Status of the Lees Ferry Rainbow Trout Fishery—2010 Annual Report

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Abstract

Rainbow trout (*Oncorhynchus mykiss*) were initially stocked in the Colorado River below Glen Canyon Dam in 1964, and since that time fish management efforts, dam operations, and flow regimes have interacted to influence the trout community. Understanding fish ecology in relation to dam operations is essential in order to integrate water, power, and fishery management goals. Standardized rainbow trout monitoring trips consisted of boat electrofishing a randomly generated group of transects that were stratified by longitudinal distance and habitat characteristics. In July 2010, a sampling trip was dedicated to rare nonnative fishes in a large backwater area using various gear types. Rainbow trout catch-per-unit-effort (CPUE; fish/min.) for all sizes during 2010 was 3.2±0.6 fish/min., which is similar to the rainbow trout CPUEs in the early 2000's. Proportional stock density has increased since 2006, though not significantly. Rainbow trout condition factor (K_n) was similar to those observed since 2008. Angler CPUE (fish/hr) from creel surveys closely resembled the trends seen in the electrofishing CPUE data for fish 152-405 mm total length since 1991. During sampling in the large backwater area in July, few rare nonnatives were captured; however, we were able to attain a population estimate of 479 (95% credible interval, 329-785) common carp in a relatively small area, which may indicate that the backwater serves as a thermal refuge and/or a spawning area. If the rainbow trout population expands and density-dependent constraints become more visible, downstream movement is possible. Potential density-dependent downstream movement could be assessed through an intensive tagging study in Lees Ferry, and subsequent monitoring in downstream reaches.

Introduction

The Arizona Game and Fish Department (AGFD) has been monitoring and performing research on trout in Glen Canyon since the mid 1960's. Rainbow trout (*Oncorhynchus mykiss*) were initially stocked in the Colorado River below Glen Canyon Dam (GCD) in 1964, and since that time fish management efforts, dam operations, and flow regimes have interacted to influence the trout community (Arizona Game and Fish Department 1996; Persons and others 1985; Marzolf 1991; Reger and others 1995; McKinney and Persons 1999; McKinney and others 1999 a, c). Impacts of regulated flow on rainbow trout in the Lees Ferry tailwater have been a source of interest and debate for resource managers and the public for several decades (Persons and others 1985; Maddux and others 1987; Reger and others 1995; McKinney and Persons 1999; McKinney and others 1999 a; McKinney and others 2001; McKinney and Speas 2001). Understanding fish ecology in relation to dam operations is essential in order to integrate water, power, and fishery management goals.

Ecology of nonnative rainbow trout in the Lees Ferry tailwater (river mile [RM] -15 to RM 0; fig. 1) is strongly influenced by operations of Glen Canyon Dam (Korman and others 2010; McKinney and Persons 1999, McKinney and Speas 2001; McKinney and others 1999 b, c; McKinney and others 2001). Nonnative rainbow trout in the tailwater provide a popular recreational fishery and coexist with native flannelmouth sucker (*Catostomus latipinnis*) and nonnative brown trout (*Salmo trutta*) and common carp (*Cyprinus carpio*). From 1991 through 1997, higher mean and less variable releases from GCD favored high standing stocks of rainbow trout, but size-related changes occurred in relative condition and bioenergetics of fish (McKinney and others 1999a; McKinney and Speas 2001). Small fish (< 305 mm) were strongly affected by low and variable releases from the dam, but not by biotic variables which allowed them to meet maintenance energy requirements. In contrast, large fish (≥ 305 mm) were not affected by flow variability but were strongly influenced by biotic factors (i.e., density-dependence) associated with degradation of the aquatic food base. Large fish rarely met maintenance energy requirements (McKinney and Speas 2001). Relative condition of large fish peaked in 1994 and then fell 10% by 1997, whereas condition of small fish was generally stable between 1991 and 1997. From 1997 to 2000, Speas and others (2004b) noted a marked reduction in year-to-year variance in catch-per-unit-effort (CPUE; fish/minute), relative condition (K_n) and proportional stock density (PSD), likely caused by the impacts of increased densities on the food base in the mid-1990's. Catch-per-unit-effort decreased through the early 2000's and remained relatively low until the fall of 2008, when a large cohort of young-of-the-year fish was observed during monitoring efforts, likely a result of alterations in the flow regime including a high flow event in March of that year, and the implementation of fall steady flows for the months of September and October.

Standardized monitoring of the trout fishery using electrofishing (Sharber and others 1994) at fixed sampling locations was initiated in 1991 and has provided data on response of the rainbow trout population to dam operations (McKinney and Persons 1999; McKinney and others 1999a, c; McKinney and others 2001). In recent years, the Grand Canyon Monitoring and Research Center (GCMRC) sponsored a series of protocol evaluation panels for external scientific review of Colorado River sampling protocols (*http://www.gcmrc.gov/pep/troutPEP.htm).* A scientific review panel convened in 2001 which recommended increasing the overall sample size through reduction in length of existing fixed transects and addition of randomly selected sites. Random components of this augmented, serially alternating sampling design (Urquhart and others 1998) are intended to give representative estimates of fishery status, whereas fixed components were to ensure continuity with existing trend data. Increasing the number of sample transects per sampling occasion also provides increased statistical power to detect changes in fishery variables on a yearly time scale (Speas and others 2004c). A protocol evaluation panel convened in 2009, and recommended developing a completely randomized design as statistical analysis showed little to no difference in metrics of interest between the fixed sites and the random sites. A completely randomized design may provide a more representative picture of the population structure throughout Glen Canyon (Bradford and others 2009). It was also recommended that one of the sampling trips be replaced by a nonnative "hot-spot" sampling event in an attempt to detect rare nonnative species that are not susceptible to techniques used during standard monitoring.

We present results from fish monitoring activities in the Lees Ferry tailwater during 2010. We will evaluate the usefulness of the nonnative sampling trip and its value relative to a standard summer monitoring trip. Our monitoring objectives have not changed since 2002 and include evaluating the status and trends in CPUE, population structure (size composition and PSD), growth rate, and relative condition (K_n) of rainbow trout.

Methods

Field Collections

Long-term monitoring

We conducted standard monitoring surveys in the Lees Ferry tailwater from April 27-30 and October 26-29, 2010 (fig. 1; table 2). We used two 16 ft. Achilles inflatable boats outfitted for electrofishing, applying pulsed DC (~410 V, ~12 A; Sharber and others 1994) to a 35-cm spherical electrode system. Sampling commenced shortly after dusk and persisted 5-7 hours per night for three consecutive nights.

During each monitoring survey, we electrofished 32 and 36 random sites, for the April and October trips, respectively, covering approximately 4 km of shoreline area, with the goal of sampling 6 sites per boat each night (Speas and others 2004b). The random transects were selected without replacement from strata containing the remaining sample units found in river kilometer (RK) 0.9 – 26.85. We stratified sample units in two ways: 1) by shoreline type/relative abundance combinations and 2) longitudinally. The shoreline type stratification was comprised of talus/cobble bar shorelines, which are characterized by the highest CPUE values observed in 2001 (5.3 fish/min.; Speas and others 2004b) and sand bar/cliff face shorelines characterized by the lowest CPUE values from 2001 (3.6 fish/min.; Speas and others 2004b). We selected specific shoreline types according to their availability (percentage of shoreline length) within river sub-reaches. The longitudinal stratification was by RK; upper (RK 0.9 – 8.15), middle (RK 8.15 - 19.05) and lower (RK 19.05 – 26.85) sub-reaches of the tailwater below GCD. Longitudinal stratification also allowed randomization while maintaining safety and logistical integrity (i.e., boats visit the same section of the river on each night) as well as among longitudinal gradients in fish density (Speas and others 2004b).

