



State of Utah
DEPARTMENT OF NATURAL RESOURCES
Division of Wildlife Resources - Native Aquatic Species

An Evaluation of the Effects of Tusher Wash Diversion Dam
on Movement and Survival of Juvenile
and Subadult Native Fish

Publication Number 01 - 1
Utah Division of Wildlife Resources
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Salt Lake City, Utah
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An Evaluation of the Effects of Tusher Wash Diversion Dam
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and Subadult Native Fish

FINAL REPORT

December 21, 2000

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Recovery Implementation Program for the Endangered Fish Species
in the Upper Colorado River Basin

Project No. CAP-15

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ACKNOWLEDGMENTS

This study was funded by the Recovery Implementation Program for the endangered fish species in the Upper Colorado River Basin. The Recovery Program is a joint effort of the U.S. Fish and Wildlife Service, U.S. Bureau of Reclamation, Western Area Power Administration, the states of Colorado, Utah and Wyoming, Upper Basin water users, environmental organizations, and the Colorado River Energy Distributors Association.

Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the author, the Fish and Wildlife Service, U.S. Department of Interior, or the Recovery Implementation Program.

I thank Tom Chart, Leo Lentsch and Mike Hudson for their efforts to secure funding for this project and taking care of program management. Mike Arra, Mike Bassett, Brandon Brown, Chris Cowan, Sheryl Kinnear-Ferris, Jared Freeman, Rebekah Haslam, Katrina Lund, Jeff Pero, Stephen Odendahl, David Svendson, Eduardo Vasquez, Darrell Willson, and Russ Willson provided valuable assistance with field work, and Kim Olson and Lee Thayne were a great help with work done at the power plant. I thank Tom Chart and Melissa Trammell for providing equipment, data and technicians, and Steve Meisner and the Larval Fish Laboratory for identifying larval fish. Heather Thomas provided valuable help with statistical analyses. This report was improved by comments provided by Louis Berg, Bob Burdick, Bob Norman, and Keith Rose.

EXECUTIVE SUMMARY

Tusher Wash Diversion Dam is located on the Green River near the town of Green River, Utah. This diversion dam supplies water to a water wheel, a gravity-fed canal, a pumping station, and a power plant. Research was conducted in 1998 to determine 1) if the dam prevents upstream movement of subadult native fish; 2) if the canal entrains native fish; and, 3) if the dam needs to be modified to better accommodate native fish. Data showed that native species are being entrained in the canal system. Larval Colorado pikeminnow were found in the canal system, but no razorback sucker larvae were captured. No subadult Colorado pikeminnow were captured in the canal system, but one hatchery-reared razorback sucker was found dead on a trash rack at the power plant. Other native species found in the canal system included flannelmouth sucker, bluehead sucker, speckled dace, and *Gila* species. Crayfish, northern leopard frogs, and several non-native fish species were also found in the canal system.

Tagged fish were able to pass the dam at flows of approximately 4,820 cubic feet (137 cubic meters) per second; however, the discharge of the Green River drops below this level during average years, so it is unknown whether or not native fish can pass the dam during low flow periods. Entrainment (and probable mortality) of native fish species into the irrigation canals and the power plant is an issue that needs to be addressed. Improvements to Tusher Wash Diversion Dam and its associated canal systems will be expensive to develop and maintain, so other options, such as reducing the amount of water that enters the canal system, should be considered as potential ways to reduce native fish mortality and improve fish passage.

LIST OF KEY WORDS

Tusher Wash Diversion Dam, Green River, Colorado pikeminnow, razorback sucker, flannelmouth sucker, bluehead sucker, subadult, larvae, fish movement, native species, Green River Canal, Thayn Power Plant, Thayne Ditch

INTRODUCTION

Study Site

Tusher Wash Diversion Dam is an 840-foot long dam that spans the width of the Green River approximately 8 river miles north of the town of Green River, Utah (Figure 1). This structure was built in 1906 and consisted of wood cribbing filled with rock. A concrete cap was poured on the 12 foot wide structure in 1936, and this configuration is still in place. The 8-foot high diversion dam was designed to force water into a canal on the west side of the river and past a water wheel on the east side of the river (Figure 2). The sluiceway on the east side of the river, which feeds the water wheel, is 11-feet wide and approximately 3-feet deep. The water wheel is in operating condition, but was only used for a few days during 1998 (personal observation). Another sluiceway is located near the center of the dam. This notch is about 150-feet long and 0.5-feet deep.

Flow measurement devices are not used on any of the irrigation or power generation facilities. However, estimates suggest that approximately 715 cubic feet per second (cfs) of water from the Green River enters the canal system on the west side of the river, when all components of the system are operating at full capacity. After flowing approximately 2,500 feet down a canal that is locally known as the raceway, the water reaches the Thayn Power Plant and pump station. At this point, about 200 cfs is used to turn a turbine that pumps 35 cfs up hill to an irrigation canal (known as the 42 foot ditch or the Thayne ditch). The remaining water can be used to turn two additional turbines and fill another irrigation canal, known as the Green River Canal. The power plant has the capacity to pass 600 cfs through its turbines to produce electricity (Thayn and Thayn 1987). The power plant was run at full capacity until early in the summer of 1999. However, a recent court decision ruled that a maximum of 435 cfs can legally pass through the power plant and pumping station (Reed Harris, U.S. Fish and Wildlife Service, personal communication). At the present time, the Green River Canal is taking 80 cfs during the irrigation season (Keith Rose, U.S. Fish and Wildlife Service, personal communication). During recent years, when the power plant and pump station was running at full capacity, irrigation diversions amounted to 0% to 4.9% of the of the average monthly discharge of the Green River, while the total diversion at Tusher Wash Diversion Dam amounted to 5.9% to 29.3 % of the average monthly discharge of the Green River (Table 1).

Native fish species, including the four endangered species of the Upper Colorado River Basin (Colorado pikeminnow (*Ptychocheilus lucius*), razorback sucker (*Xyrauchen texanus*), humpback chub (*Gila cypha*) and bonytail (*G. elegans*)) have been captured both upstream and downstream from Tusher Wash Diversion Dam. Subadult and adult Colorado pikeminnow have been documented to move upstream and downstream past Tusher Wash Diversion Dam (Tyus et al. 1980; Tyus 1985; U.S. Fish and Wildlife Service 1998). However, in most cases, discharge of the Green River at the time the fish passed the dam is not known, since several months or years had passed between the times of capture and recapture. Little data has been collected in relation to movement of other native fish species past Tusher Wash Diversion Dam or on passage of any fish species during low flow periods. A limited study conducted in 1995 and 1996 showed no fish movement past Tusher Wash Diversion Dam (Utah Division of Wildlife Resources, unpublished data). However, this study only included three days of sampling and 139 marked fish. Therefore, the probability of documenting fish moving past the dam was quite low.

Information on entrainment of larval fish in the raceway, irrigation canals, and power-generation facilities is also quite limited. Data collected in 1996 (Utah Division of Wildlife Resources, unpublished) showed that larvae of speckled dace (*Rhinichthys osculus*), unidentified suckers (*Catostomus* spp.), red shiner (*Cyprinella lutrensis*), and channel catfish (*Ictalurus punctatus*) were entrained in the canal system. The same species assemblage was captured in the Green River during the same time period.

Objectives

Since Tusher Wash Diversion Dam spans the entire width of the Green River and the raceway diverts a significant portion of the river, it was hypothesized that these structures were limiting the movement and survival of larval and juvenile native fish. However, given the sparse data that were available, it was not possible to determine what impact these structures were having on the native fish community. Therefore, this study was designed to collect more data on the impacts of the diversion dam and its associated features. This information was needed to make decisions as to whether the diversion system needed any modifications to protect native fish species. The objectives of this research were:

1. To determine if Tusher Wash Diversion Dam prevents upstream movement of subadult native fishes (particularly during low-flow periods).
2. To determine if the raceway or Green River Canal entrains native fish, and
3. To determine if Tusher Wash Diversion Dam needs to be modified to better accommodate native fishes.

The study was designed to include two years of field research. However, the Recovery Implementation Program decided not to fund the second year of field work. Unfortunately, during the year of the study, flows observed during the low-flow period were approximately twice as high as normal (Figure 3); therefore, objectives 1 and 3 were not fully addressed. In addition, the total catch of Colorado pikeminnow larvae in drift nets was much lower than the catch noted during past years, so conclusions drawn from work designed to address Objective 2 were also limited.

METHODS

Evaluation of Fish Entrainment in the Green River Canal

Larval Entrainment

Fine-mesh drift nets (12" X 18") were set from May 5 through May 26, 1998, and from June 29 through August 22, 1998. The first period was selected to target razorback sucker larvae, while the second period was selected to target Colorado pikeminnow larvae. Water temperature in the Green River was monitored during these periods with an electronic thermograph (Onset Computer Corporation). Two nets were set in the Green River and two nets were set in the Green River Canal (Figure 2) during the month of May. An additional net was set

in the Green River during the second sampling period. Occasionally, two additional nets were set in the raceway upstream from the pumping station and power plant (Figure 2), and nets were set every six hours on August 2-5. All nets were equipped with mechanical flow meters (General Oceanics, Inc.). When the measured water velocity seemed abnormally low, an estimated velocity based on readings from other meters was used rather than the actual data. Working conditions in the raceway upstream from the pumping plant and power plant were dangerous, due to the depth and velocity of the water, so nets were not set at this site very frequently; no fish were found in the samples from this additional site, so these data were excluded from data analysis. Nets were usually set at about 0700 each morning and allowed to fish for about two hours. However, many nets were deployed for shorter periods of time (especially in May) due to large amounts of debris that was suspended in the water on some occasions. Debris collected in the nets was preserved in alcohol and taken to a laboratory, where fish were removed. All larval fish collected were sent to the Larval Fish Laboratory in Fort Collins, Colorado, for identification.

