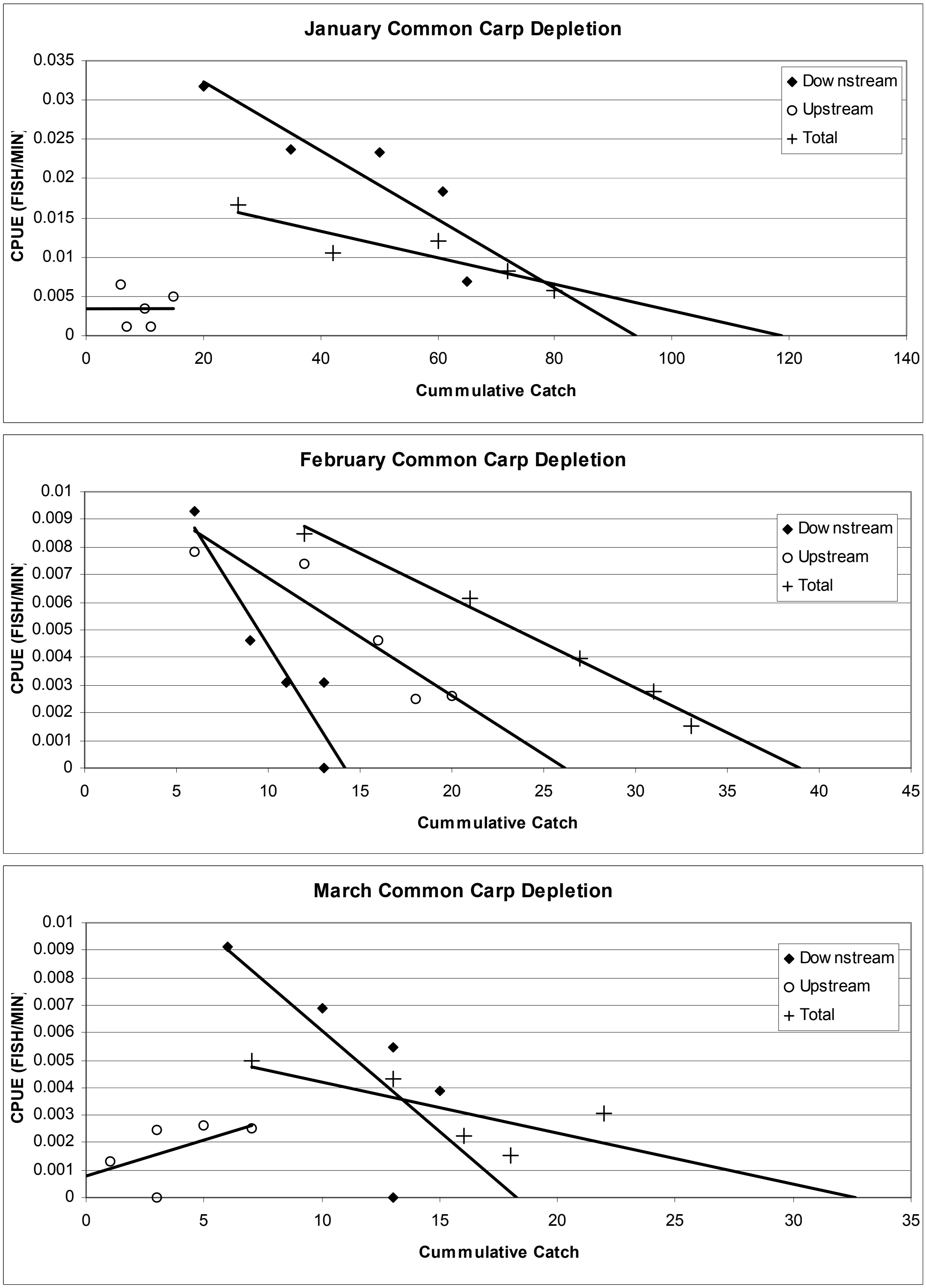

Figure 6 Simple linear regressions for common carp removal data by month and location, January – March 2003. X-axis intercepts represent initial abundance estimates.