We measured total length (TL; mm) for all fish captured, fork length for all native fish captured and weight (g) for most fish when conditions permitted accurate weight measurements. We sexed fish based on manual extrusion of gametes or, for sacrificed specimens, by internal verification of gonads. All rainbow trout > 200 mm TL received an individually numbered Floy tag, except at 9 sites per trip that were near the old fixed transects, where untagged rainbow trout > 150 mm TL were implanted with 400 kHz passive integrated transponder (PIT) tags. Untagged brown trout and native species (i.e. flannelmouth sucker) > 150 mm TL were implanted with 134.2 kHz PIT tags at all sites. We injected all PIT tags (400 kHz and 134.2 kHz) ventrally into the fish body cavity with the insertion point immediately posterior to the pelvic fin. Floy tags were inserted through the dorsal pterygiophores near the dorsal fin insertion. All salmonids receiving PIT or Floy tags received an adipose fin clip to monitor tag loss. This tagging regime was intended to produce open population estimates and information on growth and movement in the future.

A subsample of rainbow trout was sacrificed in the Lees Ferry tailwater in 2010 for age and diet analysis (AGFD) and disease determination (Washington Animal Disease Diagnostic Laboratory, Washington State University, Pullman, WA; WADDL). For the age and diet analysis, we sacrificed 4-5 (61 total) rainbow trout from each site that was near an old fixed site during each sampling trip varying in size from smallest to largest, removed their stomachs, and extracted sagittal otoliths. From sites where specimens were not collected for stomach and otolith collection, we also sacrificed 75 rainbow trout and shipped them to WADDL to test for whirling disease. Unless sacrificed for whirling disease or diet and age analysis, all fish were released alive near the location of capture.

Slough Sampling

We electrofished six transects in a large backwater known as the "slough", located on river left between RK 5.7 and 6.25. We sampled at least two times over the course of three nights with an Osprey aluminum hulled boat equipped with a Coffelt replacement complex pulse system (CPS) output regulator. We applied approximately 280-370 volts and 12-15 amps to a 35-cm stainless steel anode, while a crewmember netted stunned fish from the bow of the boat. The boat shocking was augmented by back-pack shocking along the right shoreline of the slough on the first night of sampling. A Smith-Root back-pack shocker was set at 300 volts and 90 Hz. The river-right shoreline was shocked downstream for approximately 600 seconds over three sites, for a total duration of 1,800 seconds. Two 50 ft. x 6 ft. x 1 inch mesh trammel nets and one 75 ft. x 6 ft. x 1 inch mesh trammel net were deployed on the left bank around RK 6, 5.8, and 5.75 for two approximately one-hour sets in the afternoons of July 22 and July 23. Supplemental trapping included ten mini hoop nets baited with Aquamax, ten catfish hoop nets baited with stink cheese, and 20 minnow traps baited with canned cat food. Gear was evenly distributed along right and left banks between RM's -12.1 and -12.33 and was set in the late afternoon of July 22. Monitoring was performed early and late evening on July 22, and late afternoon on July 23. In an attempt to close the system through the duration of all sampling methods, an 80 ft. x 10 ft. x ¼ inch delta mesh block net was placed approximately at the mouth of the slough (RM -11.99) prior to sampling.

Nonnative fishes were measured for total length (TL; mm) and all native fishes were measured for both TL and fork length (mm). All rainbow trout were examined for the absence of left pelvic fin (Floy tags) or adipose fins (PIT tags) to detect tag loss. All fish captured were sexed by manual excretion of gametes. Rainbow trout were only counted and were not measured or given new tags. All common carp were examined for the absence of dorsal spines to detect tag loss. All previously unmarked native fishes and common carp ≥ 150 mm TL received 134.2-kHz PIT tags and all newly tagged common carp received an operculum clip.

Data Analysis

Long-term monitoring

We computed CPUE for all fish captured during electrofishing surveys, as well as for the following length categories: <152 mm TL, 152-304 mm TL, 305-405 mm TL and >405 mm TL, with CPUE serving as an index of relative abundance. Based on creel surveys, angler CPUE (fish/hr) was calculated as rainbow trout caught per angler hour for each individual interview, and then all interviews were averaged for each year. We indexed size structure of the catch by calculating PSD as the ratio of "quality" sized fish to the sum of "quality" and "stock" sized fish using the equation:

$$\text{PSD}=\left[\frac{\text{Fish} \geq 406 \text{ mm}}{\text{Fish} \geq 305 \text{ mm}}\right]\times 100$$

Fish ≥ 406 mm have been protected from harvest by AGFD fishing regulations (Anderson and Nuemann 1996; McKinney and others 1999a). Fish ≥ 305 mm are sexually mature (McKinney and others 1999a) and, in the early 1990's, were determined to be generally desired by Arizona anglers (Pringle 1994). We determined relative condition factor (K_n; Le Cren 1951) using the equation:

$$K_n = \left[\frac{W}{W'}\right] \times 100$$

where W′ is the standard weight relationship $e^{[(-4.6 + 2.856*LN(TL))]}$ incorporating all Lees Ferry rainbow trout length and weight data collected since 1991. This was also done for the previously mentioned length categories. We report mean CPUE, angler CPUE, PSD, and K_n with ± 2 standard errors, which is a close approximation of 95% confidence intervals (Snedecor and Cochran, 1976).

Slough sampling

We computed CPUE of boat shocking only. We obtained closed population mark-recapture estimates of abundance and capture probability using a multinomial likelihood model from boat electrofishing data collected on July 22-23 (Otis et al. 1978). A Length-frequency histogram for common carp was created using 10-mm size increments. All other sampling types produced too few fish to conduct analysis.

Results

Discharges from Glen Canyon Dam varied seasonally during 2010 and fluctuated daily except for September and October (fig. 2). Mean daily flow decreased from 453 m^3/s in January to around 283 m^3/s at the beginning of March. From mid-March through June mean daily flows were around 283 to 306 m^3/s. Mean daily flows increased to 390 m^3/s for the summer months of July and August. Fall steady flows occurred in September and October at 227 m^3/s. This regime was initiated in 2008 in an attempt to raise mainstem Colorado River water temperatures around the confluence of the Little Colorado River to benefit the endangered humpback chub (*Gila cypha*; U.S. Fish and Wildlife Service 2008) and is expected to occur annually through 2012. November and December returned to daily fluctuating flows with a mean daily flow around 396 m^3/s. Throughout the months of daily fluctuating flows, mean daily flow was reduced on weekend days by as much as 57 m^3/s (*USGS Real-Time Water Data for USGS 09380000 COLORADO RIVER AT LEES FERRY, AZ http://waterdata.usgs.gov/nwis/uv?09380000*).

Water temperature declined from 9.8°C in January to 7.8°C in March. There was an increase in temperature through the summer to a high of 11.4°C in September. Temperature fluctuated between 10.0°C and 11.4°C through the remaining months of the year.

Whirling disease analyses were negative for all samples collected during 2010 (Jim Thompson, AGFD Fish Health Laboratory, personal communication). Results of AGFD age and diet analysis are incomplete at the time of submission of this report.

Long-term monitoring

A total of 2,260 fish from 3 species were captured during long-term monitoring at Lees Ferry in 2010 (table 1). Rainbow trout were the most prevalent species captured (99.7%) followed by brown trout (0.2%) and flannelmouth sucker (0.1%; table 1). A total of 77 rainbow trout were implanted with PIT tags. Two PIT tagged rainbow trout were recaptured during 2010 sampling. A total of 334 rainbow trout were implanted with Floy tags. Three Floy tagged rainbow trout were recaptured. One flannelmouth sucker was implanted with a PIT tag. One flannelmouth sucker was recaptured during 2010. A total of 2 brown trout were PIT tagged.

The mean TL of rainbow trout captured during 2010 was 144 mm. Length frequency analysis showed a typical bimodal rainbow trout distribution during April with a large mode centered around 110-120 mm, and another smaller mode centered around 280-290 mm. A large cohort of fish < 100 mm TL was observed in October, indicating a relatively strong spawning event similar to 2009 occurred in the spring (fig. 3).