Subadult and Adult Entrainment

The gates of the Green River Canal were closed on the evening of August 5, 1998 and sluice gates were opened to remove a large tree that had lodged in an overflow structure. The tree was removed on the morning of August 6, 1998; the gates were returned to their original positions and the canal was filled with water again at that time. While the canal was dry on the morning of August 6, I visually searched for stranded fish in approximately 0.25 miles of the canal near the gates and two miles of the canal through the town of Green River, Utah. The Green River Canal was shut off for the winter on November 27, 1998, but I was not notified until November 30, 1998. On that morning, I searched for stranded fish in approximately two miles of the Green River Canal and 1 mile of a smaller irrigation-drainage canal running through Green River, Utah.

The raceway gates were closed in February 1999 to allow the Green River Canal Company to build a concrete wall in front of the intake to the Thayn Power Plant. The purpose of the wall was to increase the volume of water delivered to the Green River Canal. This, in turn, reduced the volume of water delivered to the power plant. The wall caused high water velocities to form in front of a grate that is used to keep debris from entering the power plant. Water velocities between the wall and the grate were increased and were high enough to cause large fish to become impinged on the grate. One of the turbines in the power plant was shut off on May 20, 1999, which reduced the water velocity in front of the grate enough to keep most fish from becoming impinged. In addition, the wall in front of the power plant intake was removed on June 30, 1999, which further reduced water velocities in front of the grate. During the period from May 4 through May 24, 1999, fish caught on the screen were removed and identified by Kim Olsen, a Utah Division of Wildlife Resources conservation officer, and Lee Thayn, co-owner of the power plant. Neither of these individuals have any training in ichthyology, so not all of the collected fish were identified to species.

Subadult Fish Passage at Tusher Wash Diversion Dam

Subadult Tagging

A 16-foot long rubber raft, rigged with electrofishing gear, was used to sample fish in the Green River from Swasey's Rapid (river mile [rm] 132) to the Green River State Park boat ramp (rm 120). Most of the effort was expended between rm 132 and rm 125. Electricity was produced with a gasoline-powered generator and output current was controlled with a Coffelt VVP-15 electrofishing unit. Output voltage was kept near six amperes. One spherical cathode was used with one anode consisting of cable droppers. One person rowed the raft and controlled the electrofishing gear while one or two people netted fish. Nearly all of the sampling was conducted along shorelines and in shallow areas near islands. All fish captured were kept in a live well until they were measured to the nearest millimeter and weighed to the nearest gram, unless large numbers of fish were captured. In this situation, all native fish and a representative sample of non-native fish were weighed and measured. The remaining fish were only enumerated. Thirty-one Colorado pikeminnow and five *Gila* spp. were tagged with a Passive Integrated Transponder (PIT tag) injected into the body cavity. Two-hundred thirty-one flannelmouth suckers (*C. latipinnis*) and 182 bluehead suckers (*C. discobolus*) were tagged below the dorsal fin with individually numbered T-bar Anchor tags (FLOY TAG and Manufacturing, Inc.). Three-hundred thirty-four channel catfish, 35 common carp (*Cyprinus carpio*) and 1 black bullhead (*Ameiurus melas*) were tagged below the dorsal fin with T-bar Anchor tags that were not individually numbered. All tagged fish were released downstream of Tusher Wash Diversion Dam.

Subadult Telemetry

Radio transmitters were used to collect movement data on native fish. Transmitters produced by Advanced Telemetry Systems were implanted in seven subadult Colorado pikeminnow, nine subadult flannelmouth suckers, and five subadult bluehead suckers. Transmitters ranged in weight from 2.04 g to 7.59 g (life expectancy from 30 to 85 days) and were never implanted in a fish unless the weight of the transmitter was less than two percent of the weight of the fish. This protocol was followed in an effort to minimize the loss of transmitters (as recommended in Marty and Summerfelt (1986)) and behavioral changes. All transmitters were equipped with an external antenna; however, the antenna was coiled and placed within the body cavity on five of the Colorado pikeminnow, since this configuration has been shown to work well in this species (Tim Modde, U.S. Fish and Wildlife Service, personal communication).

Fish that were to be implanted with a radio transmitter were first anesthetized with tricaine methane sulfonate (Finquel brand of MS-222). Transmitters implanted in Colorado pikeminnow were inserted in an incision made along the side of the fish in a position that was anterior to the left pelvic fin. This location was used so that the transmitter would not rest upon the incision. Transmitters implanted in flannelmouth suckers and bluehead suckers were inserted in an incision along the midline of the ventral portion of the body. This location was selected because lateral incisions in suckers (especially in bluehead suckers) tend to bleed copiously (personal observation). A curved needle was used to make a small hole behind the incision used to implant the transmitter (except in the case of five Colorado pikeminnow, as described above). The antenna exited the body cavity through this opening. Fresh water was administered to the gills of the fish during the surgery. Alcohol was used as a disinfecting agent, and saline solution

was used to remove residual alcohol from the transmitters and prevent irritation of exposed tissue. After the transmitter was placed in the body cavity, the incision was stitched with absorbable chromic gut sutures. No antibiotics were administered. Fish were placed in a bucket of fresh water and allowed to recover from the effects of the anesthetic. After regaining equilibrium, fish were released into slow water in the area from 0.2 to 3.7 miles downstream from Tusher Wash Diversion Dam. Relocation was accomplished with a scanning radio receiver (Advanced Telemetry Systems). Attempts to relocate radio-tagged fish occurred as time permitted, so no specific relocation schedule was followed. The river reach between Tusher Wash Diversion Dam and the town of Green River, Utah, was searched more frequently than locations upstream or downstream of that area.

Statistical Analyses

Statistical calculations were performed with SAS statistical package version 6.11 (SAS Institute, Inc. 1995). Analysis of variance tests were calculated with Proc GLM, while descriptive statistics were calculated with Proc Means and Proc Freq. Wilcoxon Rank-Sum Tests (Proc Npar1way) were used to analyze data that were not normally distributed and could not be transformed, due to a large number of zero values. All outcomes with a probability level of less than or equal to 0.05 were considered to be statistically significant.

RESULTS

Larval Entrainment

Average temperatures in the Green River at Tusher Wash Diversion Dam ranged from 12.5°C to 15.9°C during the first sampling period and from 20.4°C to at least 23.9°C (the thermograph was not functioning during the entire sampling period) during the second sampling period (Figure 4). Total catch of larval fish was low in both the Green River and in the Green River Canal, even though large volumes of water were sampled in both locations. Native species, including Colorado pikeminnow, were caught in both locations (Table 2), although the numbers of sucker larvae captured were extremely low; no razorback sucker larvae were collected. Wilcoxon Rank-Sum tests showed that catch rates of Colorado pikeminnow were significantly higher in the Green River than in the canal. However, since the number of pikeminnow captured was very low, the validity of this significant difference is questionable. No significant differences in catch rates were noted for any of the other species captured (Table 3). Even though the number of Colorado pikeminnow larvae captured was lower in 1998 than in any other year on record, the actual abundance of larvae, as measured by a transport abundance index, was the highest ever recorded (23,200 larvae in 1998 compared to an average of 13,400 larvae during the drift periods from 1991 through 1996; Kevin Bestgen, Larval Fish Lab, personal communication). This scenario was caused by the unusually high flows that existed late into the summer of 1998.

Subadult and Adult Entrainment

Few fish were found stranded in the Green River Canal during the occasions when it was

dry. The search conducted on the morning of August 6 revealed one juvenile carp (approximately 300 mm) and one small crayfish (Decapoda; species not identified). One small fish (which appeared to be a non-native cyprinid) was observed in a pool, but it avoided capture and was not positively identified. The search conducted in the Green River Canal on November 30 revealed one carp (approximately 400 mm total length--all fleshy parts had been consumed by animals and only the head, ribs and spine remained), one speckled dace (60 mm), and one channel catfish (60 mm). Other animals found included two small crayfish (species not identified), seven live and two dead northern leopard frogs (*Rana pipiens*) and one megaloptera larva (Corydalidae; species not identified). Tracks from humans and other mammals (including what appeared to be domestic dog, coyote, racoon, muskrat, and possibly weasel) and birds (several unidentified species) were also noted in the mud along the bottom of the canal. Searching in the irrigation-drainage canal produced thousands of mosquitofish (*Gambusia affinis*), one common carp (350 mm) and two channel catfish (approximately 250 mm).

