Evaluating Effects of a High-Flow Event on Rainbow Trout Movement in Glen and Marble Canyons, Arizona, by Using Acoustic Telemetry and Relative Abundance Measures

By Kara D. Hilwig[1] and Andy S. Makinster[2]

Abstract

In March 2008, the Department of the Interior conducted a high-flow event (HFE; 1,175 cubic meters per second for 60 hours) through Glen Canyon Dam and Grand Canyon. This study evaluated the impact of the HFE on movement of adult and juvenile rainbow trout (*Oncorhynchus mykiss*) in Lees Ferry. Downstream displacement of rainbow trout could impact the endangered humpback chub (*Gila cypha*) in downstream areas and recreational angling in Lees Ferry. We evaluated rainbow trout movement by comparing relative abundance indices from electrofishing surveys and acoustic telemetry techniques before and after the HFE. We determined that rainbow trout relative abundance indices were similar before and after the HFE. Acoustic tagged rainbow trout did not appear to displace downstream, and relative movement was similar before and after the HFE. Movement of tagged rainbow trout also did not correlate with length class or sex. Abundance indices in combination with acoustic telemetry results indicate that the March 2008 HFE did not appear to cause significant downstream displacement of adult and juvenile rainbow trout in Lees Ferry. Other evidence suggests that populations of young rainbow trout (age-0 and age-1 less than 100 millimeters) were not impacted by the March 2008 HFE. However, a threefold decrease in population size of young rainbow trout was observed during the November 2004 HFE. These data suggest the need for further studies to track the fate of young rainbow trout and other environmental and temporal factors that may cause movement during future HFEs.

Introduction

High-flow events (HFE) were conducted in 1996, 2004, and 2008 by the Department of the Interior to investigate their utility in restoring natural, cultural, and recreational resources within Grand Canyon National Park. A high-flow experiment was conducted March 4–6, 2008, with flows reaching a maximum of 1,175 cubic meters per second (m^3/s) for about 60 hours. These flows were approximately three times greater than the peak flows released by Glen Canyon Dam immediately preceding the HFE.

The HFE was conducted in an attempt to move sand in the Colorado River system and conserve beach habitats. Other important resources for conservation include the Lees Ferry recreational rainbow trout (*Oncorhynchus mykiss*) fishery in the tailwaters of Glen Canyon Dam and the federally endangered humpback chub (*Gila cypha*), which is found further downstream in Grand Canyon. Lees Ferry is located approximately 15 river miles[3] downstream from Glen Canyon Dam near Page, AZ (fig. 1). Two concerns were raised regarding potential rainbow trout movement as a result of the HFE. Recreational anglers were concerned that adult rainbow trout may be displaced downstream from Lees Ferry into areas inaccessible to the majority of the angling community. Conservationists were concerned that the HFE could cause downstream displacement of adult rainbow trout into the Little Colorado River inflow reach of the Colorado River where they could prey on humpback chub. To address these concerns, we developed this investigation to evaluate the impact of the HFE on rainbow trout movement in the Lees Ferry area.

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[1] U.S. Geological Survey, Southwest Biological Science Center, Grand Canyon Monitoring and Research Center, 2255 N. Gemini Drive, Flagstaff, AZ 86001.

[2] Arizona Game and Fish Department, Research Branch, 5000 W. Carefree Highway, Phoenix, AZ 85086–5000.

[3] By convention, river mile is used to describe distance along the Colorado River in Grand Canyon.