Overall, the rainbow trout CPUE in 2010 was similar that observed since 2008, which are roughly 2-3 fold higher than those observed between 2005 and 2007. Rainbow trout CPUE for all sampling and sizes during 2010 was 3.2±0.6 fish/min, which is similar to the rainbow trout CPUEs in the early 2000's (fig. 4). The CPUE is largely attributable to high numbers of rainbow trout in the < 152 mm range which was the case in 2008 and 2009 (fig. 5*A*), indicating continued strong spawning. Recruitment appears to have decreased, or emigration increased, compared to 2009, as the CPUE for the 152-305 mm size class decreased (fig. 5*B*). However, it is likely this size class of fish was missed due to the reallocation of effort in the summer of 2010. Rainbow trout CPUE in the 305-405 mm TL size class has declined since 2003 (fig. 5*C*). Rainbow trout CPUE of fish > 405 mm TL in 2010 was similar to the low levels observed since 2000 (fig. 5*D*).

A total of 933 anglers were contacted during 339 interviews conducted near the Lees Ferry boat ramp (AGFD Region 2, unpublished data). Angler CPUE (fish/hr) from creel surveys closely resembled the trends seen in the electrofishing CPUE data for fish 152-405 mm TL since 1991 (fig. 6). That pattern has not been as evident in more recent years and likely differs from overall rainbow trout electrofishing CPUE due to the prevalence of small fish (< 152 mm TL) observed in electrofishing surveys for 2008-2010. Angler CPUE declined substantially in 2002 and the trend has fluctuated slightly since with an increase for 2009 and 2010. The increase in angler CPUE for 2009 was likely due to the recruitment of the 2008 cohort into the more catchable 152-304 mm range. Lees Ferry anglers averaged about 1.0±0.1 fish/hr during 2010. Average angler effort in 2010 was 8 hours per day.

Proportional stock density has increased since 2006, though not significantly (fig. 7). The PSD for 2010 was the highest measured since 2001, but still below those measured for 1991-2000. This was likely due to a decrease in catch of fish in the 305-405 mm range than to an increase in catch of fish > 405 mm TL.

Overall, rainbow trout K_n was similar to those observed since 2008 (mean 80.1±0.9; fig. 8), which was significantly lower than those observed during 2006-2007. Size-stratified analysis of K_n suggested an increase in condition of fish between 152-304 mm TL compared to 2010, while all other size classes were similar in condition to those observed in 2009 (fig. 9).

Slough Sampling

We captured a total of 197 (170 unique) common carp, 28 rainbow trout, five flannelmouth sucker and two green sunfish (*Lepomis cyanellus*; table 3) by boat electrofishing. Common carp ranged in size from 111-800 mm TL and flannelmouth suckers ranged from 424-527 mm TL. The two green sunfish measured were 91 and 138 mm TL. Mean common carp CPUE was 1.1±0.4. We implanted 165 common carp and three flannelmouth sucker with PIT tags. A total of 30 common carp caught were PIT recaptures, 26 of which were tagged throughout the slough sampling event. There were four common carp and one flannelmouth sucker recaptures tagged from previous sampling events (table 4). A total of seven common carp were captured during backpack electrofishing surveys, ranging in size from 216 to 858 mm TL, all of which received new 134.2 kHz PIT tags (table 3).

We captured a total of five common carp, eleven flannelmouth sucker, and one green sunfish during trammel net surveys (table 3). Common carp ranged in size from 255-588 mm TL and the flannelmouth suckers ranged from 406-534 mm TL. The green sunfish was 152 mm TL. Six flannelmouth sucker and three common carp received new PIT tags. There were two common carp recaptures that were originally PIT tagged during back-pack electrofishing on July 21. One flannelmouth sucker that received a new 134.2-kHz PIT tag possessed a 400-kHz PIT tag originating from the Little Colorado River on May 17, 1999 (table 4). Throughout the duration of this sampling, no fish were caught in any of the hoop nets or minnow traps.

The common carp population was estimated to be 479 (95% credible interval (CI), 329-785) with a capture probability at 0.13 (95% CI, 0.08-0.21). Length frequency data from unique common carp captures show a unimodal distribution between 460 and 670 mm TL representing an adult population, with a mean TL of 545 mm and only one < 150 mm TL (fig. 10). Ripe males comprised 39% of total common carp captured. Too few flannelmouth sucker were captured to conduct length-frequency analysis. However, all flannelmouth sucker captured were adults, with a mean TL of 486 mm.

Discussion

Long-term monitoring

A GCMRC-sponsored protocol evaluation panel (PEP) convened in 2001 suggested increasing overall sample size in the Lees Ferry tailwater by reducing the length of fixed electrofishing transects and incorporating randomly selected transects. The purpose of these recommendations was to: 1) increase power to detect change in the rainbow trout population, and 2) allow sampling to become more representative of the entire Lees Ferry reach (Bradford and others 2009). We initiated this augmented, serially alternating sampling regime (Urquhart and others 1998) in June 2002. Fixed transects served to ensure comparison with historical data and random transects provided representative estimates of fishery status. Our analysis of long-term fixed and random transects over similar temporal scales for 2002 through 2009 showed no differences in size-stratified estimates of relative abundance and size structure. Thus, we pooled data from both fixed and random transects to increase our ability to detect rainbow trout population trends over time (Speas and others 2004c). While our analysis of these data consisted of relatively simple statistics (ANOVA; S. Urquhart, *personal communication*), we recognize the potential for more robust statistical analysis of these data.

Another PEP was sponsored by GCMRC in the summer of 2009 which made further recommendations on the sampling effort in Lees Ferry. The PEP recommended eliminating the fixed sites and replacing them with additional random sites, which was implemented in 2010 (Bradford et al. 2009). It was also recommended that power analyses be conducted to determine if overall rainbow trout sampling effort could be reduced. Preliminary analyses indicated that a reduction in effort would not significantly impact the ability to monitor the rainbow trout fishery in Lees Ferry, thus the summer sampling trip was replaced with a nonnative species sampling trip, which was a part of this second recommendation made by the PEP.

A third recommendation made by the 2009 PEP was to incorporate the rainbow trout early life stage survival (RTELSS) work, currently conducted by Josh Korman and Dave Foster, USGS, into the AZGFD Lees Ferry monitoring. The RTELSS surveys were conducted by AZGFD and USGS personnel this year and that data will be presented in a separate report.

It was suggested in the 2008 and 2009 annual reports for Lees Ferry that the rainbow trout population may return to a state similar to previous years (i.e., 1997-2000; Makinster and others 2009, 2010) where density-dependent constraints limited food and space availability (Speas and others 2004a, b), and fish were likely too energetically compromised to produce sufficient somatic or gonadic growth (McKinney and Speas 2001). Declines in rainbow trout CPUEs were observed from 2002 to 2007 following high fish densities in 2000. Relative condition of fish inversely increased during this time period and peaked in 2007, suggesting fish were able to meet energetic demands to produce gametes during the periods of low densities. An increase in young-of-the-year CPUE was observed in 2008, and juvenile and young adult fish in 2009. Since 2008, with higher fish densities, relative condition has decreased since 2007 and remains at levels similar to 1997-1998. Since 2008, CPUE has fluctuated, but there has been no change indicating a future increase. Changes in fish metrics for 2010 do not indicate a clear trend or pattern.

The results of RTELSS has been separately reported and published since the inception of the program. The information provided, being relatively new, has not been fully incorporated in previous Lees Ferry annual reports. Recent publications (Korman 2009; Korman and Campana 2009; Korman and others 2010) and personal communications with Josh Korman, have provided information on early life stages of rainbow trout and there response to various flow regimes that may make predictions of population dynamics more accurate in the future. Preliminary results of this year's RTELSS indicate a future drop in larval survival and spawning success (J. Korman, *unpublished data*).

Prior to 1991, flows were highly variable on a daily basis. This variability was greatly reduced and the daily mean increased after 1991. The increase in rainbow trout abundance through the mid-late 1990's likely led to degradation of the food base that was further confounded by the introduction, and future dominance, of the New Zealand mudsnail (*Potamopyrgus antipodarum*,), which was first detected in 1998. New Zealand mudsnails have been known to restructure food webs in other systems (Hall and others 2006) and, though consumed in high numbers, are not bioenergetically available, as an operculum on the opening of their shell prevents digestion. A decline in rainbow trout CPUE began in 2001 and culminated in 2007 with the lowest CPUE seen since the inception of the monitoring program. Low rainbow trout CPUE in 2007 was coincident with the highest relative condition of rainbow trout seen since 1994.