Larger numbers of fish were found impinged on the grate in front of the Thayn Power Plant during the time period when the concrete wall increased water velocity in this location. These fish included one razorback sucker, four flannelmouth suckers, one bluehead sucker, and two common carp, which were all positively identified by aquatic biologists. The razorback sucker was a hatchery-reared fish that was hatched in 1995 and stocked on October 26, 1998, at rm 319 in the Green River. This fish was 384 mm long at the time of stocking and at the time of death (May 15, 1999). In addition, 228 unidentified suckers (probably a combination of flannelmouth suckers and bluehead suckers), 85 common carp, three channel catfish (including one that was estimated to weigh over five pounds), and 16 fish that were unidentified were also removed from the grate.

Subadult Tagging

Electrofishing produced 34 Colorado pikeminnow (Table 4) and 12 *Gila* spp. (Table 5). None of the Colorado pikeminnow or *Gila* spp. that were tagged during this study were recaptured. Twenty-four additional Colorado pikeminnow were observed and positively identified but avoided capture (Table 4). Two bluehead suckers, four flannelmouth suckers, and two channel catfish tagged during this study were later recaptured, as were a Colorado pikeminnow that was tagged in the Green River in 1996 (Utah Division of Wildlife Resources, unpublished data) and a flannelmouth sucker that was tagged in the Price River in 1997 (Cavalli 1999) during sampling done for other studies (Table 6). Both bluehead suckers, 1 flannelmouth sucker, and 1 channel catfish had moved upstream past Tusher Wash Diversion Dam during a period when discharge ranged from 3,660 to 7,590 cfs. The recaptured Colorado pikeminnow had negotiated the dam at some time since 1996, while the flannelmouth sucker that was tagged in the Price River had moved downstream past the dam at some time since 1997.

Electrofishing catch rates for *Gila* spp. were significantly higher upstream than downstream from Tusher Wash Diversion Dam; catch rates for bluehead sucker were also much higher upstream than downstream from the dam, but the difference was not statistically significant. Catch rates for Colorado pikeminnow and common carp were significantly higher downstream from the dam than upstream from it (Table 7). Significant differences in catch rates upstream and downstream of the dam were not noted for the other species captured, although green sunfish (*Lepomis cyanellus*) and walleye (*Stizostedion vitreum*) were only captured downstream from the dam.

The average sizes of Colorado pikeminnow (Figure 5) and channel catfish (Figure 6) captured upstream from Tusher Wash Diversion Dam were larger than the average sizes of these species caught downstream from the dam (Table 8). The average size of flannelmouth suckers caught upstream from the dam was smaller than the average size of this species caught below the dam (Figure 7), but this difference was not significant (Table 8). The average size of bluehead suckers caught upstream from the dam was nearly identical to the average size of those individuals caught downstream from the dam (Figure 8; Table 8). Common carp caught upstream of the dam were slightly larger than those found downstream of the dam (Figure 9), but this difference was not significant (Table 8). All individuals from the genus *Gila* were captured upstream of the dam and most of these individuals were too small to be sexually mature (Table 5). Very few speckled dace, black bullhead, fathead minnow (*Pimephales promelas*), green sunfish, red shiner, sand shiner (*Notropis stramineus*) or walleye were captured using electrofishing gear, so length-frequency histograms are not presented for these species. However, no significant differences by location in average size were noted for any of these species (Table 8).

Subadult Telemetry

One radio-tagged Colorado pikeminnow was never relocated after release (40.791). Another pikeminnow (40.050) moved downstream after release. After one month this fish was located in a shallow, sandy area and it remained in that location for the remainder of the study. Based on the lack of movement and the habitat conditions found in this area, it was assumed that this fish had died or lost its tag. An attempt to recover this radio from the river was unsuccessful. The other five radio-tagged pikeminnow also moved downstream soon after being released. These movements ranged from less than one mile (40.751) to over 58 miles (40.781; Table 9). However, all of these fish eventually found areas that they appeared to inhabit for extended periods of time. All of these fish were alive when the last radio contact was made, so these areas represented occupied habitat rather than the location of a dead fish or a lost transmitter.

Radio-tagged flannelmouth suckers did not move as far as radio-tagged Colorado pikeminnow. Flannelmouth suckers generally stayed near their release point. The longest distance a flannelmouth sucker moved downstream was only 6.9 miles (Radio 40.841). However, three flannelmouth suckers (Radios 40.800, 40.771, and 40.760) did move upstream past Tusher Wash Diversion Dam during September or early October (Table 10). Two of these fish moved past the dam during a period when discharge ranged from 4,100 to 4,820 cfs, while the other fish moved when the discharge ranged from 3,660 to 4,820 cfs. The average monthly discharge of the Green River is below 4,800 cfs during seven months of the year (Table 1). Most radio-tagged flannelmouth suckers, like radio-tagged Colorado pikeminnow, found small areas that were inhabited for extended periods of time.

Bluehead suckers tended to move farther than flannelmouth suckers, but not as far as Colorado pikeminnow. The longest movement documented for a bluehead sucker was 21.9 miles (40.060). However, radio contact was not made after two weeks for three of the five tagged fish. The fish that made the longest movement was also the fish that was tracked over the longest period of time. None of the radio-tagged bluehead suckers were found to have moved upstream past Tusher Wash Diversion Dam (Table 11).

DISCUSSION

Assessment of the effects of Tusher Wash Diversion Dam, Thayn Power Plant and pump station, and the Green River Canal on larval fish was hampered by low catch rates in the larval drift samples. The total catch of larval Colorado pikeminnow in the Green River was an order of magnitude lower in 1998 than the catch recorded during most years. This low catch rate was probably due to the high flows that existed late into the summer (i.e. the nets sampled a smaller proportion of the total flow than during years with lower flow) rather than due to low numbers of larvae in the river (Kevin Bestgen, Larval Fish Lab, personal communication). No razorback sucker larvae were captured in the Green River or the canal system during this study, but other native-fish species, including Colorado pikeminnow and *Gila* spp, were captured in both locations. Drift nets were set during the periods when water temperatures were suitable for spawning by razorback suckers and Colorado pikeminnow. Ripe razorback suckers have been captured on suspected spawning areas in the Green River from late April through May in water temperatures ranging from 9°C to 17°C (Tyus 1987; Tyus and Karp 1990). Colorado pikeminnow have been found spawning in the Green River from late June through mid August when water temperatures are between 19.5°C and 27.5°C (Tyus 1990). The two periods that were sampled during this study included water temperatures that fell within these ranges.

The numbers of larvae of most fish species caught in the canal were similar to those found in the Green River. Many of the flow meters used to calculate the volume of water sampled did not function properly, but this problem occurred in nets set in both the Green River and the canal system. Comparisons of catch rates between locations are probably valid, even though the actual volumes of water sampled are not accurate, due to the fact that some of the meters were functional in both locations. The similarity in catch rates between the Green River and the canal system suggests that both native and non-native fish larvae are unable to avoid the canal system. During typical years, up to 2.2% of the Green River is diverted for irrigation during the period when larval razorback suckers are drifting, and up to 4.9% of the river is diverted for irrigation during the period when larval Colorado pikeminnow are drifting. Assuming that larval fish are randomly distributed in the water column, and nearly total mortality of larvae that are entrained in irrigation water, then the facilities at Tusher Wash are responsible for the loss of about 2% of razorback sucker larvae, and nearly 5% of Colorado pikeminnow larvae. Studies conducted on other species in the Pacific Northwest show that mortality of fish through powerplants can be as low as 4% to 10%, depending on the design of the runner, the head through the power plant, the operation of the power plant, and the clearance between the runner and the hub (Office of Technology Assessment 1995). The mortality rate of endangered fish going through the power plant at Tusher Wash is unknown, but it is safe to assume that some larvae are killed in this structure. Therefore, the structures at Tusher Wash are probably responsible for the loss of more than 2% of razorback sucker larvae and over 5% of Colorado pikeminnow larvae that pass through the area.

Entrainment (and probable mortality) of native species into the irrigation canals and the power plant is an issue that needs to be addressed. The Green River carries massive amounts of debris during the period when larval fish are drifting (especially during the period when razorback sucker larvae are drifting), so deployment of a screening system that would be small enough to protect larval fish would probably be impractical. Use of rotating drums designed to move larval fish back to the river is another option, but the cost of such a system would probably be extremely high, and may not totally eliminate mortality. Another option for reducing

entrainment of larval fish is to reduce flows in the raceway during the larval drift periods. A reduction in the amount of water diverted would probably reduce entrainment of all life stages of endangered fish, but the cost of such an action (reduced crop production and power generation) could be substantial. A comparison of the costs associated with fish exclusion structures to the costs associated with reducing diversion of water during the larval drift periods should be completed in order to help make decisions about modifications to the raceway that may be needed to protect endangered fish.

