Survival and Movement of Adult Rainbow Trout During Winter and Spring in the Henrys Fork of the Snake River

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Abstract

Discharge downstream from Island Park Dam on the Henrys Fork of the Snake River in Idaho is reduced each winter to facilitate storage of irrigation water. The effect this has on survival and movement of adult rainbow trout (*Oncorhynchus mykiss*) in this area is unknown. Additionally, fish movement during the spring has not been evaluated but may affect population estimates conducted in the tailwater monitoring area downstream from Island Park Dam prior to opening of fishing season. Therefore, we used radio telemetry to evaluate winter survival and movement of 61 adult rainbow trout in the Henrys Fork downstream from Island Park Dam under low and extremely low early winter flow conditions. Spring movement was also evaluated to asses whether the population estimates conducted in the monitoring area each spring represent fish from downstream adjacent reaches of the river, and how emigration between mark and recapture periods may affect the population estimate. Survival of radio-tagged trout was nearly 100 percent during early winter under both low and extremely low flow conditions and winter movement did not differ between the two years. Few radio-tagged rainbow trout from downriver were present in the monitoring reach during the time when the population estimate is normally conducted, indicating that large fluctuations in fish numbers in downstream reaches would likely be undetected based on population estimates conducted in the monitoring area. To remedy this, establishing a separate, regular population monitoring area in downstream reaches is recommended. We determined emigration from the monitoring reach between mark and recapture to have a minimal effect on the population estimate. However, we noted that all radio-tagged trout moving out of the monitoring reach during May moved into a short section of river between the monitoring reach and Island Park Dam, presumably to spawn. Therefore, emigration could be largely eliminated by extending the monitoring reach upstream to the dam.

Key words: telemetry, movement, survival, low flow, winter, adult rainbow trout

Introduction

The Henrys Fork of the Snake River contains a world-renowned wild rainbow trout (*Oncorhynchus mykiss*) fishery from Island Park Dam downstream to Mesa Falls. Island Park Dam blocks fish passage and stores sediment that is occasionally released en mass (Van Kirk and Gamblin 2000), impacting spawning habitat (HabiTech 1994) and winter concealment habitat for age-0 trout (Gregory 2000). However, the most recurring impact to the fishery is the reduced winter flows that facilitate storage of irrigation water in Island Park Reservoir (Benjamin and Van Kirk 1999, Gregory 2000, Mitro et al. 2003). The number of juvenile rainbow trout that survive their first winter is directly related to the magnitude of late winter flows from Island Park Dam (Mitro et al. 2003, Garren et al. 2004), but the effect of low winter flows on survival of adult trout in the Henrys Fork is unknown. Winter on the Henrys Fork has been defined as the period during which juvenile rainbow trout adopt concealment behavior (Smith and Griffith 1994). In our study area, this typically occurs from October to May (J. Gregory unpublished data). However, to parse actual winter movements from spawning related movement, we defined winter as that period from October through January.

In addition to the normally occurring low winter flows from Island Park Dam (~ 5.7 m^3/s [200 cfs]), occasional dam repairs and past chemical treatments (see Van Kirk and Gamblin 2000) of the reservoir pool have necessitated complete termination of flow from Island Park Dam. When this occurs, the Henrys Fork is nearly dewatered for ~ 600 m from Island Park Dam to the Buffalo River, a spring-fed tributary that has a winter flow of ~ 5.7 m^3/s (200 cfs). During these periods, the already altered low flow through much of the Henrys Fork is further reduced. These extremely low flow conditions only occur during early winter (Nov and Dec), when flows apparently do not regulate juvenile trout numbers (Mitro et al. 2003, Garren et al. 2004). However, the effect of extremely low flows on adult trout survival is unknown.

Movement of adult rainbow trout in relation to low and extremely low winter flows and winter habitat availability in the Henrys Fork has not been previously studied. Winter concealment behavior has been observed in adult rainbow trout (Meyer and Gregory 2000) and enhances survival of juvenile rainbow trout in the Henrys Fork (Smith and Griffith 1994, Meyer and Griffith 1997a, Mitro and Zale 2002). In fact, where cobble-boulder concealment habitat is absent, juvenile trout emigrate (Meyer and Griffith 1997a) or die (Smith and Griffith 1994) as juvenile trout numbers decline in areas lacking this habitat (Griffith and Smith 1995, Mitro and Zale 2002). Because Box Canyon contains the majority of the cobble-boulder habitat in the study area, most juvenile trout that survive their first winter do so in that stream section (Mitro and Zale 2002). If cobble-boulder concealment habitat is important for adult trout in the Henrys Fork, we would expect fall/early winter movements of adult trout into Box Canyon, but it is unknown if such movements occur.