A high flow experiment (HFE) that occurred in March 2008 appeared to reset the food base in Lees Ferry which led to an increase in diatom production and a reduction in New Zealand mudsnail abundance (T. Kennedy and E. J. Rosi-Marshall, *personal communication*). The resetting of the food base along with the high relative condition of rainbow trout suggests that mature rainbow trout were able to meet maintenance energy requirements needed to spawn (McKinney and Speas 2001), and may have allowed for a highly successful spawn in the spring of 2008. Rainbow trout relative condition in 2008-2009 was reduced from 2007, though likely sufficient to produce gametes. Strong young-of-year cohorts in the summer and fall of 2009 and fall of 2010 indicate successful spawning. Also, high young-of-the-year survival probably occurred in the spring and summer of 2009-2010 (Makinster and others 2009, 2010). Recruitment of the 2009 cohort appeared to be limited in 2010, but was likely due to the absence of a summer standard monitoring event. Information provided by this year's RTELSS showed larval survival for 2010 was reduced compared to 2009 and is similar to that seen in the mid-2000's (J. Korman, *unpublished data*).

In addition to high relative condition and relatively high quality food base, a fall steady flow regime began in 2008 that will continue through 2012. Previous years when food and space availability were likely limited (i.e., 1997-2000) suggested juvenile rainbow trout experienced high compensatory survival (J. Korman, *personal communication*), particularly during late-summer, early-fall months. Based on CPUE, the timing of the 2008 through 2010 flow regime appeared to have negated any of these mechanisms that may have worked to control fry survival. However, preliminary results of the 2010 RTELLS suggest decreased fry survival. Though strong recruitment of the 2008 cohort and some recruitment of the 2009 cohort has occurred, CPUE for fish ≥305 mm TL continue to decline and it is still unclear if these new cohorts will persist within the Lees Ferry tailwater, as did the cohort that experienced a similar stable flow regime during the summer of 2000 (Speas and others 2004a). Fall steady flows may have much less of an impact on larval and juvenile survival than the lasting but decreasing effects of the 2008 spring HFE.

The purpose of Lees Ferry monitoring is to determine the effects of various flow regimes on the ecology of rainbow trout in the tailwater of Glen Canyon Dam. Foodbase studies have been conducted and there has been a food base monitoring program for the past eight years. The current foodbase program has provided valuable information that has, along with the RTELLS information, helped explain why we have seen changes in the rainbow trout population. Interpretation of monitoring results over the past three decades has been largely driven by assumptions on foodbase dynamics. It is recommended that standard foodbase monitoring continue.

The size structure of the fishery currently is similar to the lowest observed on record but has shown an increasing trend since 2006. This increase, however, is likely due to a decrease in medium sized "stock" fish (305-405 mm TL) rather than an increase in large "quality" fish (> 405 mm TL). Both of these size classes have seen decreasing CPUEs since 2003, but the rate of decrease has been greater for the medium size class. Analysis of the PSD metric began when the fishery was stocked with rainbow trout of a catchable size. Stocking ceased in 1998 and the population is now self-sustaining through natural reproduction. Overall size structure has decreased since then and PSD, as calculated, may no longer be an appropriate measurement. New (October 2010) regulations in Lees Ferry set a maximum size limit at 14 inches (356 mm TL). The formula for calculating PSD will likely include this measurement as the cutoff for "quality" sized fish with a lower limit for "stock" sized fish set at a size to be determined through future creel surveys.

As CPUEs for larger fish decline, it would be expected that angler catch rates would decline. Angler catch rates have increased since 2006, however, and the reported average size of fish caught has increased from 12 in. in 2006 to 13 in. (~297 mm to 333 mm TL). It is likely that trends in angler catch are to a large degree determined by guides' cumulative knowledge of the fishery and their response to how it changes.

As the rainbow trout population expands and density-dependent constraints become more visible, downstream movement may occur. It is unclear the fate of the 2008 and 2009 cohorts as they do not seem to be recruiting well into the >305 mm TL size class. Long-term monitoring in Lees Ferry and in the mainstem Colorado River downstream of Lees Ferry suggests very few marked fish (>199 mm TL) from Lees Ferry are recaptured downstream (Hilwig and Makinster, 2010). Potential density-dependent movement could be assessed through a large intensive tagging study.

Slough Sampling

A recommendation from the 2009 PEP was to replace one of the Lees Ferry sampling trips with a trip designed to locate rare nonnative fishes that may not be detected in standard sampling. This trip occurred in July 2010 and targeted warm springs and backwaters. Walleye (*Sander vitreus*) were detected at the base of Glen Canyon Dam in low numbers, and have been captured sporadically during long term monitoring. The main focus of this sampling effort in 2010 was a large backwater referred to as the "slough", believed to harbor large numbers of common carp, though never formally sampled. This area is presumed to be a thermal refuge for other warm-water nonnatives as well. Aside from the confirmed presence of common carp and a small number of rainbow trout, the only other nonnatives detected were three green sunfish (a species that has been previously detected by standard sampling).

Common carp are frequently caught in the Lees Ferry reach of the Colorado River, where water temperatures are relatively low for this species. Due to the common occurrence, it is thought that spawning must be occurring in warmer water areas such as backwaters. Our sampling effort showed common carp occurred in large numbers in this large backwater, and we hope to gain valuable information on movement, growth and spawning intensity in the future as a large number of these fish were PIT tagged. Since 39% of common carp captured were ripe males, and fish were in such high abundance in a relatively small area, we assume this area is a spawning site for common carp. Young-of-year common carp were captured during a youth education trip using seines, and provides additional evidence that common carp are spawning in the slough. If this site serves as a significant source of common carp in the Colorado River, and other similar such sites located, then removal of these fish may help to reduce numbers throughout Glen, Marble and Grand Canyons.

Though the nonnative sampling event may provide valuable information on common carp in the future, the value of that information must be weighed against the biological cost of a summer rainbow trout sampling trip. The purpose of the Lees Ferry monitoring program is to track changes in the rainbow trout population in response to changes in Glen Canyon Dam flow releases and other operations. The fishery is subjected to a flow regime that began in 2008 with a high flow event and has continued with fall steady flows. This change in flow regime is co-occurring with changes in the rainbow trout population. If we are to understand the influence of the current flow regime on the rainbow trout population we must monitor the population as closely as possible. While a reduction in sampling may be appropriate to monitor the general status of the rainbow trout population in Lees Ferry from year to year, it reduces the ability to detect response of various life stages of the population through time to manipulations in environment. Analyses of previous years' data suggest the summer standard monitoring is our best opportunity to track a previous year's recruitment. As the data collected in 2010 showed, absence of this sample could lead to biased results following management actions. We propose that the summer standard monitoring effort for the fishery be reinstated for the foreseeable future, and we continue to monitor common carp in the slough during the July standard monitoring trip.