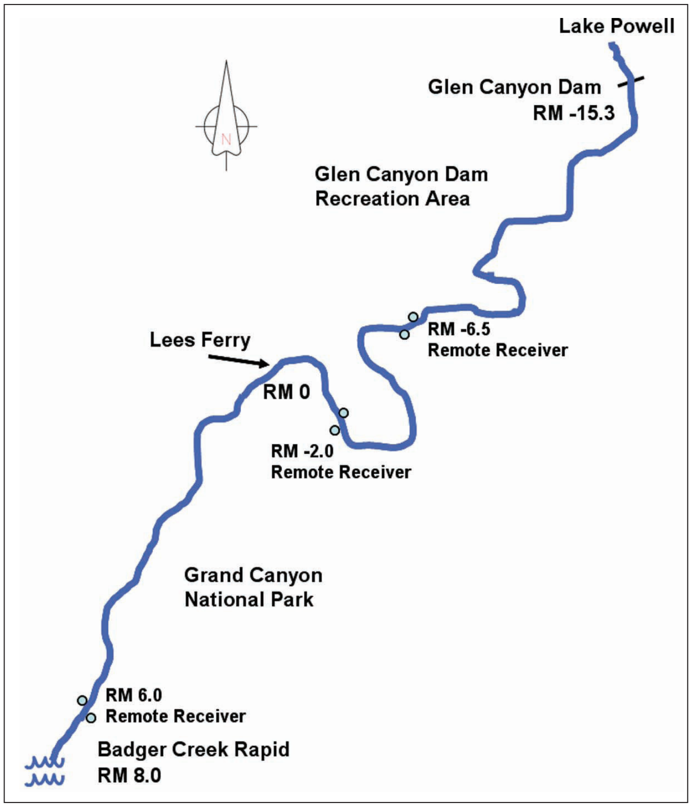

Figure 1. The study area in the Lees Ferry area from Glen Canyon Dam to Badger Creek Rapid in Glen Canyon Dam National Recreation Area and Grand Canyon National Park near Page, AZ. Dots indicate the placement of remote receivers to detect passing acoustic tagged rainbow trout. River mile (RM) is used to describe distance along the Colorado River in Grand Canyon. Lees Ferry is the starting point, RM 0, with mileage measured for both upstream (–) and downstream directions.

Inferences on fish movement can be made by comparing relative abundance indices before and after a flood disturbance (Meffe, 1984; Matthews, 1986; Meffe and Minckley, 1987), but they are limited without considering ancillary information. During a previous HFE in Grand Canyon in March 1996, an increase was observed in relative abundance of rainbow trout (<152 millimeter (mm) total length) in the Little Colorado River inflow reach of the Colorado River (Valdez and Cowdell, unpub. report, 1996). The authors hypothesized that downstream displacement of fish from Lees Ferry and Glen Canyon by the HFE was likely responsible for increased relative abundance; however, no direct linkage to the source of the displaced fish could be made. Korman (2009) observed a threefold decrease in the population size of young rainbow trout (age-0 and age-1; <100 mm) in Lees Ferry after the November 2004 HFE and hypothesized downstream displacement or mortality of these fish. In both cases, however, direct observation of displacement or the fate of displaced fish could not be made using relative abundance indices.

Determining the fate of fish displaced by flood disturbance can be difficult (Chapman and Kramer, 1991). Often researchers individually mark fish to track movement, however, marked fish must be recaptured. Few recaptures of these marked fish often limit the utility of the information in evaluating population level movement (Halls and others, 1998). Use of radio or acoustic telemetry has been useful in evaluating environmental effects, including disturbance, on fish movement in other systems (Harvey and others, 1999; Valdez and others, 2001). Given the concern for displacement of adult rainbow trout and suggested displacement of juvenile rainbow trout associated with the HFE, we developed this study to compare relative abundance indices with acoustic telemetry to evaluate movement of adult and juvenile rainbow trout before and after the HFE. The goals of this experimental study were to (1) determine if the HFE causes displacement of acoustic tagged rainbow trout downstream from Lees Ferry, (2) determine if such displacement occurs differentially among different size classes of acoustic tagged rainbow trout, and (3) compare rainbow trout relative abundance estimates in Lees Ferry before and after the HFE with acoustic tagged rainbow trout movement.

Methods

Study Area

This study was conducted in the Lees Ferry area of Glen Canyon Dam Recreation Area downstream from Glen Canyon Dam near Page, AZ (fig. 1). The study area encompassed the 15-mile reach from Lees Ferry upstream to Glen Canyon Dam and also included an 8-mile reach downstream from Lees Ferry to Badger Rapid. Discharge from Glen Canyon Dam in the year preceding the HFE typically ranged from approximately 227 to 481 m^3/s, and water temperature ranged from approximately 12.5 to 8 degrees Celsius (°C). In the month preceding the HFE, discharge fluctuated daily from approximately 227 to 396 m^3/s, and water temperature was 8 °C.