Tusher Wash Diversion Dam, Thayn Power Plant and pump station, and the Green River Canal appear to have a negative affect on subadult fish. Large numbers of native fish, including a razorback sucker, were found impinged on the grate in front of the power plant and pump station. No endangered fish have been found on the grate since the wall in front of the power plant was removed, but adult Colorado pikeminnow were caught with electrofishing gear in the Green River Canal during the summer of 2000 (Tim Modde, U.S. Fish and Wildlife Service, personal communication). Few fish were found in the Green River Canal when it was dry, but these numbers were probably affected by diversion of water out of the canal through sluice gates and the removal of fish by scavengers before sampling occurred; tracks from birds, humans, and other mammals were noted throughout the canal system. Fishing tackle was also found in the Green River Canal; local fishermen often catch fish in the canal, and some people walk the canal when it is dry to capture stranded fish (Kim Olson, Utah Division of Wildlife Resources, personal communication). Glen Baxter (personal communication), a long time resident of Green River, Utah reported having seen a 38 pound catfish that was caught in the canal several years ago, and another resident claimed to have found Colorado pikeminnow in his ditch at the end of the irrigation season (Frank Vetere, personal communication with Jeff Beck, Utah Division of Wildlife Resources). These findings and anecdotal reports suggest that modifications are needed to keep subadult and adult fish from entering the canal system. However, the debris carried by the Green River will have to be factored into the design of the modifications in order to keep maintenance costs at a reasonable level.

Tusher Wash Diversion Dam does not appear to be a complete barrier to upstream movement by subadult fish when flows are at least 4,800 cfs. The average catch rate and average size of most species were not different upstream of the dam compared to downstream of the dam. The differences in catch rates or average size that were noted can probably be explained by factors such as small sample sizes (e.g. only three Colorado pikeminnow were captured upstream from the dam) or differences in habitat availability (e.g. all of the *Gila* spp. were captured near Swasey's Rapid, which is found above the diversion dam; at this point, the valley becomes wider and the average gradient declines. Consequently, riffles are rare and there are no rapids and below this point, while both of these habitat types are common above this point). The lack of significant differences could be explained by either similar production and growth upstream and downstream from the dam or by movement of all sizes of fish across the dam. However, flannelmouth suckers, bluehead suckers, and channel catfish were documented to move upstream past the dam. Therefore, it seems likely that fish passage at the dam is possible when flows are approximately 4,800 cfs. However, the average base flow during recent years has been approximately 2,500 cfs. It is still unknown whether or not subadult fish can move upstream past Tusher Wash Diversion Dam during periods when the discharge is closer to average base flow conditions.

None of the radio-tagged Colorado pikeminnow were found to move upstream past Tusher Wash Diversion Dam. One fish was found in the same location for several weeks. This

RECOMMENDATIONS

- Entrainment (and probable mortality) of native species into the irrigation canals and the power plant is an issue that needs to be addressed. Screens small enough to exclude larval fish would help reduce mortality rates of native fish species, but the amount of debris and sediment in the Green River will probably make the use of such screens impractical. If larval screens are determined to be impractical, larger screens or vertical louvers should be installed to protect larger fish. Other options to reduce larval fish mortality are available (e.g. use of rotating drums to return larval fish to the river or reducing the amount of water that enters the canal system during larval drift periods), and should be evaluated for effectiveness and cost efficiency.
- Efforts should be made to determine if subadult and adult native fish species can pass Tusher Wash Diversion Dam during low-flow periods. Data should be collected when flows are approximately 2,500 cfs in order to determine whether or not a fish ladder is needed to facilitate fish passage during average low-flow conditions.
- Future drift netting efforts should include the use of electronic flow meters. The high failure rate of the mechanical flow meters used during this study was probably related to the silt and debris load carried in the water. These factors should not affect the performance of electronic flow meters, and this difference would improve the accuracy of the data collected.

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Table 1. Summary of discharge variables for the Green River at Tusher Wash Diversion Dam. The monthly average discharge values (cubic feet per second) of the Green River during the water years of 1988 through 1997 were calculated from data collected at the U.S. Geological Survey gage station located near Green River, Utah, while the amounts of water diverted are based on estimated values. The percentage of time when discharge is lower than 4800 cfs (the minimum discharge that radio-tagged fish were documented to move upstream past the dam) is shown for each month. The amount of water diverted at Tusher Wash Diversion Dam for irrigation and the amount diverted for all uses (irrigation, pumping, and power generation) are shown as percentages of the average monthly flow.

Month	Average Monthly Flow (cfs)	Average Percentage of Time When Q < 4800 cfs	Irrigation Diversion (Percent of Average Monthly Flow)	Total Diversion (Percent of Average Monthly Flow)
January	2,688	100.0	0	14.9
February	2,918	94.7	0	13.7
March	4,125	71.9	0	9.7
April*	5,136	62.0	2.2	13.9
May*	10,726	17.1	1.1	6.7
June**	12,051	17.3	1.0	5.9
July**	4,686	74.5	2.5	15.3
August**	2,367	97.4	4.9	30.2
September	2,442	96.0	4.7	29.3
October	2,452	100.0	4.7	29.2
November	2,854	100.0	0	14.0
December	2,520	96.8	0	15.9

*months when larval razorback sucker are drifting

**months when larval Colorado pikeminnow are drifting

Table 2. Number of fish caught in drift nets set in the Green River and in the Green River Canal during sampling conducted from May 5-26, 1998, and from June 29, 1998, through August 22, 1998. The column labeled "Volume" shows the amount of water sampled at each site. Species are abbreviated as follows: CS: Colorado pikeminnow, CH: chub (unidentified *Gila* species), SD: speckled dace, BH: bluehead sucker, FM: flannelmouth sucker, FH: fathead minnow, CC: channel catfish, SS: sand shiner, RS: red shiner, CP: common carp, WS: white sucker, NNC: non-native cyprinid (unidentified species). Abbreviations and values for native species are shown in bold italic print.

Location	Volume (m ³)	<i>CS</i>	<i>CH</i>	<i>SD</i>	<i>BH</i>	<i>FM</i>	FH	CC	SS	RS	CP	WS	NNC
Green River	31,564	<i>12</i>	<i>6</i>	<i>74</i>	<i>17</i>	<i>2</i>	1	18	0	1	2	0	3
Canal	26,689	<i>1</i>	<i>1</i>	<i>25</i>	<i>9</i>	<i>6</i>	4	21	1	3	1	1	3

Table 3. Wilcoxon rank-sum comparisons of catch rates (mean score of the number caught per cubic meter of water sampled) for species caught in drift nets set in the Green River and in the Green River Canal during 1998. Native species and significant differences are shown in bold. Analyses were conducted on 200 samples from the Green River and 139 samples from the Green River Canal.

SPECIES	Location		Prob \geq S-Mean
	Green River	Canal	
bluehead sucker	169.58	170.61	0.08080
Colorado pikeminnow	172.97	165.73	0.0309
<i>Gila</i> species	171.25	168.20	0.2613
flannelmouth sucker	168.70	171.88	0.1734
speckled dace	173.78	164.57	0.1124
common carp	170.20	169.71	0.7135
channel catfish	168.20	172.59	0.3534
fathead minnow	168.36	172.36	0.1633
non-native cyprinid (species unidentified)	170.05	169.92	0.7218
red shiner	169.35	170.94	0.4708
sand shiner	169.50	170.72	0.4100
white sucker	169.50	170.72	0.4100

Table 4. Information collected from Colorado pikeminnow observed or captured while electrofishing in the Green River near Tusher Wash Diversion Dam. The capture location shown is the number of river miles upstream from the confluence with the Colorado River; Tusher Wash Diversion Dam is located at river mile 128.3. Total length is abbreviated as TL, standard length is abbreviated as SL, unknown values are denoted with a question mark and estimated values are preceded by a tilde.

Date	TL (mm)	SL (mm)	WT (g)	Location	PIT Tag #	Comments*
7/30/98	~550	?	?	131.5		a
7/30/98	~450	?	?	131.3		a
7/30/98	~350	?	?	130.5		a
7/30/98	434	356	570	127.6	1F20075862	b
7/30/98	538	446	1288	127.2	1F1E2F4B49	c
7/30/98	~200	?	?	127.0		a
7/31/98	621	510	1768	129.6	2010495037	d
7/31/98	296	237	168	126.6	1F1E4F3D37	b
7/31/98	~550	?	?	?		a
7/31/98	438	355	530	124.6	1F1E311A78	b
8/4/98	271	213	148	131.6	1F1F5E756F	e
8/4/98	437	357	550	128.1	1F20182108	b
8/4/98	439	361	634	127.6	1F30225837	b
8/4/98	276	222	136	127.3	1F20054E6E	b
8/4/98	285	231	182	127.2	1F20380108	
8/4/98	406	331	464	126.2	1F224A690C	b

Continued on next page

Table 4. (continued)

Date	TL (mm)	SL (mm)	WT (g)	Location	PIT Tag #	Comments*
8/4/98	515	422	956	126.0	1F1351601D	c
8/4/98	~150	?	?	125.0		a
8/4/98	~400	?	?	125.0		a
8/4/98	303	246	212	125.0	1F20095D5B	
8/4/98	176	142	32	125.0	1F20175555	
8/12/98	~400	?	?	131.7		a
8/12/98	~350	?	?	131.6		a
8/12/98	~500	?	?	127.7		a
8/12/98	270	217	142	127.5		f
8/12/98	235	187	78	127.5		g
8/12/98	425	343	?	126.5	1F203A6423	
8/13/98	~500	?	?	126.7		a
9/1/98	~400	?	?	131.5		a
9/1/98	261	206	130	127.9	1F204A294E	
9/1/98	300	240	172	127.6	1F1F714F02	
9/1/98	291	234	184	126.7	1F1F7D1530	
9/2/98	~500	?	?	131.8		a
9/2/98	469	383	768	130.3	1F1E2F573D	
9/2/98	~200	?	?	128.1		a
9/2/98	~550	?	?	128.0		a
9/2/98	~250	?	?	128.0		a
9/2/98	262	210	128	128.0	1F20453A42	
9/2/98	507	405	830	126.5	1F1F6E2A2A	
9/2/98	265	213	124	125.1	1F20201110	h