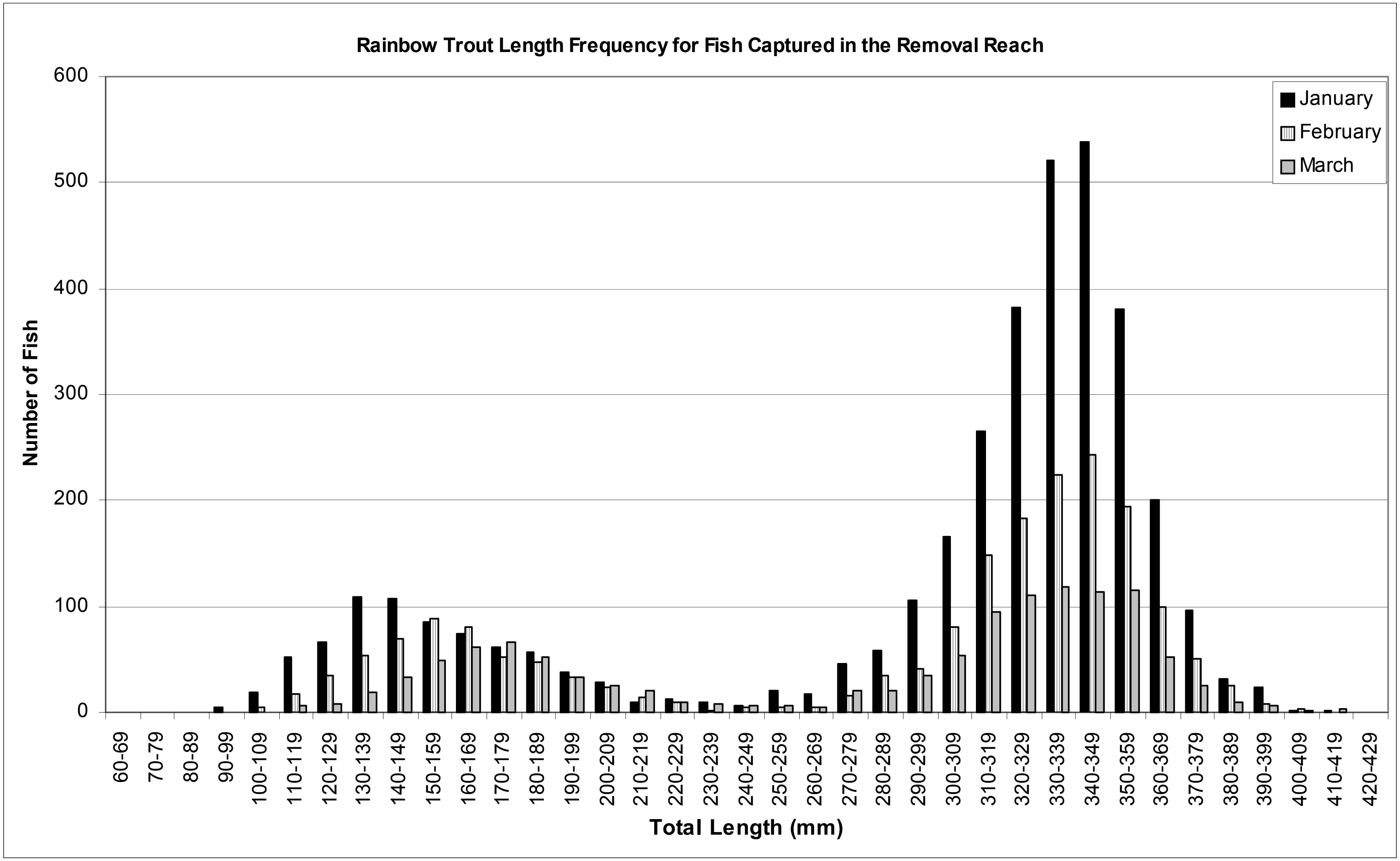

Figure 7 Length frequency distributions by month for rainbow trout captured in the removal reach, January – March 2003.