Electrofishing Surveys

We sampled the tailwater upstream from Lees Ferry on February 28–March 1, 2008 (pre-HFE), and March 18–20, 2008 (post-HFE). As part of standardized monitoring, we sampled the same 34 sites during both sampling events once per sampling event using a raft mounted electrofishing rig. Sampling was conducted with an Achilles inflatable raft equipped with Coffelt CPS output regulators. We applied approximately 350–400 volts and 12–15 amps to a 35-centimeter (cm) stainless steel anode while two crew-members netted stunned fish from the bow of the boat. These surveys were conducted to determine relative abundance (catch-per-unit-effort, CPUE) of adult and juvenile rainbow trout before and after the HFE. Electrofishing was also used to capture rainbow trout for surgical implantation of acoustic tags.

Analysis of Electrofishing Captures

Size stratified rainbow trout relative abundances (number captured per minute of electrofishing effort) were compared before and after the HFE by using a one-way analysis of variance. All statistical tests were considered significant at the $\alpha = 0.05$ level. Size classes analyzed were fish <152 mm, 152–304 mm, 304–405 mm, and >405 mm total length (TL). These length categories approximate age-1, age-2, age-3, and age-4+ rainbow trout, respectively.

Surgical Implantation and Tagged Fish Locations

The surgery protocol used to implant acoustic tags was developed by the U.S. Geological Survey (USGS) Columbia River Research Laboratory in Cook, WA. Carbon dioxide was used to anesthetize fish. Following surgical and anesthetic protocols, 19 rainbow trout were implanted with dummy tags and held for 60 days in a hatchery to evaluate long-term post-surgery survivorship. Following this same protocol for the field experiment, Sonotronics acoustic tags (thirty-two IBT-96-1 and sixty-two IBT-96-2; configured for minimum 60-day ping duration) and passive integrated transponders (PIT) tags were surgically implanted in 94 rainbow trout. Implanted rainbow trout ranged in size from 157 mm to 409 mm TL and were released at six locations above Lees Ferry ramp (February 14–23, 2008). Implanted fish were held in a perforated plastic can for a minimum of 24 hours post-surgery. Additionally, six test fish were implanted with dummy tags following the same procedures and held in the pens for 72 hours post-surgery. Remote receivers were placed at three locations to detect acoustic tagged rainbow trout between manual tracking events (fig. 1). We selected remote receiver locations that encompassed the Lees Ferry boat ramp where anchoring options were adequate and river channel was deep and flat. Four manual tracking events were conducted from Glen Canyon Dam to Badger Rapid to locate tagged fish and monitor movement; two events each were conducted pre- (pre-HFE1 February 23–24, pre-HFE2 March 2–4) and post- (post-HFE1 March 10–11, post-HFE2 March 27–28) HFE.

Acoustic tagged rainbow trout positions were recorded on a touch screen computer with ArcGIS ArcMap Version 9.2. Point locations of each fish were located on orthorectified digital images of the river corridor. Each tagged rainbow trout position was then assigned to the nearest tenth of a river mile.

Analysis of Tagged Fish Movement

Individual fish movement was calculated as change in river miles for four periods: (1) from the point of release to pre-HFE1, (2) from pre-HFE1 to pre-HFE2, (3) pre-HFE2 to post-HFE1, and (4) post-HFE1 to post-HFE2. Relative upstream and downstream movement is represented by positive and negative values, respectively. Relative average movement was calculated by averaging change in individual fish positions before the HFE (point of release to pre-HFE2) and after the HFE (pre-HFE2 to post-HFE2). The analysis period after the HFE encompassed movement that occurred during the HFE. Average fish movement of tagged trout before and after the HFE was compared using one-way analysis of variance. Analysis was also stratified by size class and sex of tagged rainbow trout. All statistical tests were considered significant at the $\alpha = 0.05$ level. Size classes analyzed were consistent with length categories used for electrofishing surveys (see above).

Results

Electrofishing

During the pre-HFE sampling event, we captured a total of 412 rainbow trout ranging in size from 48 mm to 439 mm TL. During the post-HFE sampling event, we captured a total of 352 rainbow trout ranging in size between 62 and 435 mm TL. The length frequency distribution of all rainbow trout captured during the pre- and post-HFE sampling events showed a bimodal distribution dominated by fish <200 mm TL (fig. 2).

Preliminary data indicate mean CPUE (fish caught per minute of electrofishing) of all rainbow trout did not differ significantly between pre- and post-HFE sampling events (1.40 ± 0.44 and 1.34 ± 0.51, respectively; mean ± 2 standard errors; fig. 3). Analysis showed that mean size-specific rainbow trout CPUE also did not differ between pre- and post-HFE sampling events including the youngest rainbow trout size class (<152 mm; fig. 4).