Rainbow trout spawning habitat in the study area is most abundant within the Box Canyon reach, which creates an interesting situation relative to springtime fish population monitoring conducted in this reach. The Idaho Department of Fish and Game (IDFG) conducts annual mark-recapture population estimates within Box Canyon before the fishing season opens in late May (Garren et al. 2008), which coincides with the rainbow trout spawning period. The estimates produced are thought to reflect population trends in Box Canyon and in downriver adjacent reaches of the Henrys Fork. However, how many rainbow trout from downstream reaches may be represented in those estimates because of movement to Box Canyon for either winter habitat, spawning, or other purposes, is unknown.

Emigration, immigration, or mortality of rainbow trout during the springtime population estimate violates the assumption of a closed population. To minimize departure from a closed population, the mark and recapture events were typically separated by 7 days. We believe this relatively short time interval allows fish to redistribute themselves within the monitoring area, while avoiding excessive immigration and emigration (D. Garren, IDFG, personal communication). However, the extent of immigration and emigration within this time period in the monitoring area was unknown. Although mortality within the monitoring area during the sampling period was unknown, spawning-related mortality can be high for rainbow trout (Hartman et al. 1962). High mortality rates during spawning may again violate the assumptions of a closed population, i.e., no deaths occurred within the sampling period.

The objectives of this study were to 1) evaluate survival and movement of adult rainbow trout during typical and extremely low winter flows, 2) assess the extent to which rainbow trout from downstream reaches move into Box Canyon during the winter or spring and are represented in the population estimate, and 3) assess how rainbow trout movement and mortality between the mark and recapture periods may affect springtime population estimates.

Understanding winter movement

and mortality of adult rainbow trout in the Henrys Fork will help managers understand whether flow regimes devised to enhance survival of juvenile rainbow trout (Mitro et al. 2003) affect adult rainbow trout. Springtime movement patterns of adult trout will reveal the extent to which population trends observed in the monitoring area may represent fish from other reaches of the river. Furthermore, quantifying movement and mortality during the time when population sampling is conducted will help managers understand the validity and variability of population estimates.

Study Area

The Caldera Section of the Henrys Fork is about 47 km long and is located in eastern Idaho within the Island Park Caldera (Van Kirk and Benjamin 2000). Our study area was the upstream portion of that section and extended from Island Park Dam to the downstream boundary of Harriman State Park, a distance of 21.4 km (Fig 1).

The river has a higher gradient, and has more available spawning habitat in the upstream reach (Box Canyon, 0.5%) and both gradient and availability of