Continued on next page

Table 4.(continued)

Date	TL (mm)	SL (mm)	WT (g)	Location	PIT Tag #	Comments*
9/2/98	~300	?	?	125.0		a
9/2/98	~550	?	?	124.8		a
9/2/98	~450	?	?	124.6		a
9/2/98	~400	?	?	124.6		a
9/9/98	311	254	224	128.1	1F20392068	
9/9/98	455	369	800	127.7	1F1F6E6A6A	
9/29/98	225	179	73	125.0	1F1F5C3333	
9/29/98	439	355	490	124.8	1F20521F50	
9/30/98	328	264	215	123.3	2037521245	
9/30/98	~350	?	?	122.7		a
9/30/98	301	243	175	121.9	1F1F5E6E76	
9/30/98	310	251	180	121.8	1F20285C3D	
9/30/98	~200	?	?	121.7		a
9/30/98	~500	?	?	120.7		a
10/21/98	~500	?	?	131.7		a
10/21/98	525	429	1618	131.5	1F1F623D23	
10/21/98	327	264	230	124.7	1F20487900	
10/22/98	273	220	138	122.8	1F1F7C6C5A	

*Comments are coded as follows:

- a. Positive identification, but not captured
- b. Radio tagged
- c. Ripe male with tubercles
- d. Recapture; fish tagged 9/18/96 at river mile 128.3 in the Green River
- e. Incision made, but bleeding badly, so no radio was implanted
- f. Fish was in poor condition
- g. Mortality
- h. Tag 1F40407909 was injected but would not read so another tag was injected

Table 5. Information collected from *Gila* spp. captured by electrofishing in the Green River near Tusher Wash Diversion Dam. The capture location shown is the number of river miles upstream from the confluence with the Colorado River; Tusher Wash Diversion Dam is located at river mile 128.3. Total length is abbreviated as TL, standard length is abbreviated as SL, unknown or questionable values are denoted with a question mark and estimated values are preceded by a tilde. The column labeled "Fin Rays" shows the number of dorsal rays followed by the number of anal rays.

Date	Species*	TL (mm)	SL (mm)	WT (g)	Fin Rays	Location	PIT tag #
8/12/98	CH	34	25	?	?	131.8	
8/12/98	CH	158	127	30	?	131.8	1F2036206B
8/12/98	CH	143	112	28	?	131.7	1F20170723
8/12/98	RT	155	121	28	?	131.5	1F1F601250
9/1/98	CH	49	39	?	9/10	131.7	
9/1/98	CH	150	117	28	9/9	131.6	
9/2/98	HB	190	147	56	9/10	131.8	1F20461269
9/2/98	HB?	164	127	38	9/10	131.8	1F20393058
9/30/98	HB?	118	92	?	10/9	131.8	
9/30/98	CH	70	55	?	9/12	~131.8	
10/21/98	CH	152	117	28	9/10	131.7	
10/22/98	CH	125	97	14	9/9	~131.8	

*Species are coded as follows:

CH=unidentified *Gila* species
 RT=Roundtail chub
 HB=Humpback chub

Table 6. Information collected at time of capture and at time of recapture from fish collected in the Green River near Tusher Wash Diversion Dam. Locations shown are the number of river miles upstream from the confluence with the Colorado River, unless otherwise noted. Tusher Wash Diversion Dam is located at river mile 128.3. Standard length is abbreviated as SL, weight is abbreviated as WT, unknown values are denoted with a question mark and estimated values are preceded by a tilde. Channel catfish were tagged with non-numbered tags, so much of the information pertaining to this species is unknown.

Species* & Tag #	Capture Date & Recapture Date	Release Location & Recapture Location	Total Length (mm)	Std. Length (mm)	Wt (g)	Notes**
			@ Capture & @ Recapture	@ Capture & @ Recapture	@ Capture & @ Recapture	
BH 1093	8/12/98 9/29/98	128.3 131.8	249 261	205 209	108 120	e
FM 1156	8/13/98 9/29/98	127.4 131.8	378 394	304 315	? 500	e
FM 1253	9/02/98 9/29/98	128.1 126.4	459 456	378 374	852 770	a
FM 1004	7/30/98 9/1/98	128.3 ~127.0	419 415	341 330	652 600	a
FM 1242	9/2/98 9/2/98	128.1 ~128.0	378 380	300 300	400 408	
BH 1028	7/31/98 9/9/98	128.1 ~131.4	341 355	276 290	340 348	e
CC None	after 8/11/98 10/21/98	downstream of 128.3 ~127.8	? 293	? 226	? ?	
CC None	after 8/11/98 9/30/98	downstream of 128.3 131.8	? ~250	? ?	? ?	b, e
FM PR770	6/1/97 8/13/98	PR 21.8 ~126.6	455 443	372 360	870 800	a, c f
CS 20104950 37	9/18/96 7/31/98	128.3 129.6	562 621	? 510	? 1768	d e

*Species are coded as follows:
 Bluehead Sucker=BH
 Channel Catfish=CC
 Colorado Pikeminnow=CS
 Flannelmouth Sucker=FM

**Notes are coded as follows:
 a. Measurements were larger at time of recapture than at time of capture
 b. Caught by an angler
 c. Tagged in Price River during an unrelated study; total movement of approximately 33.2 miles; tag insertion point was an open sore at time of recapture
 d. Tagged during a preliminary study by Tom Chart, Utah Division of Wildlife Resources
 e. Fish passed Tusher Wash Diversion Dam moving upstream
 f. Fish passed Tusher Wash Diversion Dam moving downstream

Table 7. Wilcoxon rank-sum comparisons of average catch rates (mean score of the number caught per hour) for species caught by boat electrofishing in the Green River near Tusher Wash Diversion Dam in 1998. Fish caught upstream from the dam are labeled "Upstream", while fish caught downstream from the dam are labeled "Downstream". Native species and significant differences ($\alpha = 0.05$) are shown in bold. Analyses were conducted on 13 samples collected above the dam and 24 samples collected below the dam.

SPECIES	LOCATION		Prob \geq S-Mean
	Upstream	Downstream	
bluehead sucker	23.69	16.46	0.0517
Colorado pikeminnow	11.85	22.88	0.0014
flannelmouth sucker	20.35	18.27	0.5878
<i>Gila</i> spp.	24.54	16.00	0.0007
speckled dace	15.92	20.67	0.1788
black bullhead	17.77	19.67	0.3843
channel catfish	14.61	21.38	0.0719
common carp	12.50	22.52	0.0061
fathead minnow	18.12	19.48	0.6727
green sunfish	16.50	20.35	0.1398
red shiner	16.23	20.50	0.1285
sand shiner	14.00	21.71	0.0104
walleye	18.00	19.54	0.5315

Table 8. Analysis of variance comparisons of average total length (mm) for each species caught by boat electrofishing in the Green River near Tusher Wash Diversion Dam in 1998. Sample sizes are shown below each average length. Native species and significant differences ($\alpha = 0.05$) are shown in bold.

SPECIES	LOCATION		Prob>F
	Upstream from Dam	Downstream from Dam	
bluehead sucker	244.5 187	243.8 88	0.9333
Colorado pikeminnow	538.33 3	345.13 31	0.0018
flannelmouth sucker	378.4 202	394.5 208	0.0514
<i>Gila</i> spp.	125.7 12	Not Applicable 0	Not Applicable
speckled dace	73.1 7	77.4 25	0.3406
black bullhead	165.0 1	160.3 4	0.9075
channel catfish	234.1 203	196.8 489	0.0001
common carp	432.4 55	419.7 156	0.3633
fathead minnow	61.5 4	57.0 1	0.6789
green sunfish	Not Applicable 0	83.7 6	Not Applicable
red shiner	60.5 2	54.6 14	0.1701
sand shiner	60.0 1	52.9 14	0.3230
walleye	Not Applicable 0	433.0 2	Not Applicable

Table 9. Radio locations from Colorado pikeminnow released downstream from Tusher Wash Diversion Dam on the Green River. The frequency (MHZ) of the radio implanted is shown below the PIT tag number. Locations shown are river miles upstream from the confluence with the Colorado River. Tusher Wash Diversion Dam is located at river mile 128.3. See Table 4 for size information from each fish at time of capture.