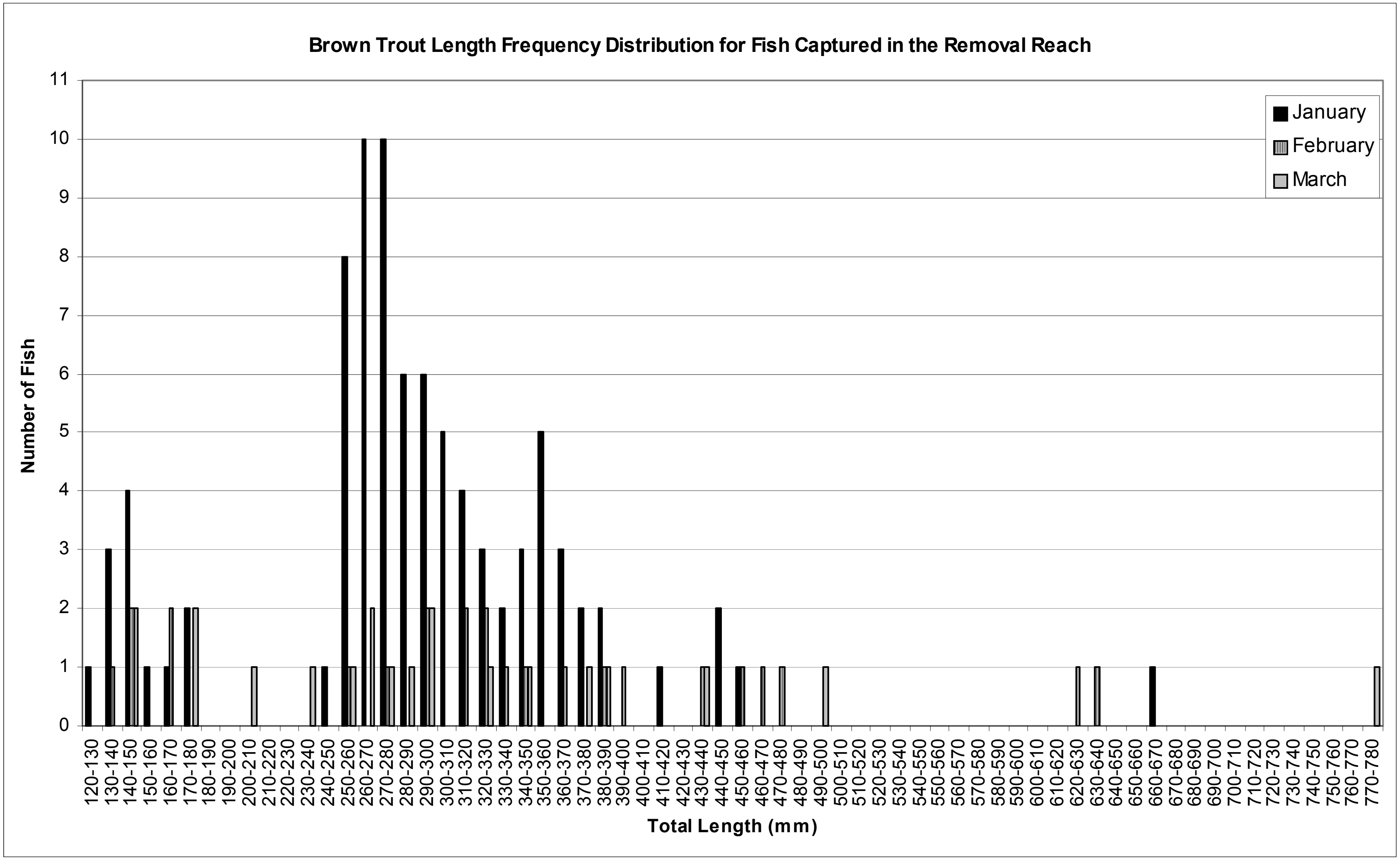

Figure 8 Length frequency distributions by month for brown trout captured in the removal reach, January – March 2003.