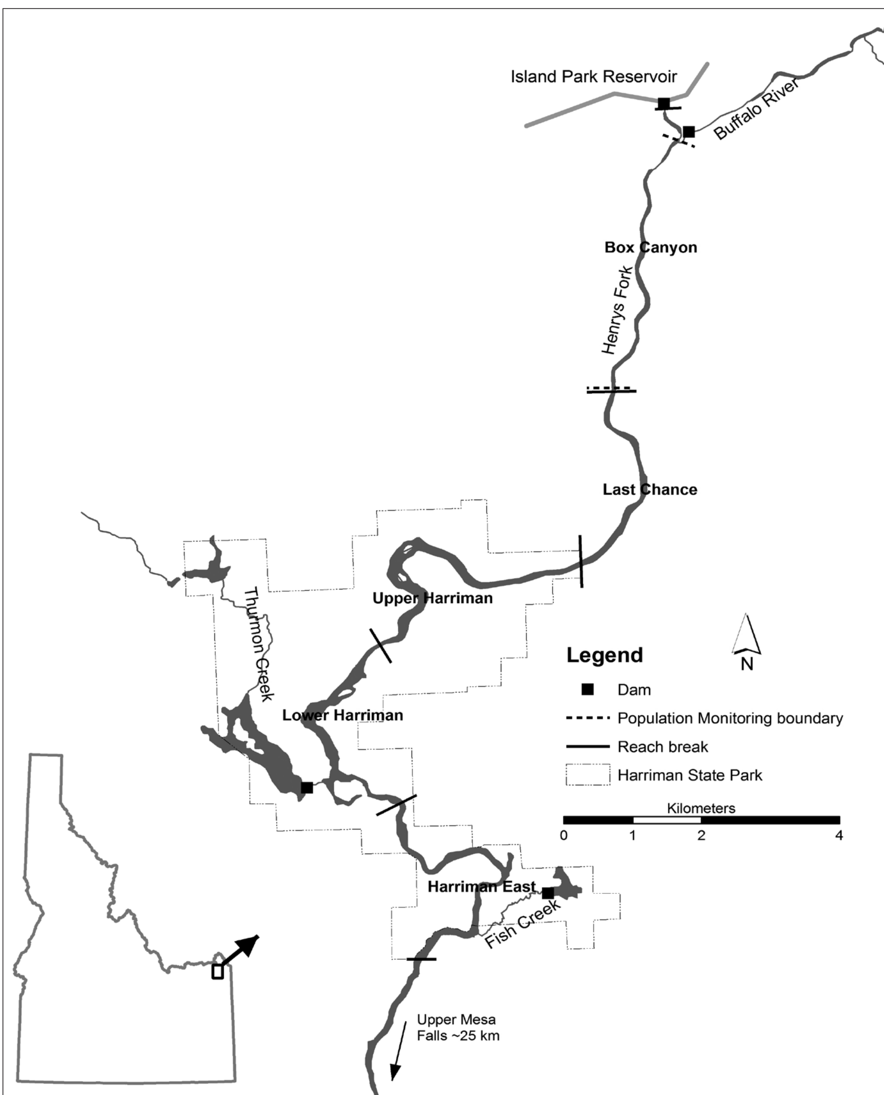

Figure 1. Location of the Caldera Section of the Henrys Fork in eastern Idaho and the various reaches within the study area.

spawning habitat decrease incrementally in downstream reaches to Harriman East, which is characterized with a low gradient (0.1%) and fine substrates.

The study area contains four tributaries that contain spawning habitat: the Buffalo River, along with Blue Spring, Thurmon, and Fish Creeks. The Buffalo River is blocked by a small hydroelectric project dam, about 200 m upstream from its mouth, which adult rainbow trout can pass by means of a fish ladder (Gregory 2000). Rainbow trout spawning habitat is present in the Buffalo River upstream from the dam, but is limited in Blue Spring Creek and the accessible portions of Thurmon and Fish creeks (Gregory 1998).

The IDFG conducts population estimates nearly every May in a monitoring area within Box Canyon. The monitoring area begins at the mouth of the Buffalo River, 0.6 km downstream from Island Park Dam, and extends 3.7 km downstream to the bottom of a riffle near the mouth of the canyon (Garren et al. 2008; Fig. 1). Population estimates (n = 10) from 1995 to 2006 of rainbow trout ≥ 150 mm have a mean density of 1747 trout/km and have ranged from 1018 to 3471 trout/km or about a total of 3767 to 12,841 rainbow trout within the monitoring area in Box Canyon (Log-likelihood method; Garren et al. 2008). Brook trout (*Salvelinus fontinalis*) are present but rare and mountain whitefish (*Prosopium williamsoni*) are plentiful. The entire study area is managed with catch-and-release regulations for rainbow trout and is closed to fishing from December through late May.

Methods and Materials

Mortality and movement of rainbow trout in the Henrys Fork was evaluated by implanting radio transmitters into 61 adult rainbow trout during the fall, and tracking their movements through the following spring. The Henrys Fork in the study area was divided into five reaches (Fig. 1) of analogous habitat types (see Mitro and Zale 2002): Box Canyon (4.9 km), Last Chance (3.3 km), Upper Harriman (4.8 km), Lower Harriman (3.7 km) and Harriman East (4.7 km). In late October of water year 2004, we collected 11 rainbow trout from the Last Chance/ Upper Harriman Reach and 11 rainbow trout from the Lower Harriman Reach by drift-boat electrofishing. Trout were radio tagged and released at the downstream ends of the Upper and Lower Harriman reaches, respectively. The following day, an additional 18 rainbow trout were collected immediately downstream from Island Park Dam by netting during a salvage operation, when flows from Island Park Dam were terminated to facilitate repairs to the outlet works. These fish were radio-tagged and released where water from the Buffalo River Hydroelectric Project enters the Henrys Fork, just upstream from the mouth of the Buffalo River. During November of water year 2005, an additional 21 fish were captured by hook-and-line throughout Box Canyon and were radio tagged and released at their capture locations.