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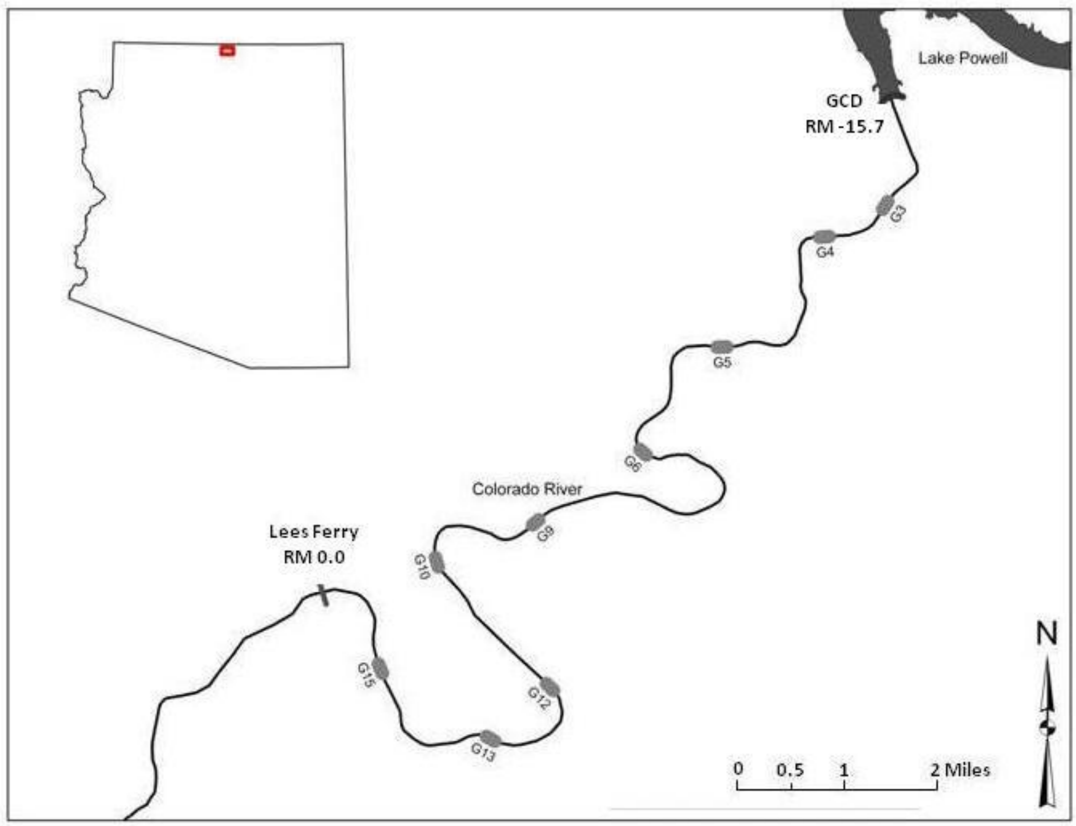

Figure 1. Diagram of the Lees Ferry rainbow trout tailwater reach of the Colorado River from Glen Canyon Dam (GCD, RM 0.0) to the historical ferry location (RM 15.7), located near the Arizona-Utah border. Monitoring locations for randomly selected electrofishing transects occur throughout the reach. Shaded areas represent the nine shortened versions of historical fixed transects.

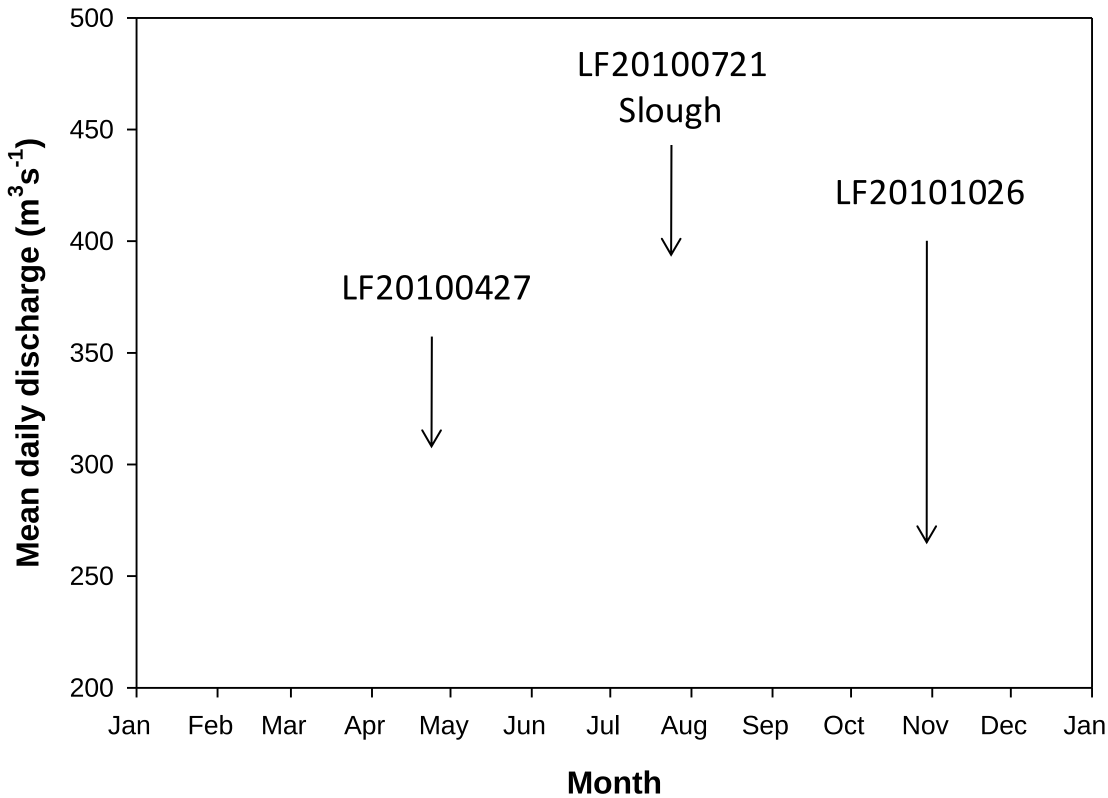

Figure 2. Mean daily discharge (cms) from Glen Canyon Dam during 2010. Arrows and associated text depict AGFD sampling events.

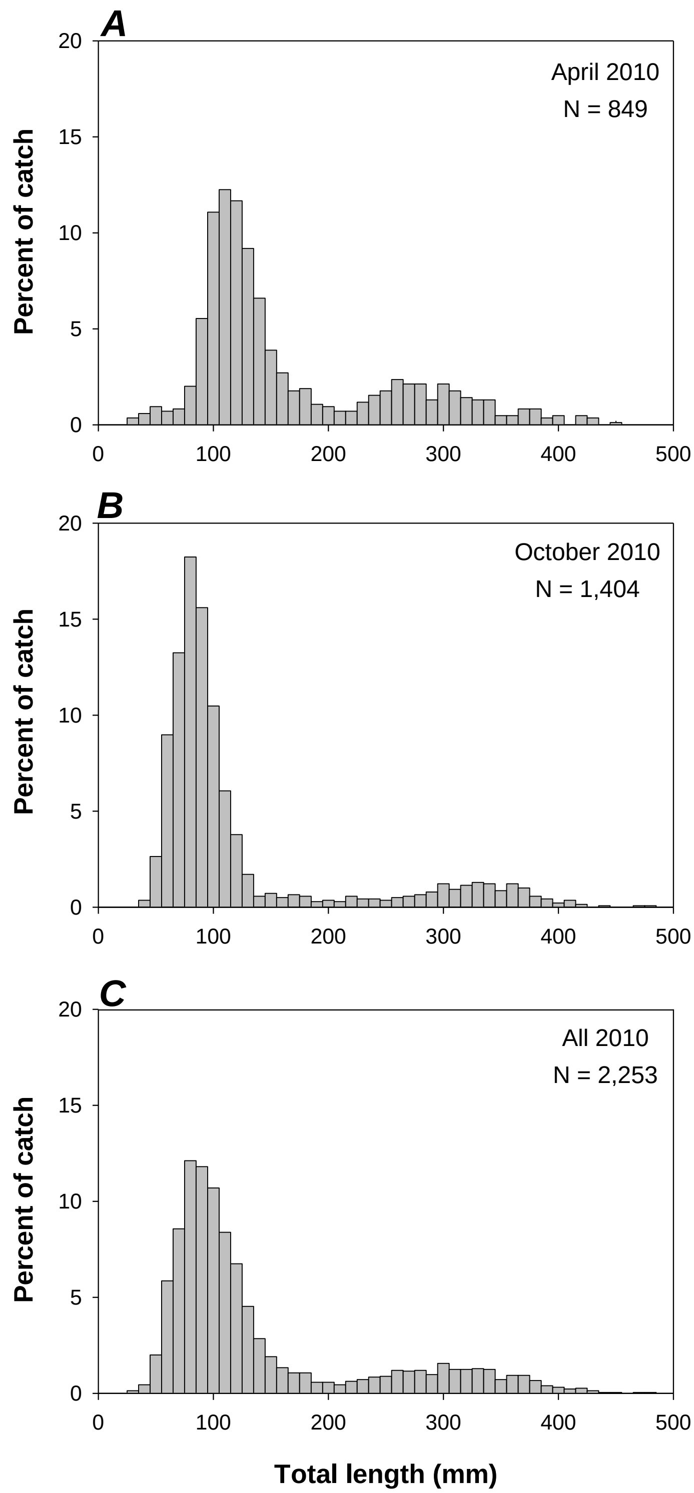

Figure 3. Lees Ferry rainbow trout length-frequency distribution. *A*, April. *B*, October. *C*, all sampling in 2010. Data includes both fixed and random transects.