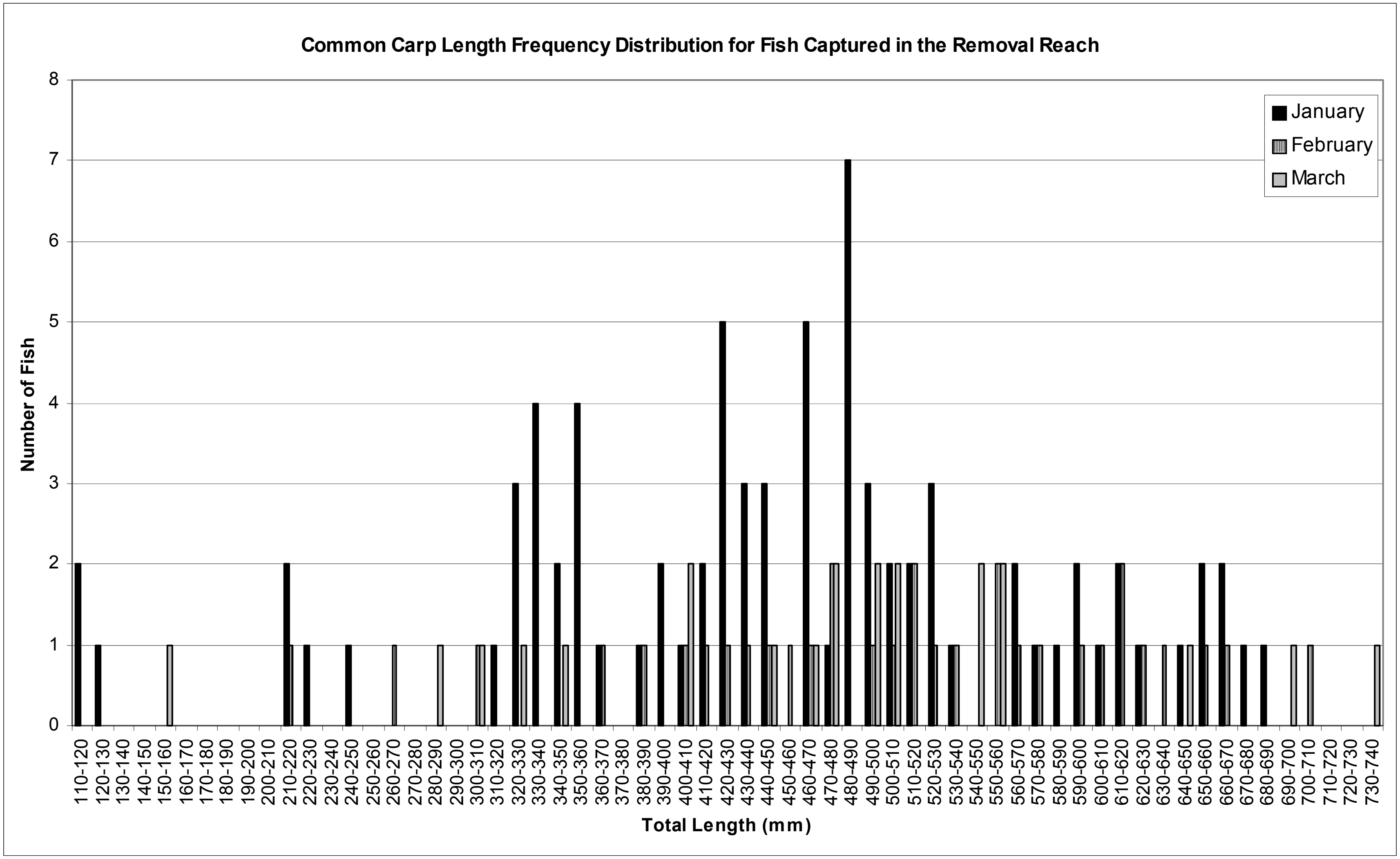

Figure 9 Length frequency distributions by month for common carp captured in the removal reach, January – March 2003.

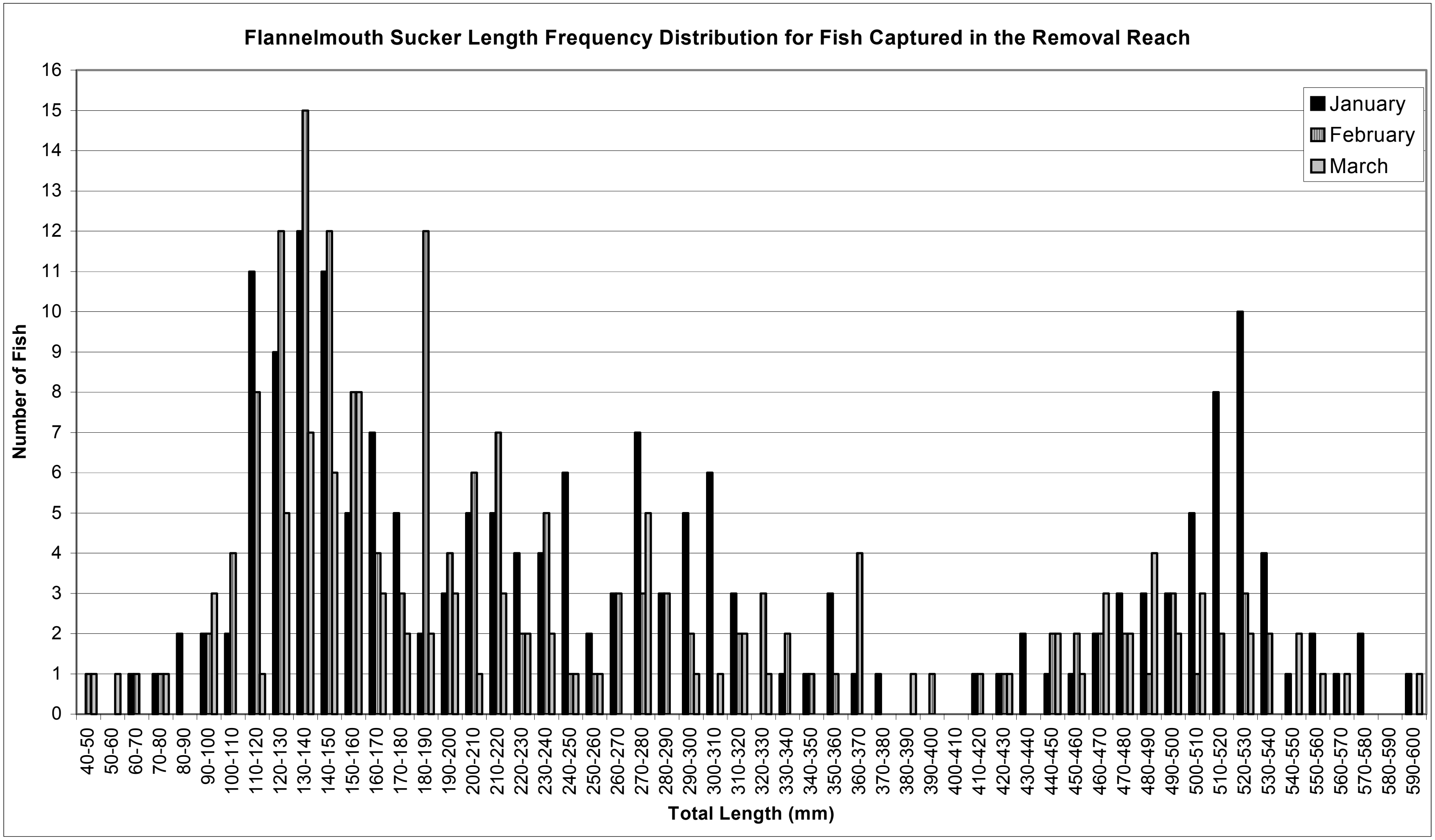

Figure 10 Length frequency distributions by month for flannelmouth sucker captured in the removal reach, January – March 2003.