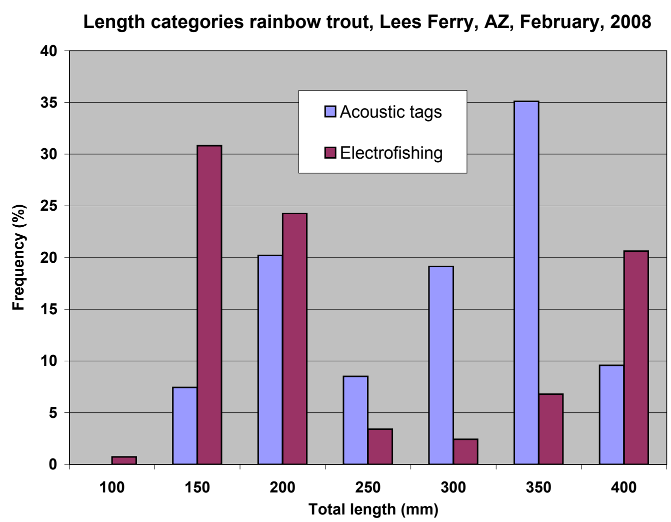

Figure 2. Length frequency of rainbow trout sampled with electrofishing and those that were implanted with acoustic tags in the Lees Ferry area during the March 2008 high-flow experiment. Fish less than 157 mm were too small to carry the acoustic tag, and fish larger than 400 mm were not susceptible to deep anesthesia required for surgery using carbon dioxide.

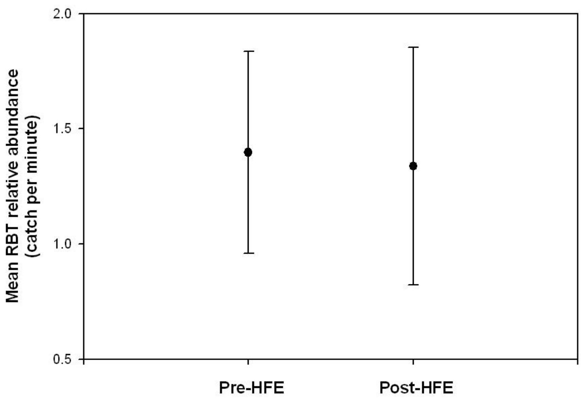

Figure 3. Mean relative abundance (catch per minute of electrofishing) of all size classes of rainbow trout (RBT) captured with electrofishing during pre- (February 28–March 1, 2008) and post-high flow experiment (HFE; March 18–20, 2008) sampling in the Lees Ferry area of the Colorado River, AZ. Bars represent ±2 standard errors of the mean.

Surgical Implantation

No mortality was observed in rainbow trout held for 60 days post-surgery or in dummy tagged rainbow trout held in Lees Ferry 72 hours post-surgery. Two study fish with active tags exhibited abnormal behavior 24 hours post-surgery and were replaced with two healthy fish. One acoustic tagged fish was captured by electrofishing crews 7 days post-surgery. The crew commented that the sutures had dissolved and the incision was healing well.

The length frequency of acoustic tagged fish did not exactly overlap that of fish captured during electrofishing surveys (fig. 2). Fish less than 157 mm were too small to carry the acoustic tag, and fish larger than 409 mm were not susceptible to deep anesthesia required for surgery using carbon dioxide. Therefore, movement analysis for acoustic tagged rainbow trout was limited to adult fish 152–304 mm and 305–405 mm. Thus, the population of rainbow trout that we were able to implant with tags did not proportionally represent the size classes of rainbow trout present in Lees Ferry.