Radio transmitters were surgically implanted using a shielded-needle technique similar to Winter (1996) and Swanberg et al. (1999). Transmitters (Advanced Telemetry Systems model F1815, 3 volt, 12 mm diameter x 36 mm long, 7 g, 150 MHz) had a 30.5 cm trailing whip antenna and a mortality switch that was activated when they remained motionless for 24 hrs. Transmitters were programmed to turn on for 12 hrs every 4 days. Radio transmitters and surgical instruments were sanitized prior to each surgery with either a betadine solution or isopropyl alcohol. Prior to surgery, fish were anesthetized with clove oil (Anderson et al. 1997) at a concentration of 60 mg/l, and were weighed and measured. Length of all radio-tagged trout ranged between 340 and 600 mm and weighed between 0.45 and 2.70 kg. Therefore, transmitter weight was always less than 2 percent of the fish's body weight as suggested by Winter (1996). Surgeries were conducted by placing the fish upside down on a wooden trough-shaped operating table that was submerged in the above anesthetic solution. An incision (~15 mm long) was made anterior to the pelvic girdle and slightly removed from the fish's mid-ventral line. An 18-gauge needle was then pushed through the body wall slightly posterior and laterally from the incision. The transmitter antenna was inserted into the incision and then pushed through the needle; the needle was then removed leaving the antenna extending through the hole made by the needle. The transmitter was then placed inside the body cavity and moved posterior by pulling gently on the antenna. The incision was closed with stainless steel staples (Swanberg et al. 1999) and/or sutures. Fish were observed until the effects of the anesthetic had subsided, and were then released.

Radio-tagged fish were relocated about once every month from the time of tagging until early March. Thereafter, fish were relocated every 4 days until the end of May, and then twice a month throughout the summer and fall. Tracking ended in mid-July 2005. Fish were tracked with an Advanced Telemetry Systems R2100 receiver while either floating the river or following it along the bank. Tracking began at Island Park Dam and proceeded downstream through Lower Harriman and sometimes through Harriman East. Fish locations were recorded relative to Global Positioning System (GPS) reference points along the river. GPS reference points were spaced about 400 m apart in Box Canyon with this spacing increasing to 700 m downstream from Box Canyon. When fish were located near reach breaks or the monitoring area boundaries, care was taken to determine which reach they were in and whether or not they were within the monitoring area. When a mortality signal was encountered the fish was recorded as deceased and the tag was recovered, if possible. Fish that died within four weeks of tag implantation were assumed to be the result of handling and surgery.

Results

Survival of radio-tagged trout during the winter was high during both years.

All fish radio-tagged in Box Canyon survived the early winter period (Nov and Dec) both during extremely low flows (water year 2004) and during the same period of low flows the following water year (Fig. 2). Additionally, late-winter (Jan - Mar) survival of radio-tagged fish was 100 percent for fish that experienced extremely low early winter flows (water year 2004) and was > 80 percent for fish that experienced low early winter flows the following year. Winter survival of radio-tagged fish downstream from Box Canyon was also high; two fish were considered tagging mortalities and the remaining 20 survived through mid-March (Fig. 2).

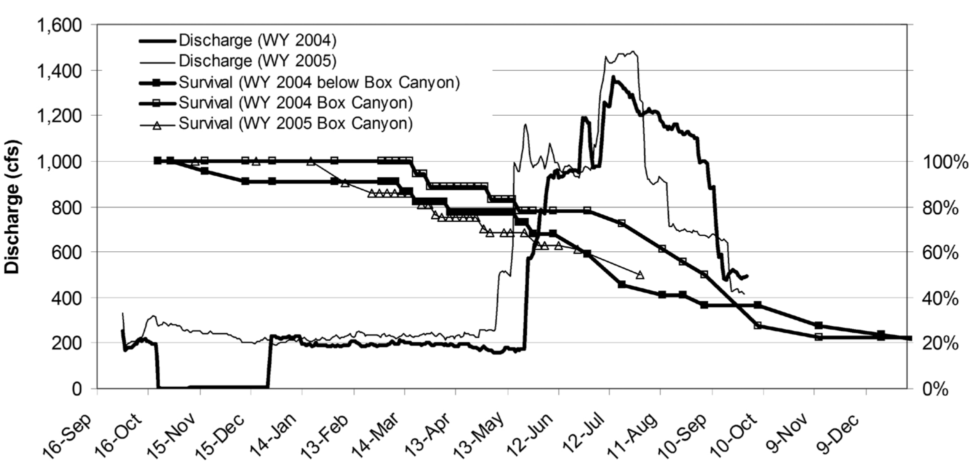

Figure 2. Survival of radio-tagged rainbow trout collected downstream from Box Canyon during water year (WY) 2004 and in Box Canyon during (WY) 2004 and 2005 relative to discharge at Island Park Dam during (WY) 2004 and 2005.