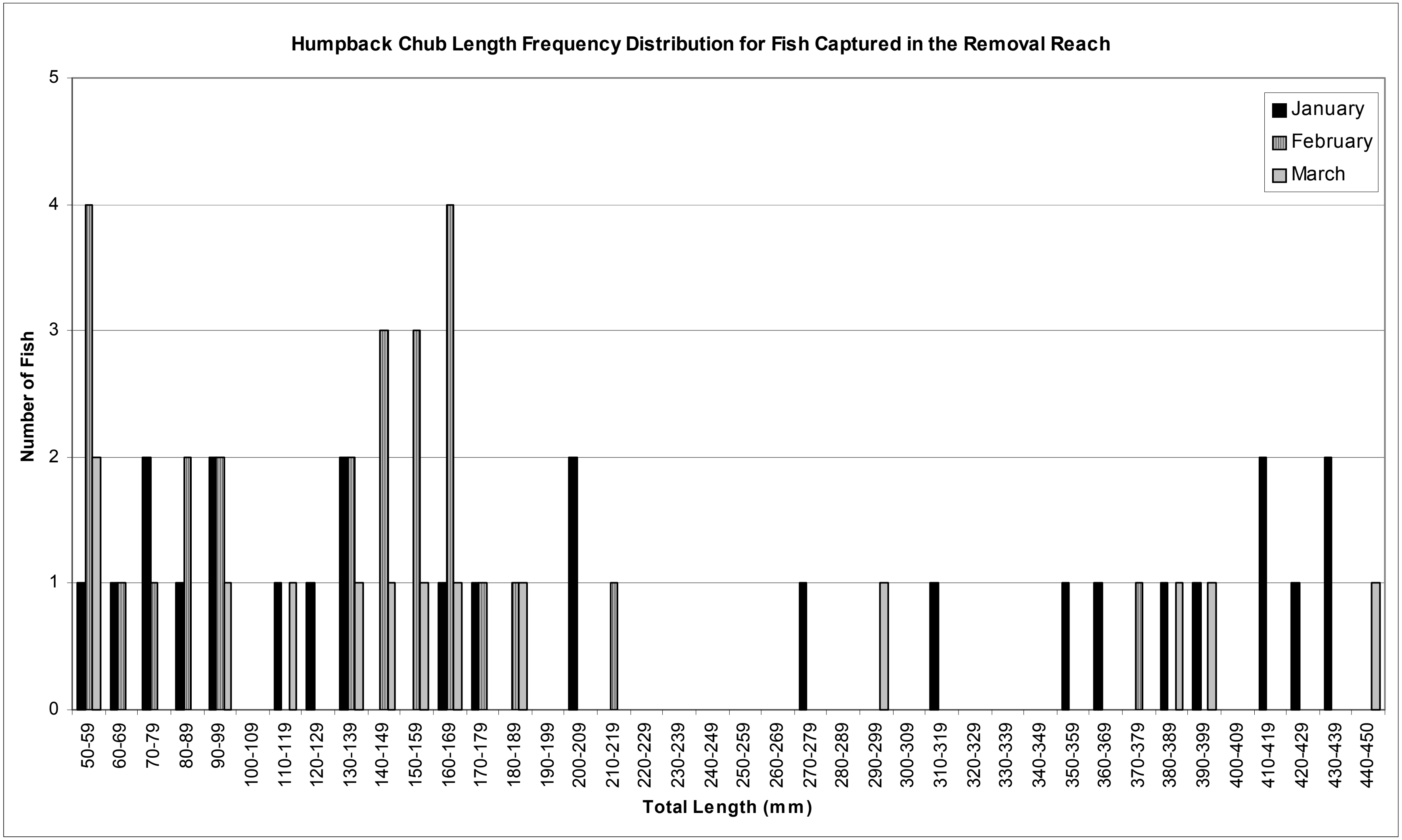

Figure 11 Length frequency distributions by month for humpback chub captured in the removal reach, January – March 2003.