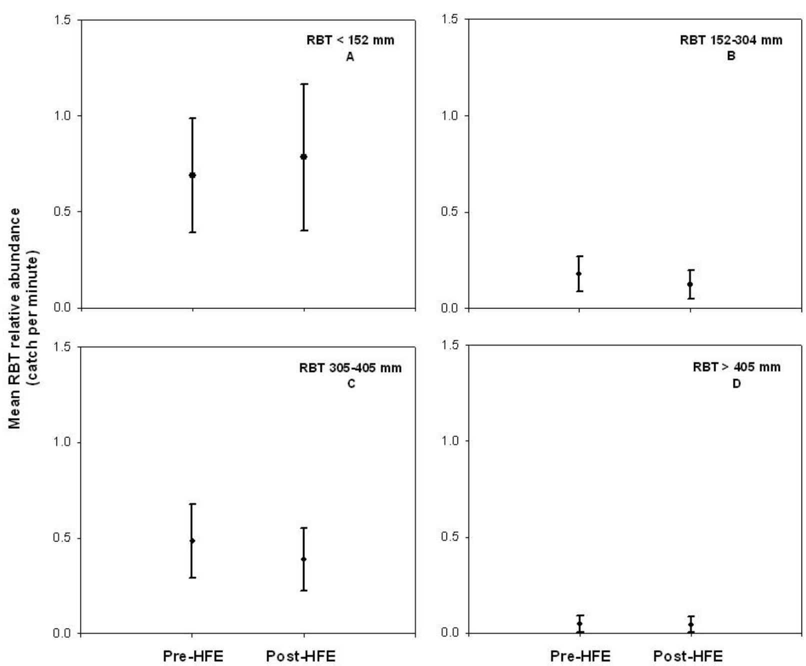

Figure 4. Size-stratified mean relative abundance (catch per minute of electrofishing) of rainbow trout (A) <152 mm total length (TL), (B) 152–304 mm TL, (C) 305–405 mm TL, and (D) >405 mm TL captured with electrofishing during pre- (February 28–March 1, 2008) and post-high flow experiment (HFE; March 18–20, 2008) sampling in the Lees Ferry area of the Colorado River, AZ. Bars represent ±2 standard errors of the mean.

Acoustic Tag Detection and Movement

Fifty-seven of 94 tagged fish were detected during pre-HFE manual tracking events. Of these 57 fish located before the HFE, 50 were also located after the HFE positioned in the Lees Ferry reach (88 percent of tags known to be present in Lees Ferry before the HFE). Six additional tagged fish were located upstream from Lees Ferry after the HFE that had not been located before the HFE, indicating significant tag detection problems. No fish were positioned at the exact same location throughout the duration of the study, indicating survivorship of tagged fish. No significant differences were determined in mean relative movement before and after the HFE among sexes ($P = 0.69$) and length classes ($P = 0.36$; table 1). Three tagged rainbow trout were detected by a remote receiver located 6 miles downstream from Lees Ferry 3–6 days before the HFE. The greatest documented movement of a tagged trout was more than 15.5 miles downstream and occurred before the HFE. The greatest upstream movement of a tagged trout was 11.2 miles and also occurred before the HFE. Individual fish movement was highly variable and did not relate to the occurrence of the HFE (fig. 5), length class, or sex (table 1). Average relative movement of tagged rainbow trout 305–405 mm tended to be less variable after the HFE.

Table 1. Average movement of acoustic tagged rainbow trout in Lees Ferry by size class and sex before and after the March 2008 high-flow experiment (HFE; mean ± 2 standard errors). Positive and negative values represent relative upstream and downstream movement, respectively. No significant differences were detected in movement before and after the HFE among sexes (P = 0.69) and length classes (P = 0.36).

[N, number; mm, millimeter]

Rainbow trout	Pre-HFE (miles)	N	Post-HFE (miles)	N	P-value
152–304 mm	0.3 ± 1.4	22	–0.9 ± 1.8	14	0.29
305–405 mm	0.1 ± 0.6	79	–0.1 ± 0.2	76	0.55
Female	0.3 ± 1.3	25	–0.6 ± 1.3	21	0.34
Male	–0.2 ± 1.0	33	–0.1 ± 0.2	34	0.75