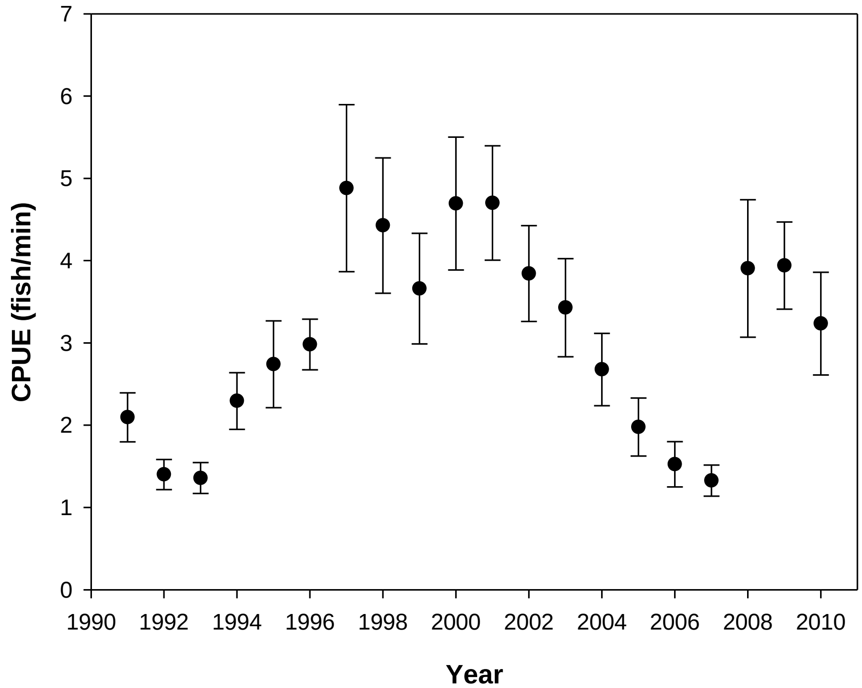

Figure 4. Rainbow trout mean CPUE (catch per minute) in the Lees Ferry tailwater fishery, 1991-2010. Figure represents data from all size classes in both fixed and random transects. Bars represent ±2 standard errors of the mean (close approximation of 95% confidence intervals).

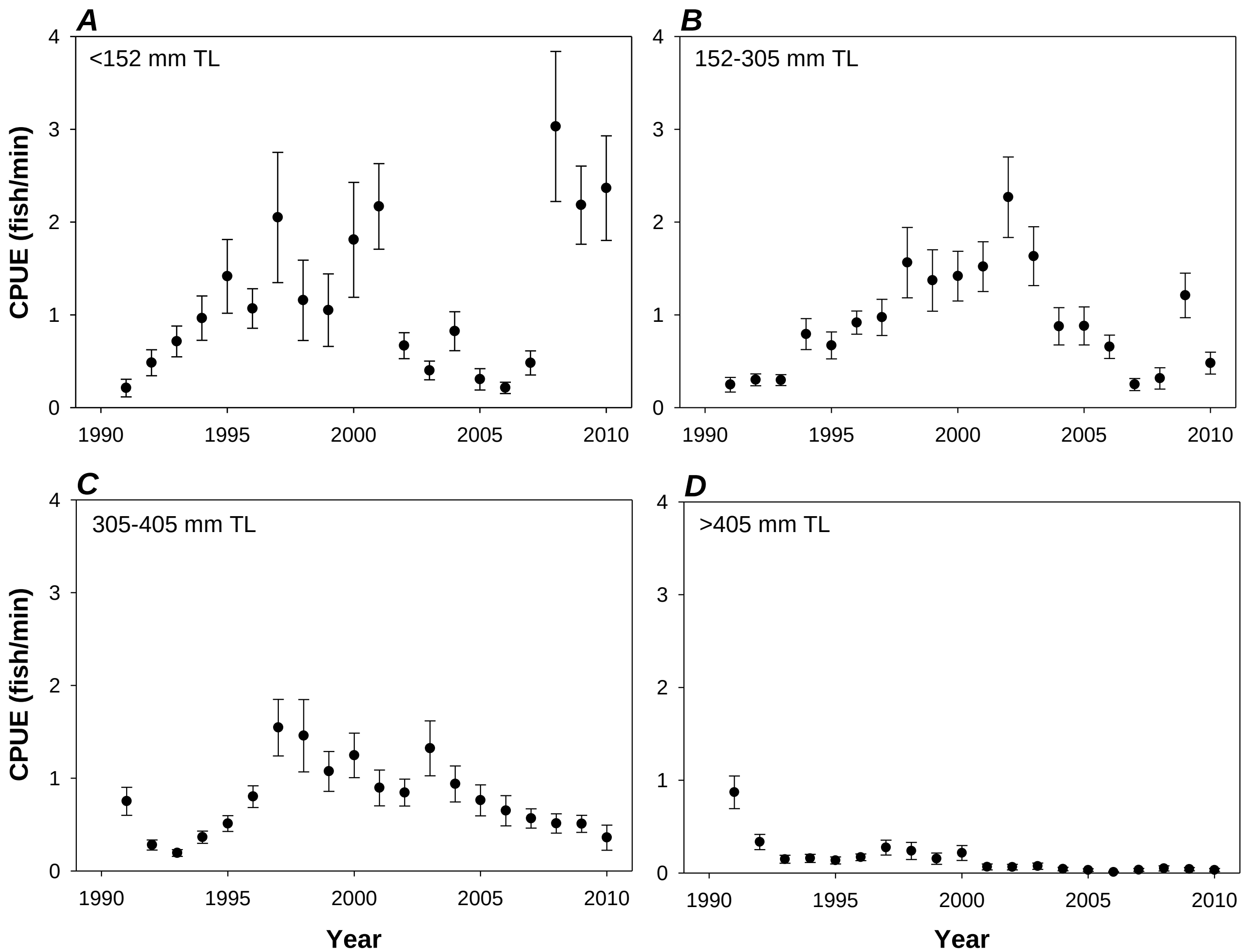

Figure 5. Rainbow trout mean CPUE by size class in the Lees Ferry tailwater fishery, 1991-2010. *A*, <152 mm total length (TL). *B*, 152-304 mm TL. *C*, 305-405 mm TL. *D*, >405 mm TL. Figure represents data from both fixed and random transects. Bars represent ±2 standard errors of the mean (close approximation of 95% confidence intervals).

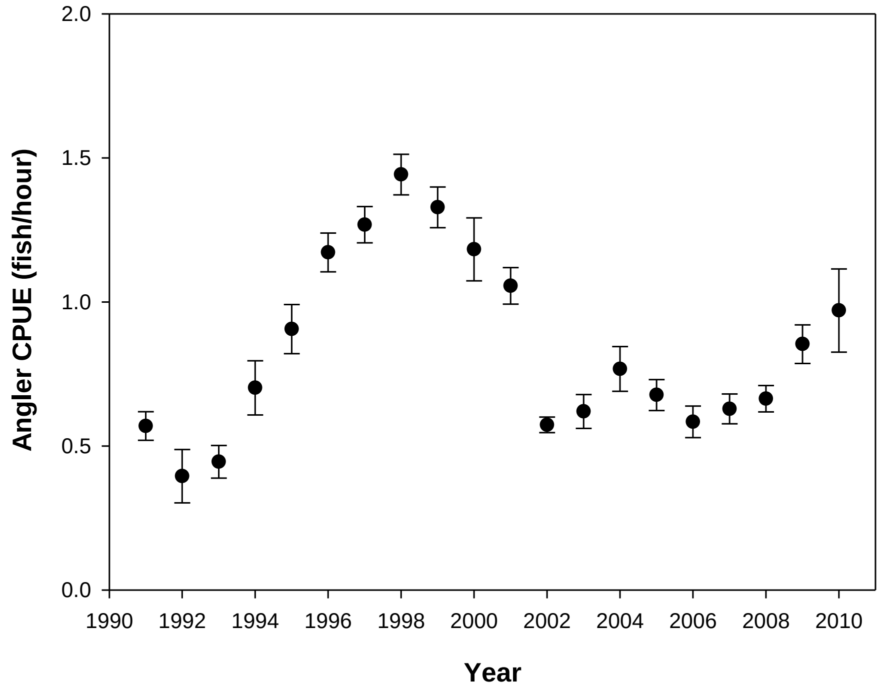

Figure 6. Mean angler CPUE (fish/hr) of rainbow trout in the Lees Ferry tailwater fishery, 1991-2010. Data collected from creel surveys at the Lees Ferry boat ramp area. Bars represent ±2 standard errors of the mean (close approximation of 95% confidence intervals).