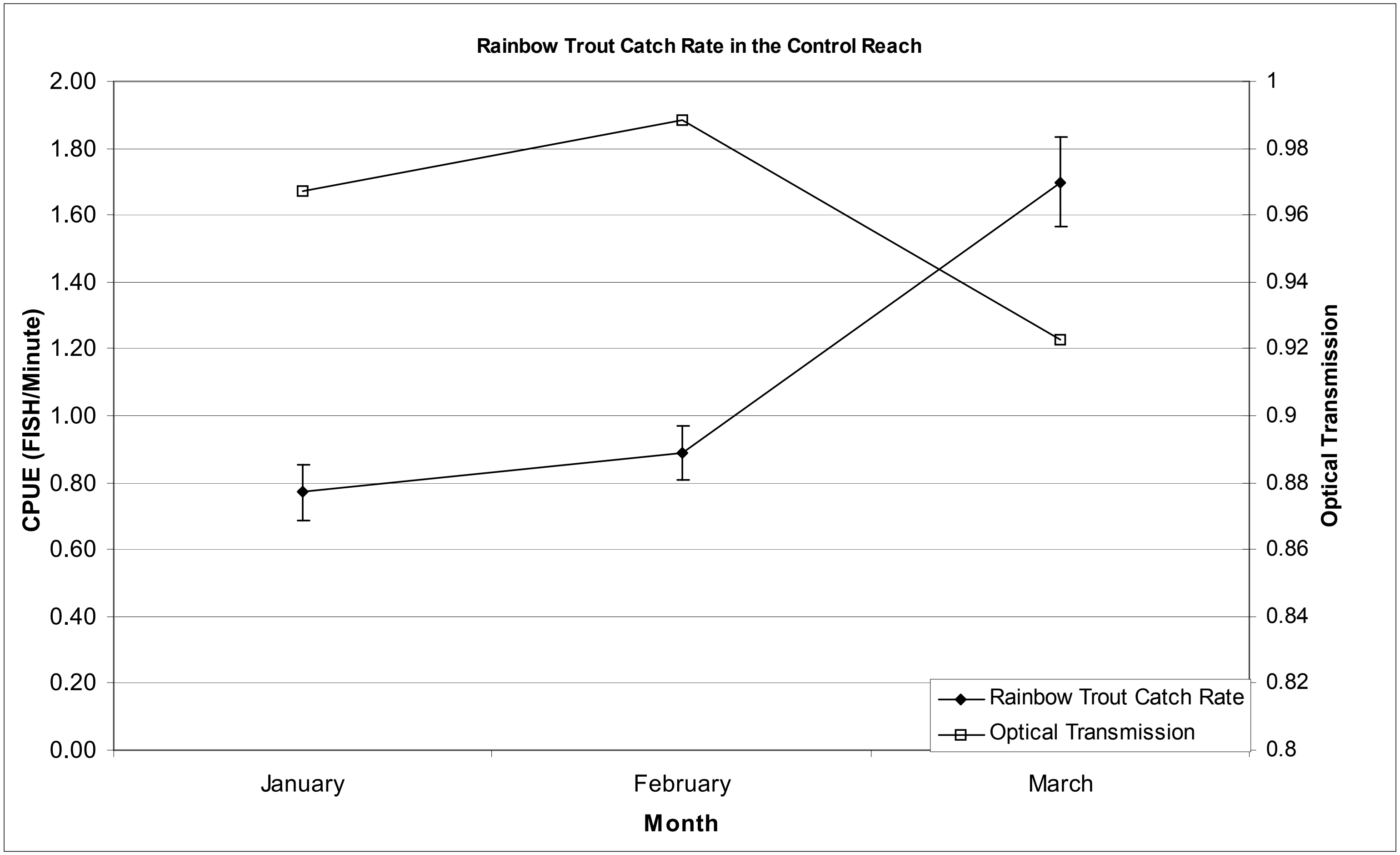

Figure 12 Electrofishing catch rate of rainbow trout and optical transmission by month, January – March 2003. Optical transmission is a measure of water clarity and varies between 0 (opaque) and 1 (absolutely clear). Optical transmission data provided by D. Topping, USGS WRD. Error bars on catch rate estimates are +/- 1 standard error.