PIT Tag # (Radio Freq.)	Release Date and Location	Contact Date and Location	Comments
1F20075862 (40.791)	7/30/98 RM 127.3		no contact after release
1F1E4F3D37 (40.690)	7/31/98 RM 126.5	8/3/98 RM 123.6 8/4/98 RM 123.6 8/5/98 RM 123.6 8/7/98 RM 123.6 8/7/98 RM 123.6 8/14/98 RM 122.6	moved upstream slightly from 8/5/98 location moved back to same location as on 8/5/98
1F1E311A78 (40.781)	7/31/98 RM 124.6	8/16/98 RM 65.9 10/11/98 RM 65.8	fish moved downstream immediately moved down 100 yards and then back to original location; opposite side of river from 8/16/98 location
1F20182108 (40.811)	8/4/98 RM 127.6	8/5/98 RM 120.3 8/5/98 RM 119.0 8/5/98 RM 118.7 8/5/98 RM 118.5 8/15/98 RM 88.7 10/11/98 RM 88.4	fish disappeared after about 2 minutes-direction moved unknown fish frightened by canoe?

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Table 9. Continued

PIT Tag # (Radio Freq.)	Release Date and Location	Contact Date and Location	Comments
1F30225837 (40.751)	8/4/98 RM 125.3	8/5/98 RM 124.9 8/5/98 RM 124.7 8/7/98 RM 124.8 8/8/98 RM 124.8 8/8/98 RM 124.7 8/14/98 RM 124.7 9/3/98 RM 124.7 9/24/98 RM 124.9 10/10/98 RM 124.7	fish quickly moved about 100 yards downstream fish moving downstream a little faster than the current
1F20054E6E (40.700)	8/4/98 RM 125.3	8/5/98 RM 123.8 8/14/98 RM 107.9 10/10/98 RM 107.8	
1F224A690C (40.050)	8/4/98 RM 125.3	8/5/98 RM 125.7 8/5/98 RM 125.8 8/7/98 RM 125.9 8/8/98 RM 125.8 8/12/98 RM 123.6 8/14/98 RM 123.5 9/3/98 RM 121.6 9/10/98 RM 121.6 9/24/98 RM 121.6 10/10/98 RM 121.6 11/9/98 RM 121.6	shallow & sandy-mortality or tag loss? same location as above same location as above same location as above same location as above

Table 10. Radio locations from flannelmouth suckers released downstream from Tusher Wash Diversion Dam on the Green River. The frequency (MHZ) of the radio implanted is shown below the total length of the fish. Locations shown are river miles upstream from the confluence with the Colorado River. Tusher Wash Diversion Dam (TWDD) is located at river mile 128.3.

Total Length (Radio Freq.)	Release Date and Location	Contact Date and Location	Comments
340 mm (40.820)	7/31/98 RM 124.6	8/3/98 RM 121.7 8/5/98 RM 121.4	moving slowly downstream moving slowly upstream
376 mm (40.831)	8/13/98 RM 128.1	8/13/98 RM 128.0 8/14/98 RM 127.5 9/3/98 RM 126.3 9/10/98 RM 126.1 11/9/98 RM 126.3	
367 mm (40.841)	9/1/98 RM 128.1	9/2/98 RM 128.1 9/3/98 RM 127.1 9/10/98 RM 126.3 9/24/98 RM 121.2 10/10/98 RM 121.3	
370 mm (40.800)	9/1/98 RM 128.1	9/3/98 RM 128.0 10/13/98 RM 128.7 10/14/98 RM 128.7 10/21/98 RM 128.8 10/22/98 RM 129.0 10/22/98 RM 129.8 11/9/98 RM 129.5	signal lost immediately moved upstream of TWDD upstream of TWDD upstream of TWDD upstream of TWDD upstream of TWDD upstream of TWDD
364 mm (40.011)	9/9/98 RM 128.1	9/10/98 RM 127.3 9/24/98 RM 121.3 10/10/98 RM 121.4 11/9/98 RM 121.4	Lost signal immediately moving below a riffle
353 mm (40.041)	9/9/98 RM 128.1	9/9/98 RM 128.1 9/10/98 RM 126.8 9/24/98 RM 123.1 10/10/98 RM 122.7 11/9/98 RM 122.7	
375 mm (40.771)	9/29/98 RM 128.1	10/13/98 RM 130.5 11/9/98 RM 131.3	moved upstream of TWDD upstream of TWDD
365 mm (40.071)	9/29/98 RM 128.1	10/1/98 RM 128.0 10/9/98 RM 128.0 10/21/98 RM 128.0 10/22/98 RM 128.1 11/9/98 RM 127.7	slightly upstream and closer to shore than location on 10/1/98 in a riffle
394 mm (40.760)	9/29/98 RM 128.1	10/13/98 RM 131.2 11/9/98 RM 130.5	moved upstream of TWDD upstream of TWDD

Table 11. Radio locations from bluehead suckers released downstream from Tusher Wash Diversion Dam on the Green River. The frequency (in MHZ) of the radio implanted is shown in the column with the total length of the fish. Locations shown are river miles upstream from the confluence with the Colorado River. Tusher Wash Diversion Dam is located at river mile 128.3.

Total Length (Radio Freq.)	Release Date and Location	Contact Date and Location	Comments
260 mm (40.711)	8/4/98 RM 125.3	8/5/98 RM 125.8 8/14/98 RM 119.0	
281 mm (40.661)	8/12/98 RM 128.1	8/12/98 RM 128.0 8/13/98 RM 128.0 8/14/98 RM 128.0	
345 mm (40.060)	8/13/98 RM 128.1	8/13/98 RM 128.0 8/14/98 RM 128.0 10/10/98 RM 106.2	
322 mm (40.651)	9/1/98 RM 128.1	9/9/98 RM 128.0 9/10/98 RM 128.1	on opposite side of river from release location
340 mm (40.100)	9/29/98 RM 128.1	10/9/98 RM 127.8 11/9/98 RM 127.0	

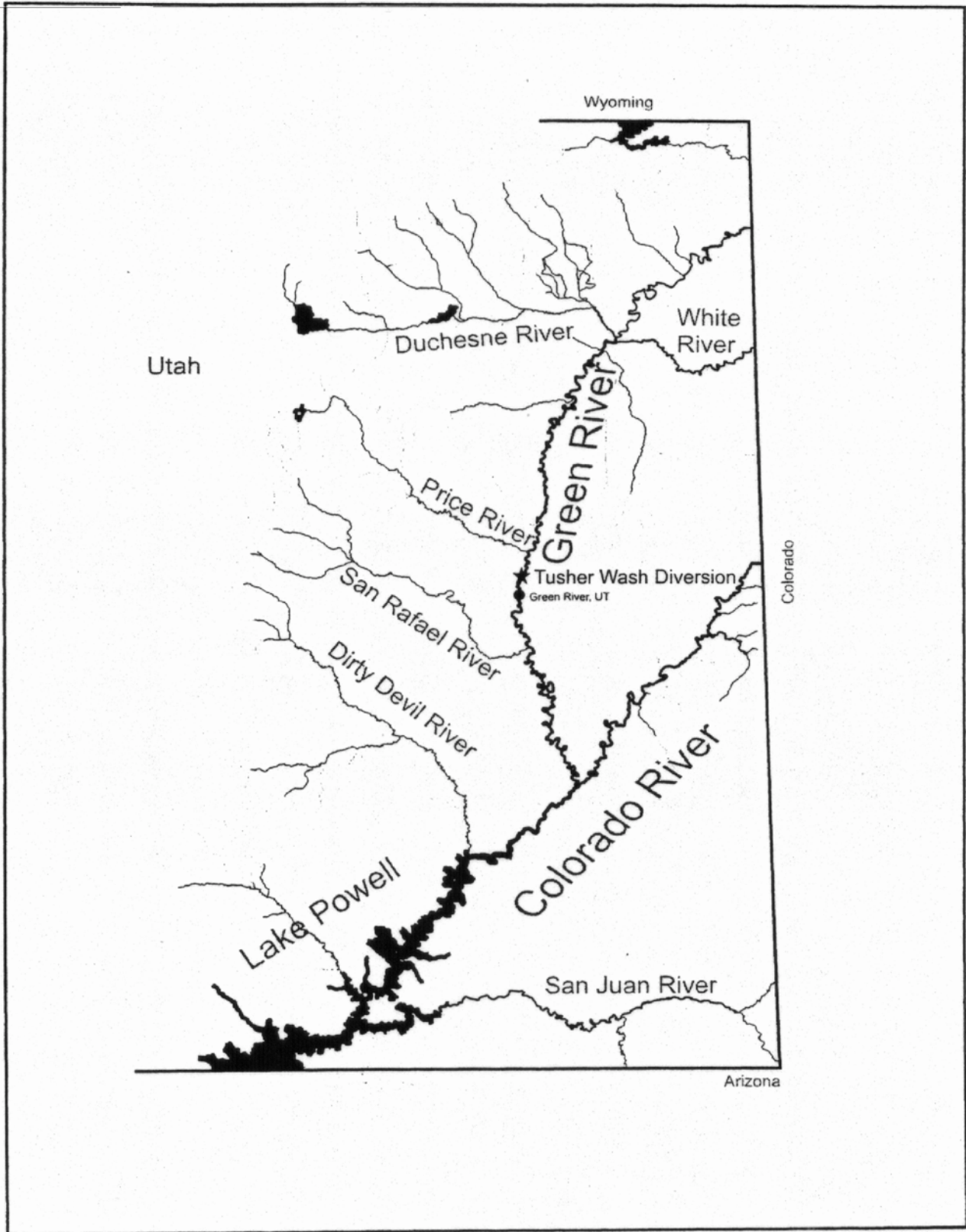


Figure 1. Map of Utah portion of the Green River showing the location of Tusher Wash Diversion Dam.