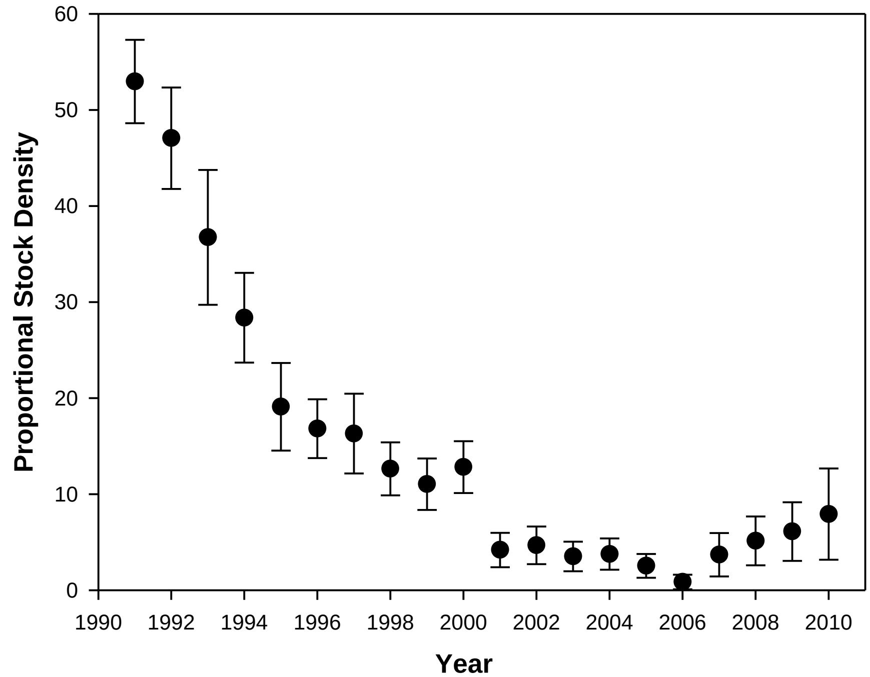

Figure 7. Rainbow trout mean proportional stock density ([# fish ≥ 406 mm TL / # fish ≥ 305 mm TL]*100; PSD) in the Lees Ferry tailwater fishery, 1991-2010. Figure represents data from both fixed and random transects. Bars represent ±2 standard errors of the mean (close approximation of 95% confidence intervals).

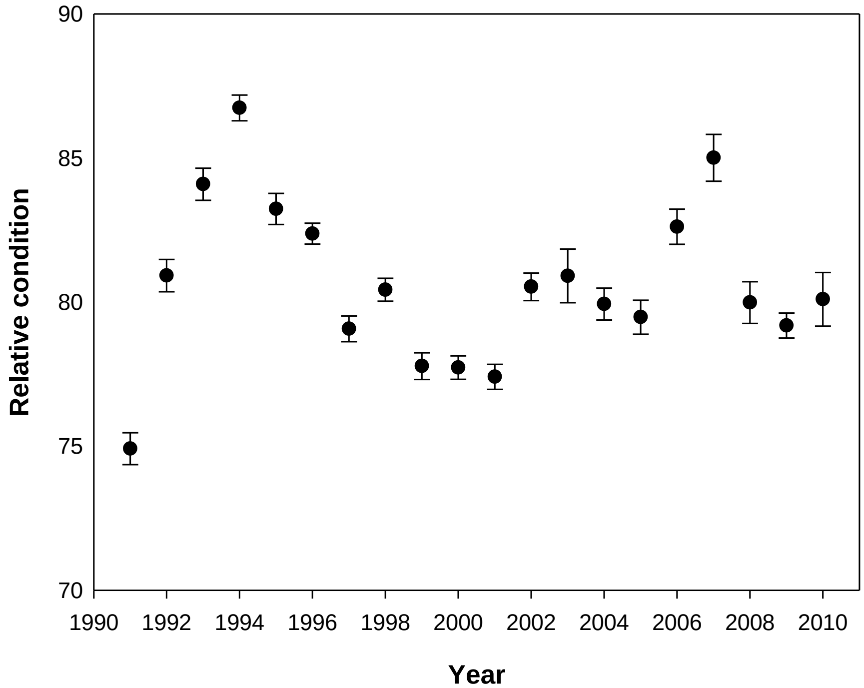

Figure 8. Rainbow trout mean relative condition (*Kn*) in the Lees Ferry tailwater fishery, 1991-2010. Figure represents data from all size classes in both fixed and random transects. Bars represent ±2 standard errors of the mean (close approximation of 95% confidence intervals).