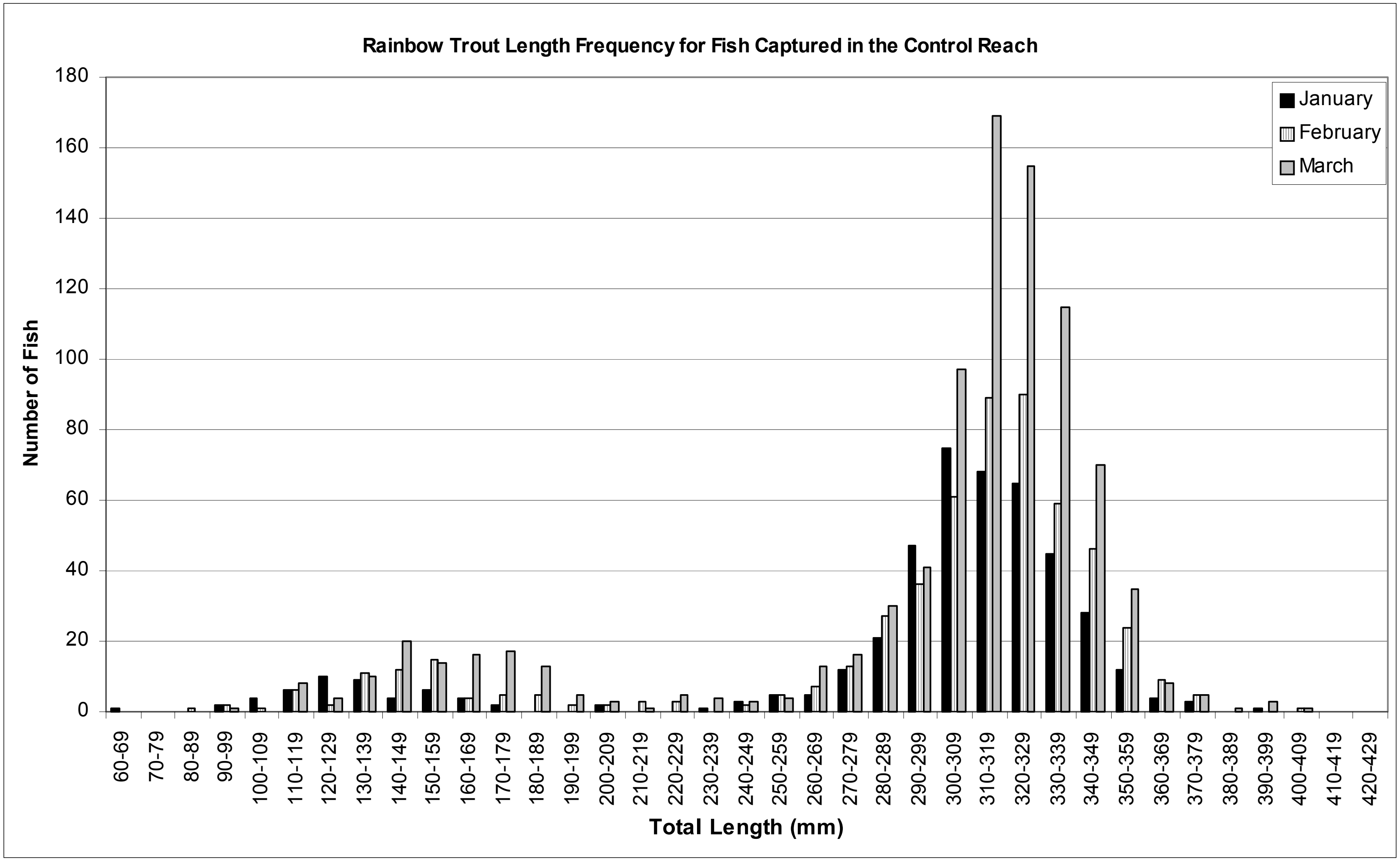

Figure 13 Length frequency distributions by month for rainbow trout captured in the control reach, January – March 2003.