Aside from redistribution movements immediately after tagging, trout movement among fish tagged in Box Canyon was similar during the extremely low flow period and during a corresponding time period the following year. Movements between tracking periods for radio-tagged trout during this period (Nov and Dec) averaged about 0.5 km and ranged from 0 to 2.9 km. Redistribution movements following tagging differed between years. In water year 2004, salvaged fish redistributed themselves rather quickly following tagging. These fish dispersed downstream through Box Canyon within one month (average movement 1.2 km, range 0 to 4.4 km) where they spent the winter, and they did not immediately return to their capture location when water was again released from the dam on 26 December. In water year 2005, a similar redistribution movement was not observed, but rather most fish remained near their capture location (average movement 0.5 km, range 0.0-5.0 km).

Fish tagged in the upper and lower Harriman reaches moved back upstream into the areas from which they were captured within one month, and 15 of 20 were never observed downstream from their release location. Most of the radio-tagged trout from the Last Chance and Harriman reaches did not migrate to Box Canyon before February. The exception to this was one fish that spent the winter immediately downstream from Box Canyon and was located in the lower end of Box Canyon during a single tracking period in December.

Radio-tagged trout from downstream reaches made apparent spawning migrations into the population monitoring area from February through May (Fig. 3), but because movements were staggered and some of those fish moved back out of the monitoring area before May, not all of those fish would have been represented in a population estimate. Throughout this period, radio-tagged fish of all size classes tagged moved to the monitoring area from the Last Chance/

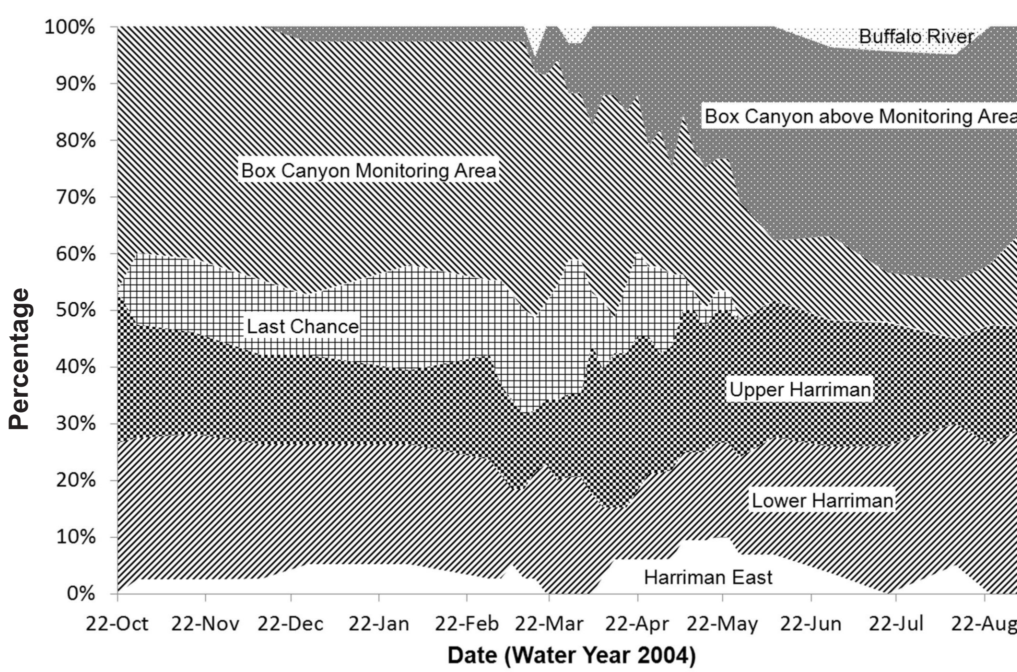

Figure 3. Percentage of radio-tagged adult rainbow trout present in each section of the study area throughout water year 2004.

Upper Harriman reaches (2 of 10) and the Lower Harriman Reach (4 of 10). However, during any given 8-day period in May 2004, during which a population estimate could have been conducted, 6 to 12 percent of fish radio-tagged downstream from Box Canyon were present in the monitoring area. Most of the radio-tagged fish that survived through May returned to their pre-spawning location by June. Most of the radio-tagged fish (11 of 16) that were salvaged immediately below Island Park Dam during water year 2004, returned to their pre-capture location during the apparent spawning period.