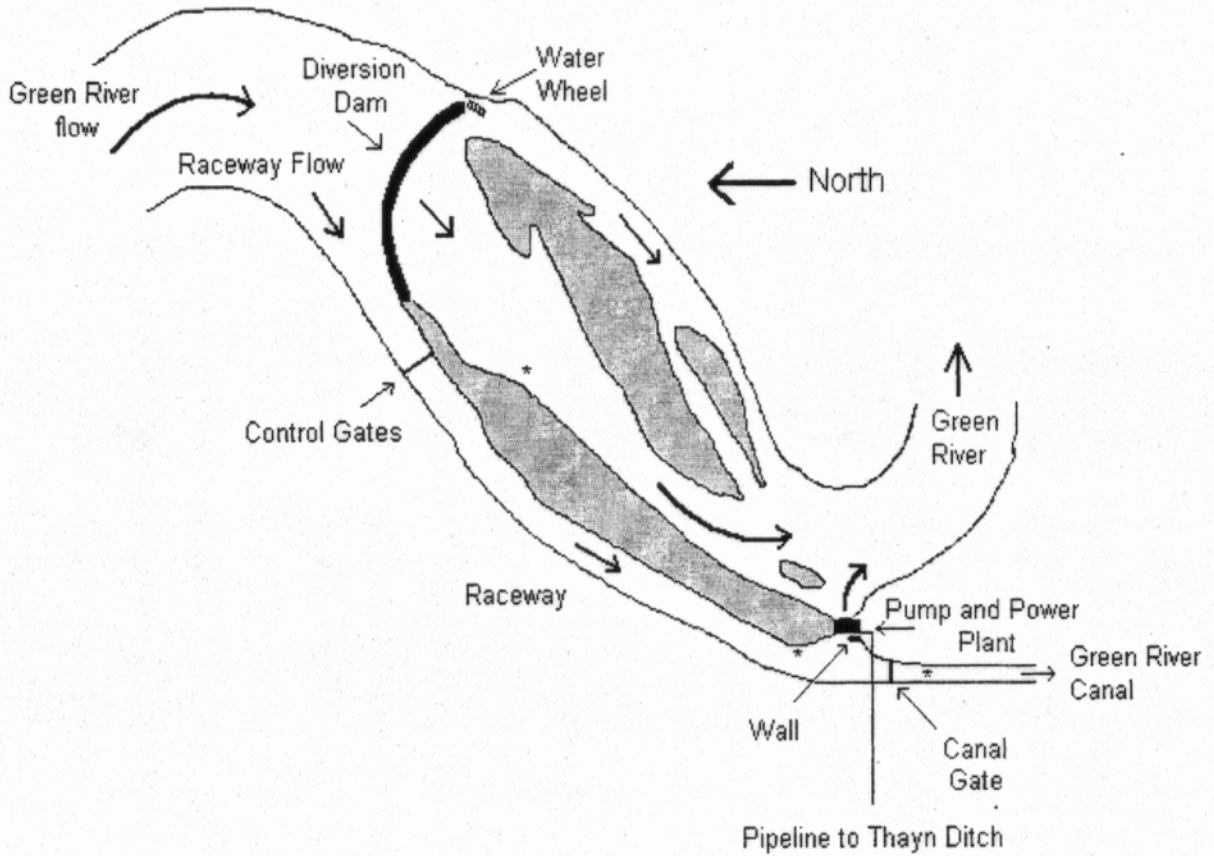


Figure 2. Map of the Green River in the area near Tusher Wash Diversion Dam. Islands are shown in grey and drift net sites are denoted with an asterisk. Note: map is not to scale.

Green River Discharge

1998 vs. 10 Year Average

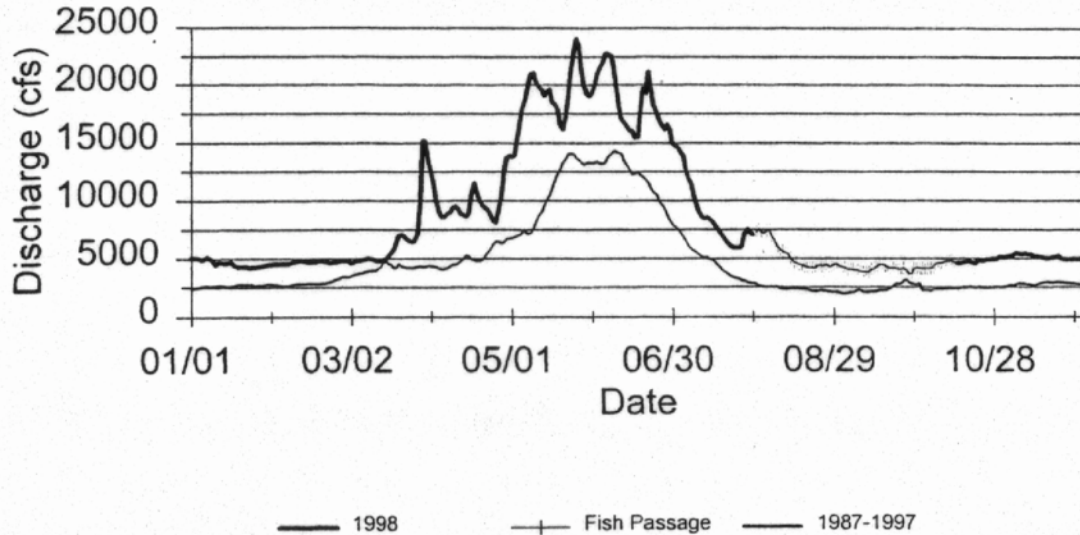


Figure 3. Discharge (cubic feet per second) of the Green River in 1998 compared to the average discharge of the Green River from the 1988 through 1997 water years. Dates in 1998 when tagged fish could have passed Tusher Wash Diversion Dam are also highlighted. Data were collected at the U.S. Geological Survey gage station located near Green River, Utah.

Green River 1998

Average Daily Temperature

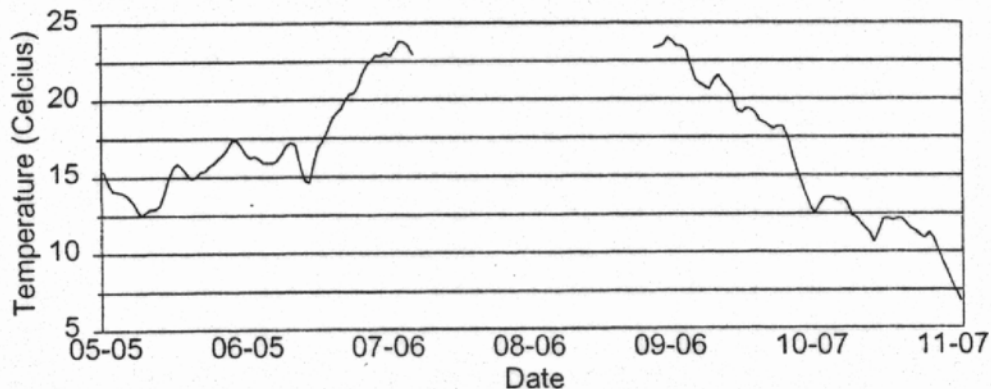


Figure 4. Water temperature (Celsius) of the Green River at Tusher Wash Diversion Dam during the 1998 sampling period. The thermograph was not collecting data during the middle of the summer so no data are shown for that period.

Colorado Pikeminnow Lengths

Upstream vs. Downstream from Dam

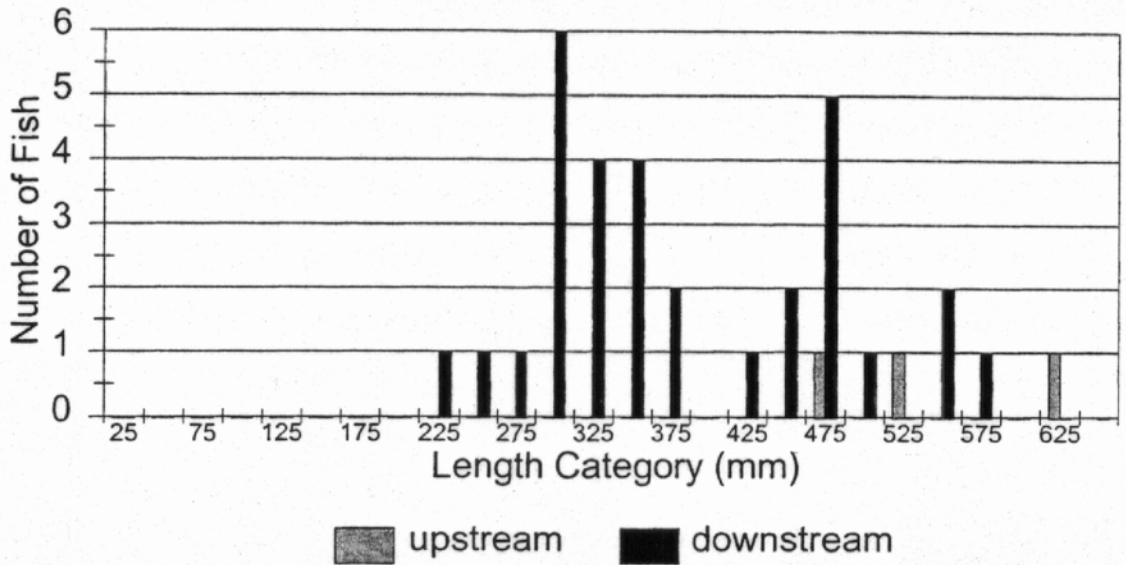


Figure 5. Length-frequency histogram for 34 Colorado pikeminnow captured in the Green River near Tusher Wash Diversion Dam in 1998.