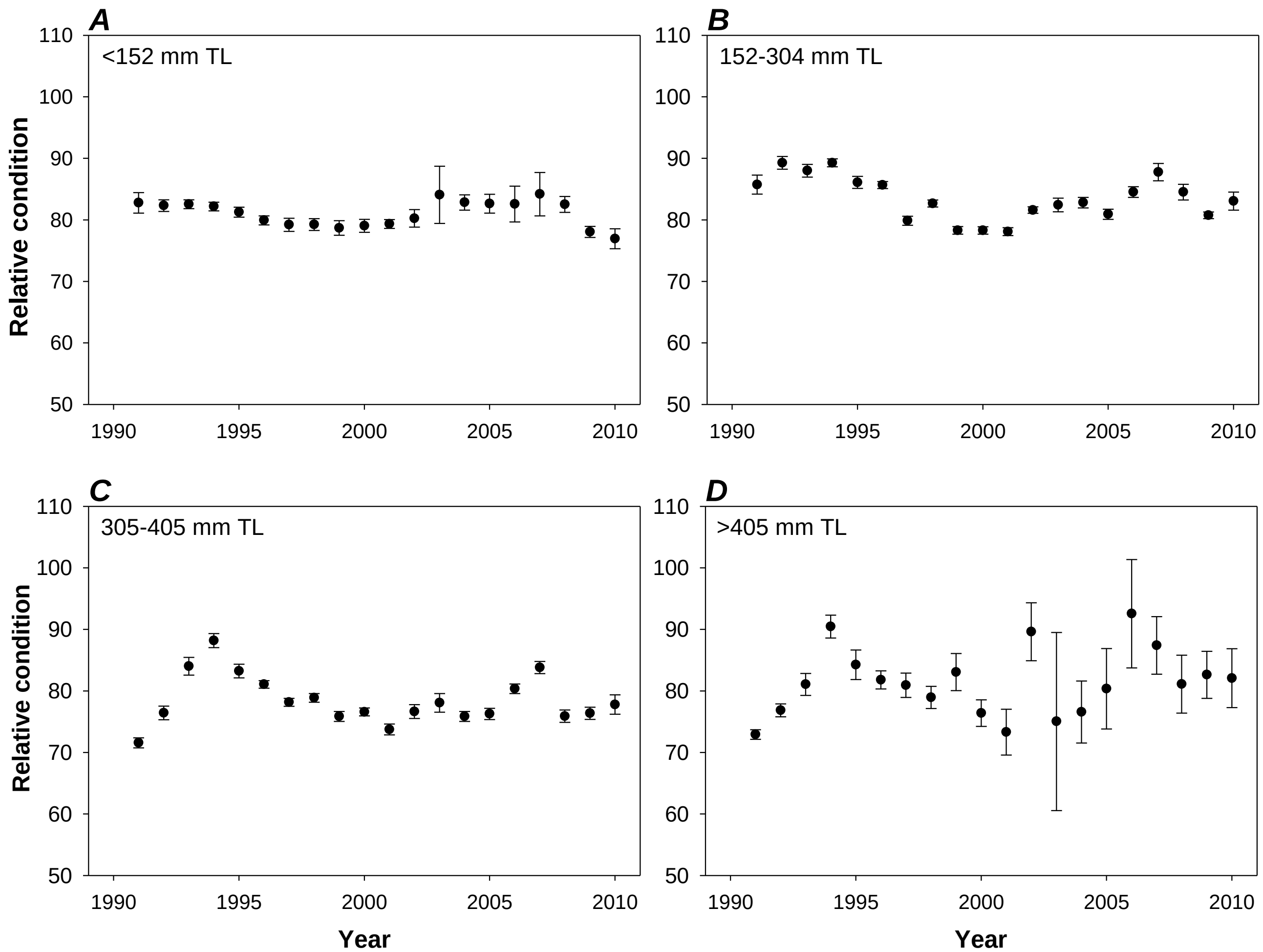

Figure 9. Rainbow trout mean relative condition (Kn) for rainbow trout in the Lees Ferry tailwater fishery, 1991-2010. *A*. <152 mm total length (TL), *B*. 152-304 mm TL, *C*. 305-405 mm TL, *D*. >405 mm TL. Figure represents data from both fixed and random transects. Bars represent ±2 standard errors of the mean (close approximation of 95% confidence intervals).

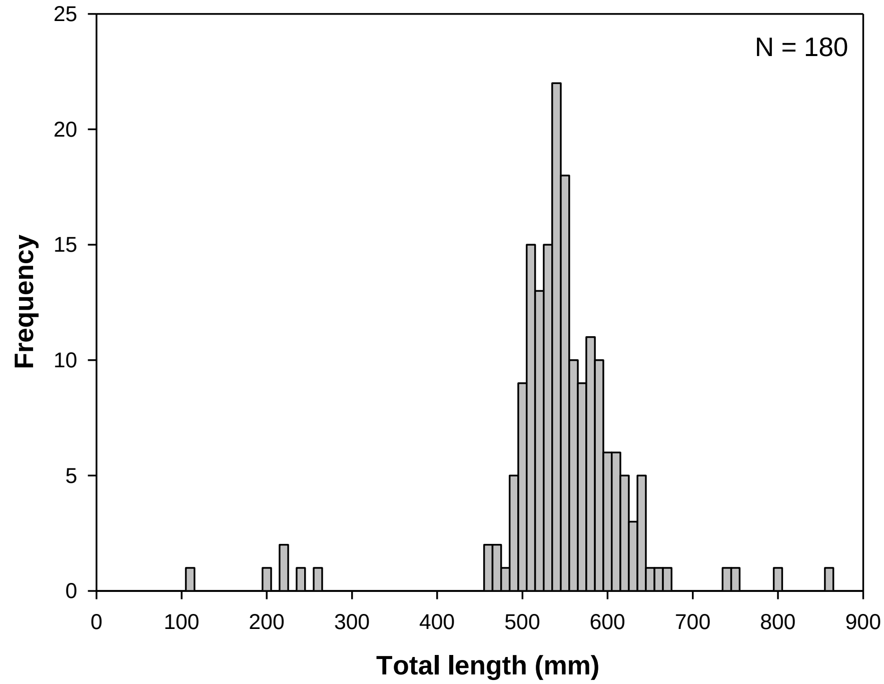

Figure 10. Common carp length-frequency distribution for fish captured during the July nonnative fish detection trip.

Table 1. Species composition data collected during 2010 Arizona Game and Fish Department Lees Ferry rainbow trout monitoring trips.

Trip ID	Dates	Rainbow trout	Brown trout	Flannelmouth sucker
LF20100427	04/27-04/29/2010	849	1	1
LF20101026	10/26-10/29/2010	1,404	3	2
Total		2,253	4	3
Percent of Catch		99.7	0.2	0.1

Table 2. Recapture information for Passive Integrated Transponder (PIT) and Floy tagged fish captured during electrofishing surveys in the Lees Ferry tailwater, 2010.

Tag type	Species	Tag number	Date marked	Mark location (RM)	Date recaptured	Recap location (RM)	Days at Liberty	Mark length (mm)	Recap length (mm)	Distance moved (miles)	Instant growth (mm/day)
PIT	Flannelmouth Sucker	3D9.ABF255FF29	6/14/2006	127.8	10/28/2010	-9.5	1,597	269	431	-137.3	0.10
PIT	Rainbow Trout	4364012C1C	2/29/2008	-14.7	4/29/2010	-14.6	790	352	369	0.1	0.02
PIT	Rainbow Trout	43447B0A68	2/29/2008	-14.7	4/29/2010	-14.7	790	152	351	0.0	0.25
Floy	Rainbow Trout	AGFD 2016	7/16/2009	-6.7	4/28/2010	-6.6	286	382	382	0.1	0.00
Floy	Rainbow Trout	AGFD 2627	11/5/2009	-8.1	4/28/2010	-8.0	174	223	286	0.1	0.36
Floy	Rainbow Trout	AGFD 3130	04/29/2010	-12.6	10/27/2010	-12.6	181	273	304	0.0	0.17

Table 3. Species composition data collected using various sampling gears near RM -12.0 during July 2010 sampling.

Date	Method	Common carp	Flannelmouth sucker	Rainbow trout	Green sunfish
7/21/2010	Backpack electrofishing	7	0	0	0
7/21/2010	Boat electrofishing	13	0	3	0
7/22/2010	Boat electrofishing	114	3	19	2
7/22/2010	Trammel net	3	7	0	0
7/23/2010	Boat electrofishing	70	2	6	0
7/23/2010	Trammel net	2	4	0	1
Total		209	16	28	3
Percent of catch		82	6	11	1

Table 4. Recapture information for Passive Integrated Transponder (PIT) tagged fish captured during July 2010 sampling near RM -12.0. Mark location LCR indicates fish were tagged in the Little Colorado River.

[minus (-), upstream movement; plus (+), downstream movement; EF, electrofishing]

Method	Species	Tag number	Date marked	Mark location (RM)	Date recaptured	Recap location (RM)	Days at Liberty	Mark length (mm)	Recap length (mm)	Distance moved (miles)	Instant growth (mm/day)
Boat electro-fishing	Common carp	3D9.1BF198D35C	11/3/2003	-12.0	7/22/2010	-12.28	2,453	399	504	-0.28	0.04
	Common carp	3D9.1BF198D3F4	11/3/2003	-12.0	7/23/2010	-12.28	2,454	451	519	-0.28	0.03
	Common carp	3D9.1BF198DAFA	11/3/2003	-11.8	7/22/2010	-12.33	2,453	403	513	-0.53	0.05
	Common carp	3D9.1BF1CD38D4	7/12/2004	-0.2	7/22/2010	-12.28	2,201	286	502	-12.08	0.10
	Flannelmouth sucker	3D9.1BF22A9837	1/12/2006	45.1	7/22/2010	-12.33	1,652	449	527	-57.43	0.05
Trammel net	Flannelmouth sucker	5116164E1E	5/17/1999	LCR 0.04	7/22/2010	-12.31	4,084	396	507	-74.05	0.03
	Flannelmouth sucker	3D9.1BF256209C	4/7/2006	LCR 0.07	7/22/2010	-12.19	1,567	265	504	-73.96	0.15
	Flannelmouth sucker	3D9.1BF1CD2BF6	4/8/2006	132.5	7/22/2010	-12.31	1,566	186	406	-144.81	0.14
	Flannelmouth sucker	3D9.1BF1CD322B	4/8/2006	73.7	7/23/2010	-12.31	1,567	195	438	-86.01	0.16
	Flannelmouth sucker	3D9.1C2D8AF6F6	6/30/2010	-12.3	7/22/2010	-12.31	22	504	521	-0.06	0.77
	Flannelmouth sucker	3D9.1BF198D35C	11/3/2003	-12.0	7/22/2010	-12.28	2,453	399	504	-0.28	0.04