All of the fish tagged in Box Canyon during water year 2005 were within the population monitoring area during the first tracking period in May (Fig. 4). During any given 8-day period of May, 8 to 23 percent of those fish moved upstream, out of the population monitoring area, and none moved downstream out of the monitoring area. All of these trout were > 400 mm. No radio-tagged rainbow trout died in the monitoring area during May. However, one radio-tagged trout that had moved upstream out of the monitoring area in May then died 8-12 days later in its new location.

Discussion

Radio-tagged adult rainbow trout winter survival and movement was similar during low and extremely low flow years. Winter survival of radio-tagged rainbow trout in our study was nearly 100 percent, suggesting that even extremely low winter flows do not limit adult trout numbers in the study area at contemporaneous densities (1197 trout ≥ 150 mm/km in the Box Canyon monitoring area; see Garren et al. 2008). Therefore, adult trout survival is not affected by the Island Park Dam current operating procedure of releasing less water in early winter in exchange for more water later in the winter, which increases survival of juvenile rainbow trout (Mitro et al. 2003). One caveat to this assertion is that survival could be negatively impacted if air temperatures drop to the point that ice formation occurs. While shelf ice provides concealment habitat for juvenile

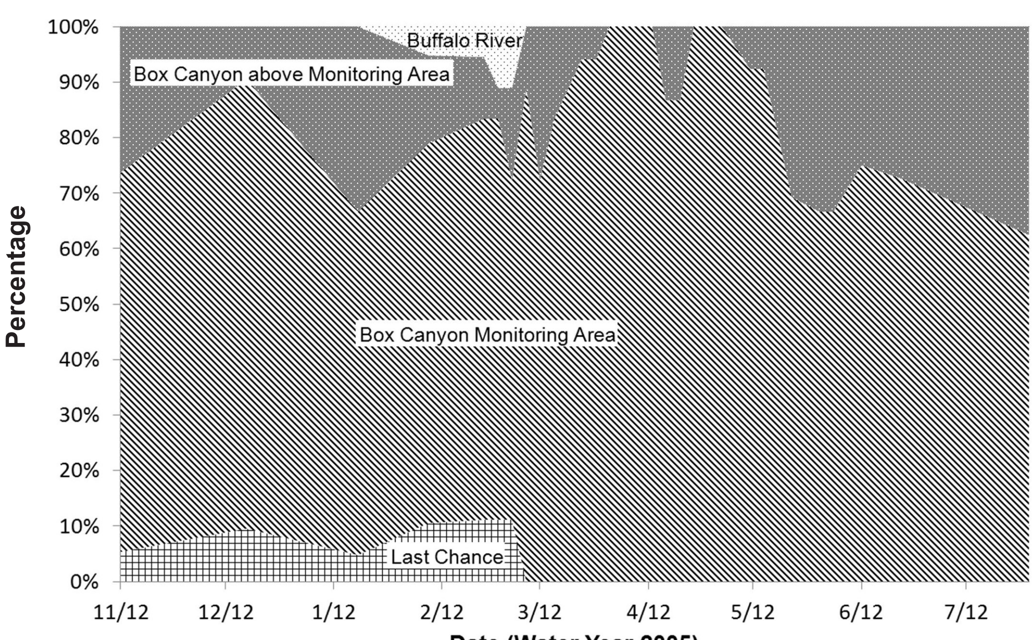

Figure 4. Percentage of radio-tagged adult rainbow trout present in each section of the study area throughout water year 2005.

and adult trout and can cause them to be less reliant on other types of concealment cover (Gregory and Griffith 1996, Jakober et al. 1998), frazil ice (Simpkins et al. 2000) and anchor ice (Chisholm et al. 1987, Jakober et al. 1998, Lindstrom and Hubert 2004) can reduce habitat suitability and result in emigration of fish which may increase mortality. Water released from the hypolimnion of Island Park Reservoir and tributary inflows from the spring-fed Buffalo River typically keep Box Canyon free of ice. However, the resulting open water facilitates formation of frazil ice and anchor ice in downstream reaches (Last Chance and Harriman) of the study area. This frazil ice can adhere to macrophytes causing rapid macrophyte sloughing (Griffith and Smith 1995, Simpkins et al. 2000) effectively reducing concealment habitat for juvenile and likely adult trout (Heggenes et al. 1993) at a time when conditions for trout movement are most severe.