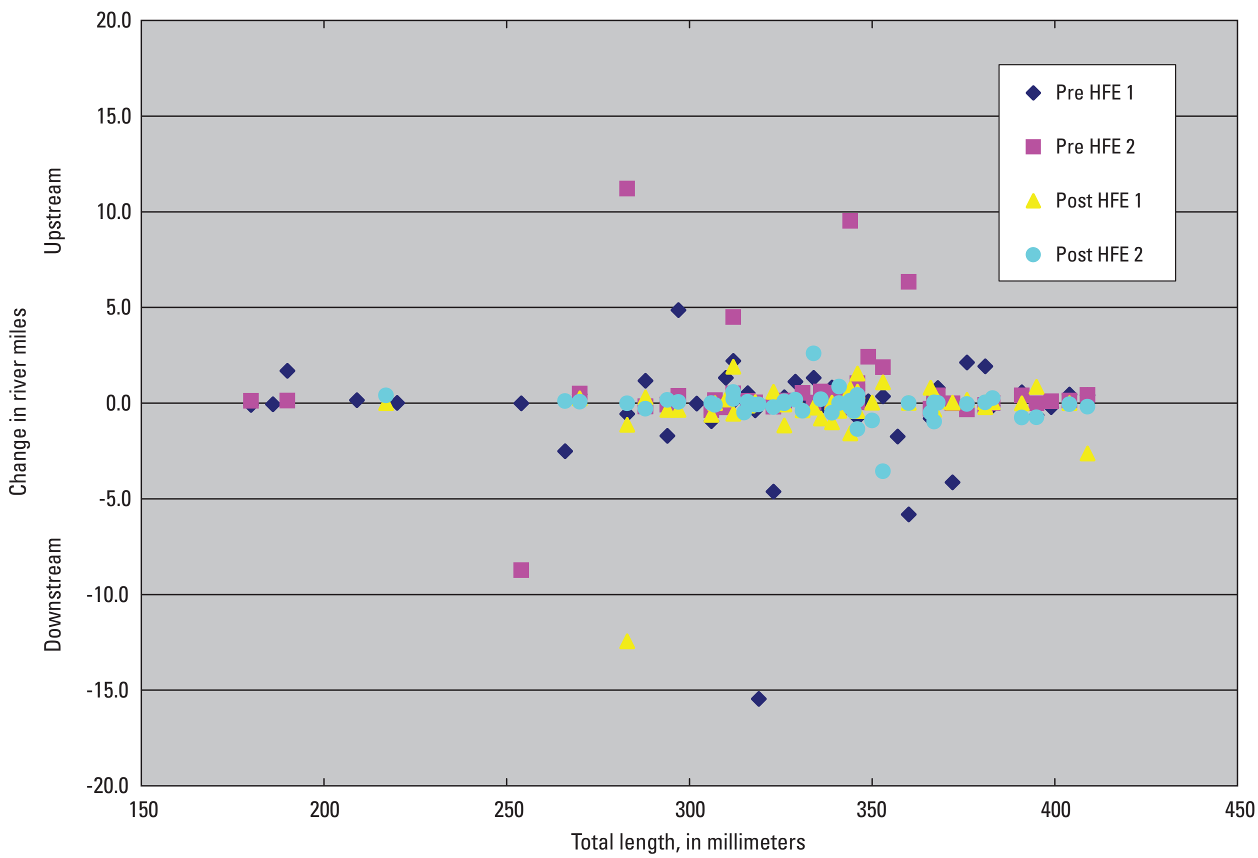

Figure 5. Scatter plot showing individual acoustic tagged rainbow trout movement in the Lees Ferry reach during the two tracking events before (Pre-HFE 1 and 2) and two tracking events after (Post-HFE 1 and 2) the March 2008 high-flow experiment (HFE). Individual tagged fish movement was highly variable and did not correlate to length or the occurrence of the HFE.

Discussion

Preliminary data from relative abundance indices and acoustic telemetry indicate the HFE conducted during March 2008 did not cause significant downstream movement of juvenile and adult rainbow trout below Lees Ferry. Relative abundance was similar before and after the experiment, which suggests that 41,500 ft^3/s did not cause significant displacement of rainbow trout downstream from the Lees Ferry reach for any size class fish (48–439 mm). The size structure of the rainbow trout sampled with electrofishing was similar before and after the March 2008 HFE, indicating no size-specific impacts. This assessment is supported by acoustic telemetry data, indicating 88 percent of tags located before the HFE were relocated after the HFE in Lees Ferry. Further, no significant difference in movement of tagged fish between 157–404 mm occurred after the HFE. Telemetry data also indicate that movement did not relate to sex. The combined results indicate that no significant rainbow trout displacement occurred from the Lees Ferry trout fishery in association with the HFE.