Channel Catfish Lengths

Upstream vs. Downstream from Dam

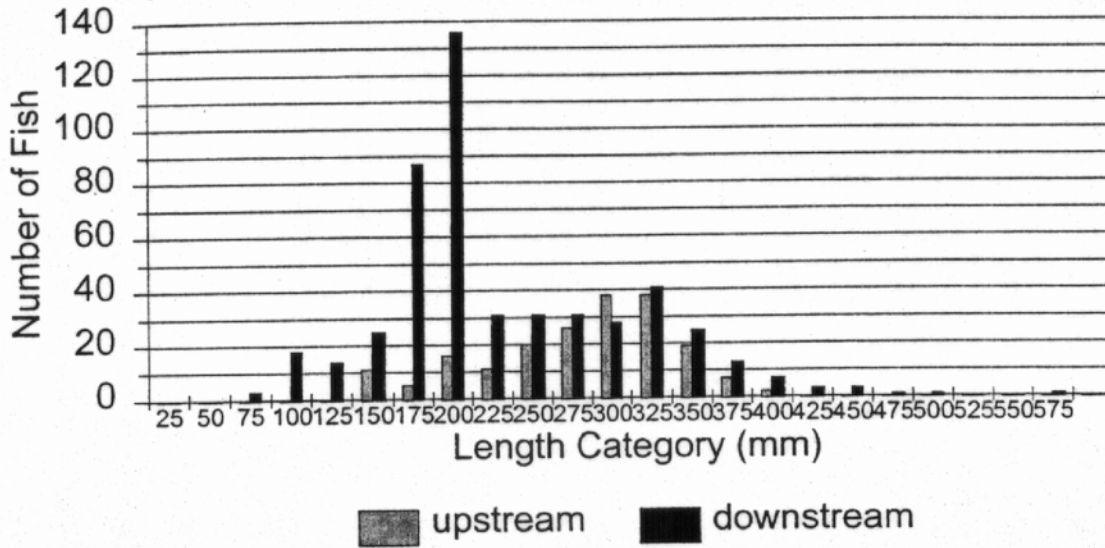


Figure 6. Length-frequency histogram for 692 channel catfish captured in the Green River near Tusher Wash Diversion Dam in 1998.

Flannelmouth Sucker Lengths

Upstream vs. Downstream from Dam

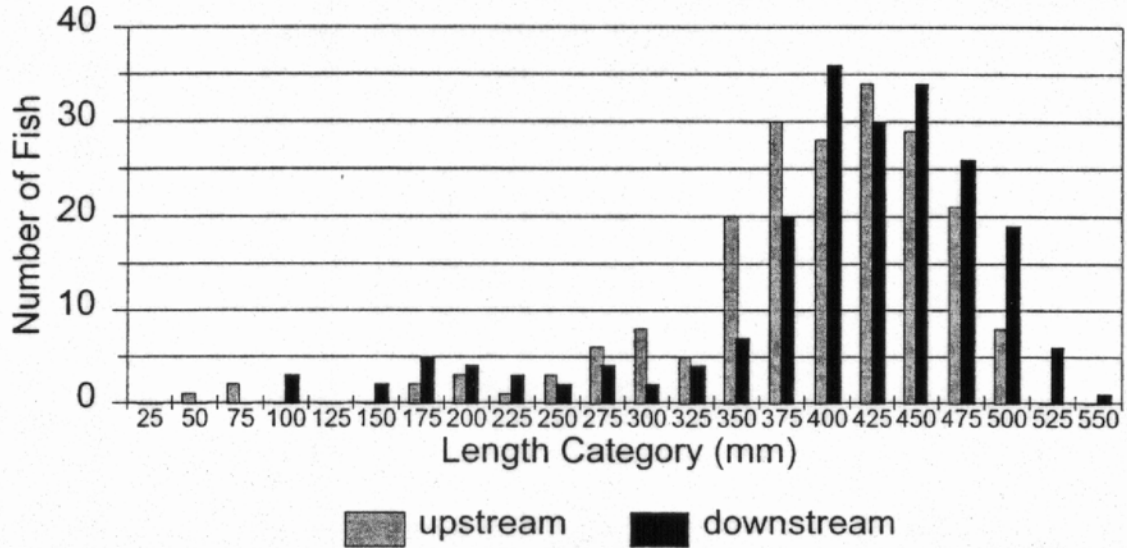


Figure 7. Length-frequency histogram for 409 flannelmouth suckers captured in the Green River near Tusher Wash Diversion Dam in 1998.

Bluehead Sucker Lengths

Upstream vs. Downstream from Dam

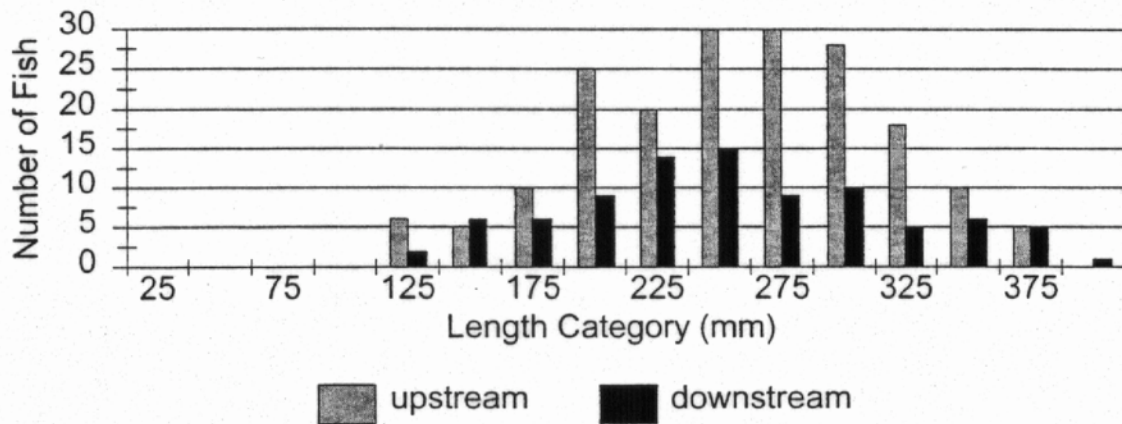


Figure 8. Length-frequency histogram for 275 bluehead suckers captured in the Green River near Tusher Wash Diversion Dam in 1998.

Common Carp Lengths

Upstream vs. Downstream from Dam

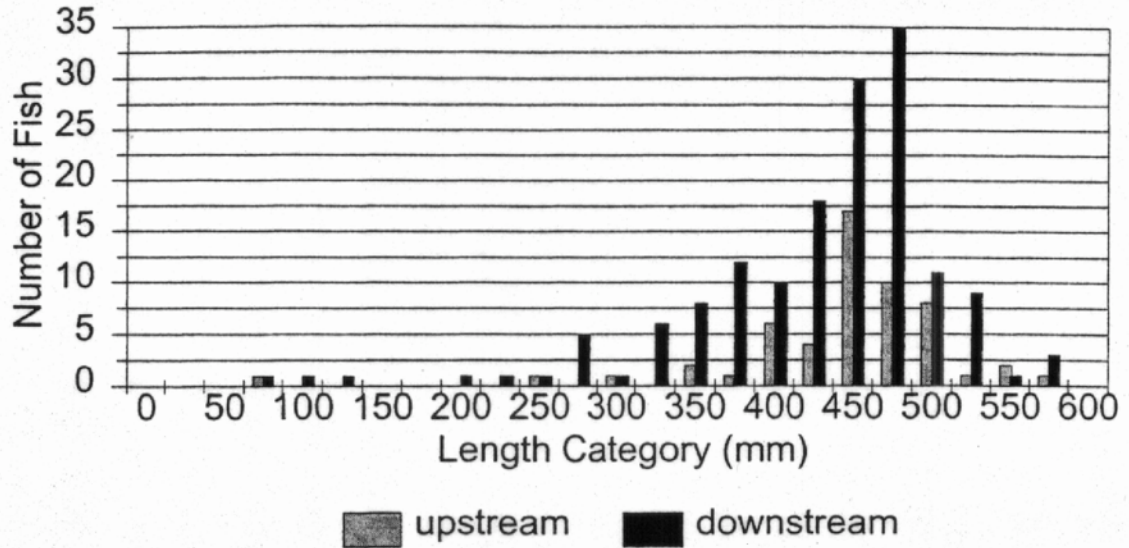


Figure 9. Length-frequency histogram for 211 common carp captured in the Green River near Tusher Wash Diversion Dam in 1998.