Our observations that survival of adult rainbow trout in the Henrys Fork does not appear to be affected by low winter flows is consistent with those of Sutton et al. (2000) who found no clear demonstrable effect of low winter flows on health of rainbow trout in the San Juan River downstream from Navajo Dam. Furthermore, McKinney et al. (2001) suggested that in the Colorado River downstream from Glen Canyon Dam, small rainbow trout were more strongly influenced by physical factors, such as winter flow, than were large trout. This also seems to be the case in our study area (Mitro et al. 2003, Garren et al. 2004, this study). Given this, we suggest that consideration of juvenile rainbow trout needs may be more important than the needs of adult rainbow trout in formulating winter flow regimes below hypolimnetic release dams. However, additional research is needed to assess this hypothesis in other areas and to determine how it may change in areas further downstream from dams, where stream habitat conditions may be more affected by ice.

Average winter movements for radio-tagged trout in Box Canyon between tracking periods were 0.7 km. These movements are much larger than winter movements observed for rainbow trout (Gido, et al. 2000) and cutthroat trout (*Oncorhynchus clarkii*) (Jakober et al. 1998) in other areas. The stationing of our reference GPS points along the stream could have caused movements to appear magnified. However, the studies outlined above reported a general lack of winter movement for trout, which is contrary to what we observed. Radio-tagged trout in this study may have moved more often because of the relatively moderate winter water temperatures resulting from hypolimnetic releases from Island Park Dam and inflow from the spring-fed Buffalo River.

Radio-tagged fish in our study did not make late-fall or winter migrations among study reaches. Trout migration to wintering areas has been observed in other rivers (Meka 2003), whereas lack of migration to wintering areas suggests that adequate winter habitat was available in reaches where trout also spend the summer (Young 1998). Some radio-tagged fish in our study over-wintered in areas containing minimal small woody debris or cobble-boulder habitat (Last Chance through Harriman East), even though adult rainbow trout have been observed to utilize these structures for concealment during winter days in nearby rivers (Meyer and Gregory 2000). However, other winter habitat features were available in these reaches including submerged aquatic macrophytes and deep pools. These habitat types have also been observed to provide winter cover for adult trout (Heggenes et al. 1993, Cunjak 1996).

Few rainbow trout from downstream reaches are represented in the population estimate that takes place in the monitoring area each spring. Assuming that the movements of our radio-tagged fish are representative of similarly sized untagged trout, between 6 and 12 percent of the ~ 1700 fish > 300 mm present in 2008 from Last Chance through Lower Harriman (IDFG unpublished data) could be expected to be present in the monitoring area when the population estimate is typically completed. This would mean that 102-204 fish from downstream would be represented in the population estimate. The estimated number of fish in the Box Canyon monitoring area fluctuates between 3,700 and 12,900 fish > 150 mm (Garren et al. 2008). Therefore, immigrating trout from down-river could represent 0.7 to 5.4 percent of the estimated number of trout in Box Canyon.

Because migrant fish from downstream are a small portion of the Box Canyon population estimate, downstream fish numbers could fluctuate widely (maybe even by a factor of 10) and independently of Box Canyon fish numbers and not be noticed. For example, if the total Box Canyon population estimate were low, e.g., 4,000 fish, and the fish numbers from downstream increased by a factor of ten, then instead of 200 fish from downstream reaches moving into the monitoring area, 2000 fish could have moved to that area. This would result in an increase in the population estimate from 4000 fish to 6000 fish, a 50-percent increase, but it is unlikely to suggest to managers that fish numbers downstream have increased 10-fold. When fish numbers in Box Canyon are high, fluctuations in fish numbers downstream would be even more obscured. Fish numbers in Box Canyon and areas downstream likely fluctuate together based on some factors such as drought (Erman 1986, Binns 1994), but also may fluctuate independently based on changes in macrophyte abundance, which are an important component of trout habitat downstream from Box Canyon but not in Box Canyon (Van Kirk and Martin 2000). Given the dynamic changes recently observed in macrophyte density and species composition (Van Kirk and Martin 2000, Henry 2010) in the Last Chance and Harriman reaches, regular trout population estimates within that area are needed to reflect fish population trends in those reaches.