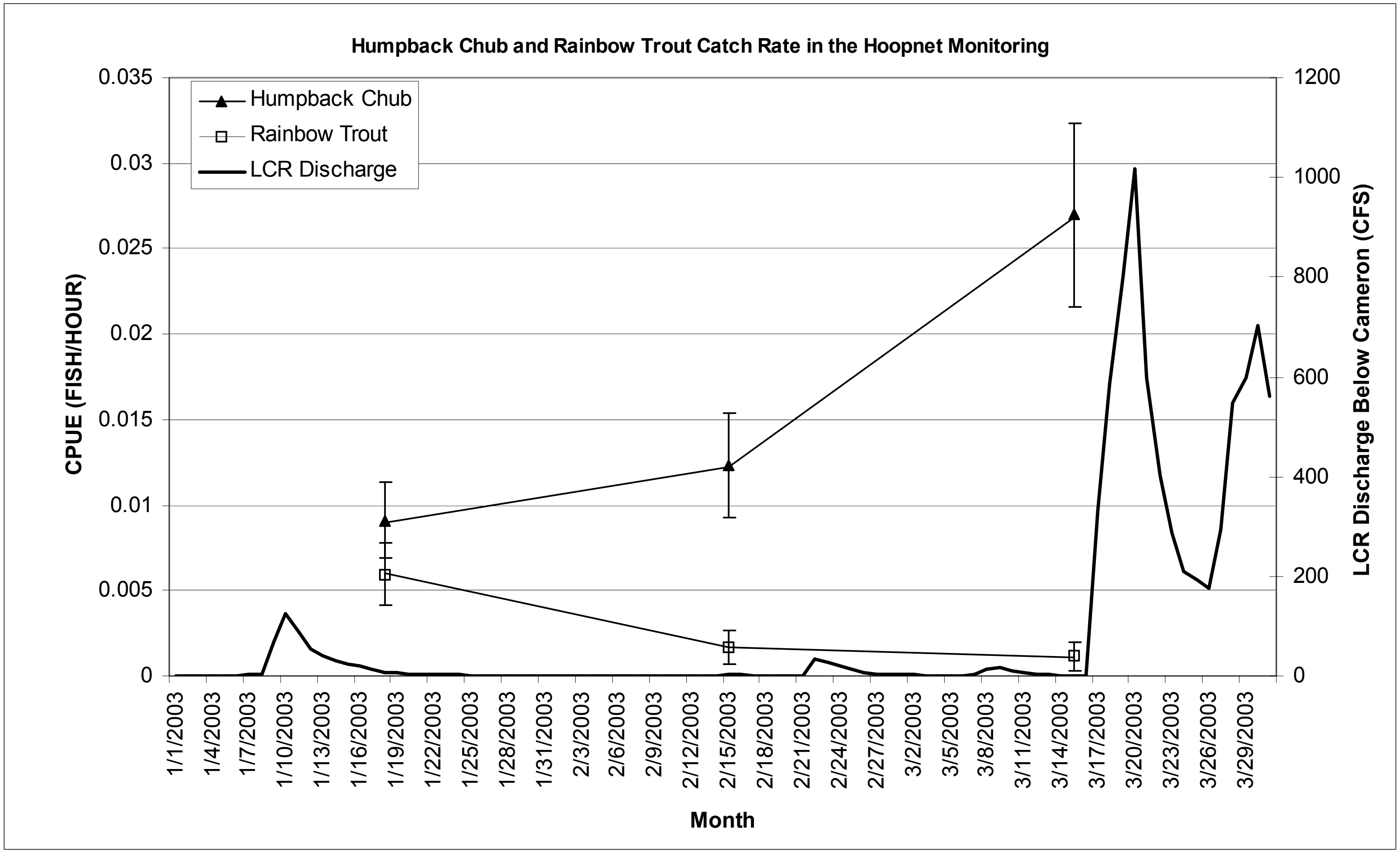

Figure 14 Catch rate of humpback chub and rainbow trout during hoopnet monitoring within the removal reach, January-March 2003. Error bars on catch rate estimates are +/- 1 standard error. Also plotted is average daily discharge in the Little Colorado River below Cameron, Arizona (USGS provisional data) depicting minor freshets on February 22 and March 8, 2003.

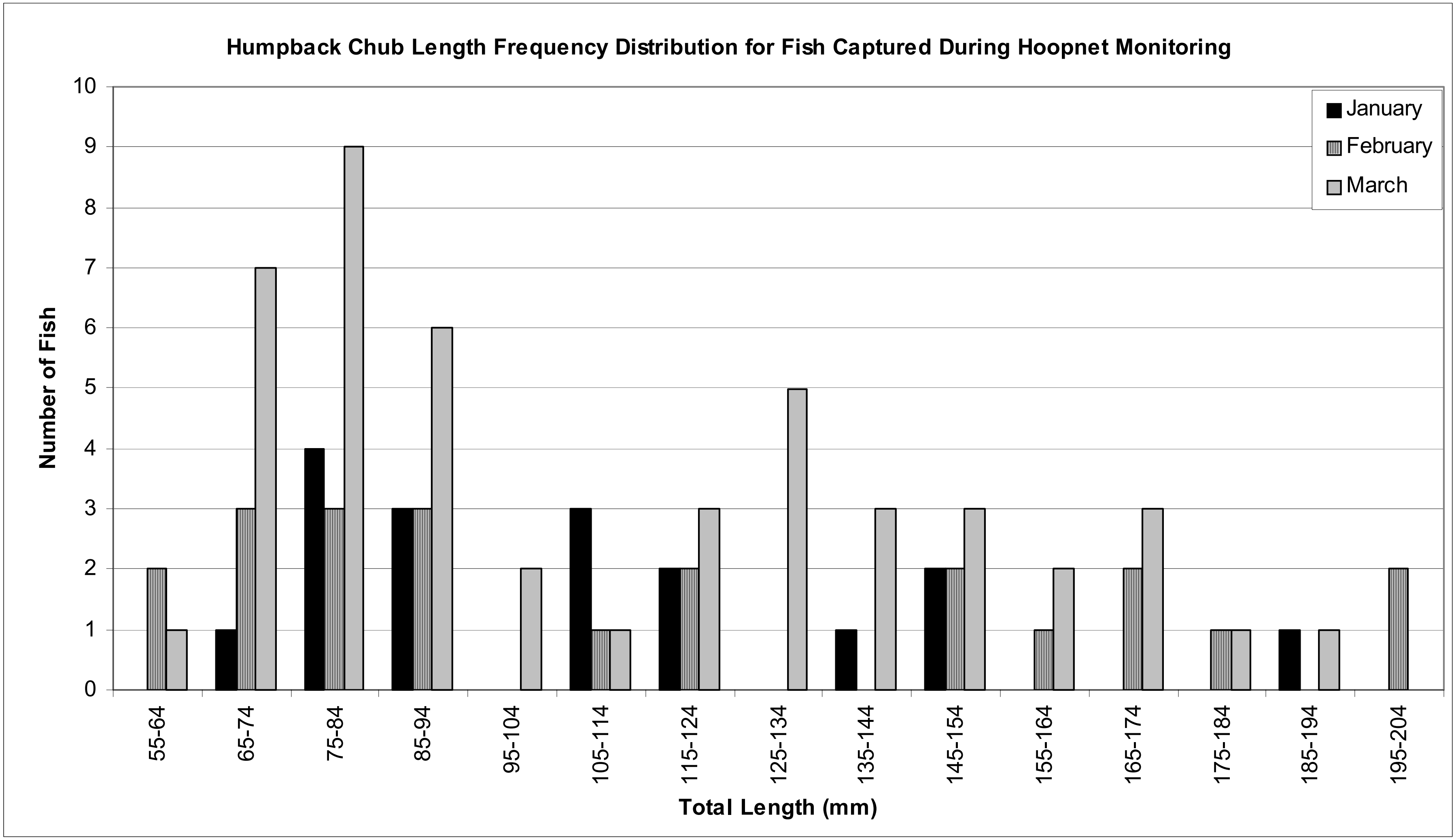

Figure 15 Length frequency distributions by month for humpback chub captured during hoopnet monitoring in the removal reach, January – March 2003.