Movement of rainbow trout in Lees Ferry was also investigated by using radio telemetry (Angradi and others, unpub. report, 1992). Eight tagged rainbow trout were located throughout a 1-year period in November 1990–1991 associated with various flow operations. Three tagged trout demonstrated substantial up and downstream movement of several miles (5+ miles) throughout the study. One tagged rainbow trout traveled 2 miles downstream from Lees Ferry and was not relocated during the duration of the study. Daily movement ranged from 0.02 to 0.08 miles during various flow regimes, and fish demonstrated considerable site fidelity. Methods for locating radio-tagged fish included triangulation to approximate location within a few feet, whereas methods used during this study were to locate tags to the nearest tenth of a mile (to accommodate locating 50 or more tags per day). Long-range movement observed during this study was consistent with long-range movement observed in radio-tagged rainbow trout. During both of these telemetry studies, tagged rainbow trout were observed dispersing downstream from Lees Ferry. This observed dispersal, though only four observations, indicates that rainbow trout from Lees Ferry can disperse into areas where angler access is limited and potentially have impacts on humpback chub in downstream reaches.

The March 2008 HFE appeared not to impact trout movement; however, study results from previous HFEs indicate a negative impact of large flows on young trout populations. Analysis of relative abundance data showed young rainbow trout (<152 mm) were not subjected to downstream displacement during the March 2008 HFE. This observation is supported by independent data (U.S. Geological Survey, unpub. data, 2008) in Lees Ferry, which indicate no change in absolute abundance for young trout (40–140 mm) immediately before and after the HFE. However, during the November 2004 HFE, a threefold decrease in abundance of young trout in Lees Ferry was observed (Korman, 2009). Temperatures of water released from Glen Canyon Dam during the November 2004 and March 2008 HFEs were approximately 15 °C and 8 °C, respectively. These data suggest the need for further studies to track the fate of young rainbow trout and other environmental and temporal factors that may increase young rainbow trout displacement risk during future HFEs. These factors may include water temperature, food availability, rainbow trout density, timing of the HFE, differences in ramp rates, diurnal timing of initial ramping, and other factors.

Implications for Management

Downstream movement of rainbow trout from Lees Ferry is a concern for managers of the Lees Ferry rainbow trout fishery and the endangered humpback chub population. The results of this experiment indicate that there was no significant impact of the March 2008 HFE on rainbow trout movement. However, during this study and a previous study (Angradi and others, unpub. report, 1992), tagged adult rainbow trout were observed dispersing downstream from Lees Ferry. In addition, Korman (2009) observed a threefold decrease in population size of age-0 trout in Lees Ferry during the November 2004 HFE. The fate of these age-0 fish was not directly measured; however, it was assumed that these fish likely displaced downstream or did not survive. These results suggest the need for further studies to track the fate of rainbow trout <150 mm and other factors that may cause adult fish movement downstream from Lees Ferry. This effort would require continuation of robust long-term monitoring protocols for all life-history stages of rainbow trout, development of more suitable individual fish tracking methods for fish <150 mm, and continued commitment to conducting experimental high flows in Grand Canyon.

Acknowledgments

Grand Canyon Monitoring and Research Center (GCMRC) would like to thank Arizona Game and Fish Department for their contributions to the pilot testing of the acoustic technology in Grand Canyon and for conducting additional monitoring trips in Lees Ferry. We thank Marty Liedtke and Lisa Gee of the USGS Columbia River Research Station for providing the facilities and staff to train project personnel in anesthetic and surgical techniques as well as providing holding facilities and staff to assess long-term survival of tagged rainbow trout. We also thank Goldendale Hatchery and Washington Department of Fish and Wildlife for providing hatchery fish for developing surgical skills. We thank Marble Canyon Outfitters for logistic assistance, and Tom Gushue of the USGS provided valuable technical assistance in analyzing telemetry data. We thank Josh Korman of Ecometrics, Inc., for providing valuable field assistance and data. We appreciate the individuals and their organizations that provided valuable assistance, including Western Area Power Administration, Colorado Division of Wildlife, Kootenai Tribe of Idaho, and Western Region Geospatial Information Office. We also thank Sonotronics for participating in multiple troubleshooting field expeditions. GCMRC thanks Humphries Summit Support for providing logistical support for field operations. Lew Coggins, Dan Gwinn, and Angela Abel contributed substantially to the development and implementation of this project. This project could not have succeeded without the efforts of everyone involved and funding from the Bureau of Reclamation through the Glen Canyon Dam Adaptive Management Program.

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