Between 8 and 23 percent of our radio-tagged rainbow trout moved upstream out of the monitoring area during any given 8-day period in May 2005, however, it does not necessarily follow that the same proportion of all sizes of untagged fish moved out of the monitoring area. The movement we observed likely reflects spawning movements, which would be expected to involve only the mature adult portion (> 400 mm) of the population. The lack of movement out of the monitoring area by radio-tagged fish < 400 mm supports this hypothesis. In 2005, fish > 400 mm made up 41 percent of rainbow trout captured in the monitoring area (IDFG unpublished data). Therefore, maximum upstream spawning emigration may involve 9 percent of the total population, which is the 23 percent maximum observed emigration rate of radio tagged fish x 41 percent of fish in the population that are > 400 mm and therefore likely to move upstream.

An accurate population estimate for the marking period is based on two assumptions 1) no births or immigration between the mark and recapture periods, and 2) deaths and emigration between those periods affects marked and unmarked fish equally (Gatz and Loar 1988). Therefore, if these assumptions were met, the actual population estimate of 4430 (95% confidence interval 3922-4937) rainbow trout > 150 mm in the monitoring site during 2005 (Garren et al. 2008) should accurately portray the fish present during the marking period. To assess if emigration may have affected the estimate, and therefore what the estimated population would be during the recapture period (after the emigration had occurred), we removed 19 marked fish (23% of the marked fish > 400 mm) from the analysis and calculated a new hypothetical population estimate using the same log-likelihood estimator used by Garren et al. (2008). These calculations yielded a hypothetical population estimate of 4369 (95% confidence interval 3863-4874) rainbow trout > 150 mm. These two estimates are not significantly different as evidenced by their overlapping confidence intervals.

Sources of potential error, besides emigration, exist in the population estimate conducted in the monitoring area each spring. While this study showed that immigration from downriver into the monitoring area is relatively small, we do not know the extent of immigration into the monitoring area from the area between Island Park Dam and the mouth of the Buffalo River, upstream from the monitoring area. Additionally, even though no radio-tagged trout died in Box Canyon during May, a few untagged fish may experience spawning related mortality within the monitoring area during this time period.

The primary use of the population estimate for management purposes is not to identify the absolute number of individuals per se, but rather to compare the population estimate obtained with previous and subsequent population estimates to determine whether the population is increasing or decreasing. These comparisons will be biased if detection probabilities are differentially affected by such things as emigration; subsequently, statistical tests should be run to determine if detection probabilities are equal among comparison years (MacKenzie and Kendall 2002).

Based on our study, there may be a relatively easy way to eliminate some of the potential effects of detection probabilities from emigration. During May, migration from the monitoring area by radio-tagged rainbow trout only included movements upstream, into the area between Island Park Dam and the mouth of the Buffalo River. Therefore, this emigration from the monitoring area could be eliminated by extending the monitoring area upstream to Island Park Dam. However, this may cause additional problems such as estimates from the extended monitoring area may not be comparable to estimates from the current monitoring area because fish density may be higher in the added area. Also, the additional time necessary to sample fish in the extended area may result in fewer marking runs being completed, ultimately expanding confidence intervals and making changes in the population more difficult to detect. Another way to eliminate some effects of fish movement or mortality is to conduct the population estimate during the fall when emigration and mortality rates are lower than during the spawning period. However, this is a popular fishery and conducting estimates during the fishing season could be socially unacceptable. After 30 November, when the fishing season has ended, discharge from Island Park Dam is reduced to facilitate storage of irrigation water and is typically too low to conduct an estimate.

Conclusions

- Survival of radio tagged trout in Box Canyon during early winter was 100 percent at low and extremely low flows.
- Consideration of juvenile trout needs may be more important in formulating winter flow regimes below hypolimnetic release dams than are the needs of adult trout.
- Trout movement among radio-tagged rainbow trout in Box Canyon was similar during the extremely low flow period and during a corresponding time period the following year.
- Trout from downstream reaches are present in Box Canyon during May, when population estimates are conducted, but these fish are a small proportion of the overall estimated population. Therefore, fish density fluctuations in downstream reaches could be extensive and yet not be apparent within the population monitoring area in Box Canyon.
- Given the dynamic habitat conditions in the Last Chance and Harriman reaches, regular trout population estimates within that area are needed to reflect fish density trends in those reaches.
- Emigration between the mark and recapture periods of the population estimate causes the estimate to calculate the number of trout present in the monitoring area during the mark period. However, a hypothetical population estimate, which accounted for emigration of marked fish, was not significantly different from the actual population estimate.
- Deciphering trends in population abundance in the monitoring area should include analyses to determine whether detection probabilities are the same.

- Differences in detection probabilities among years may be lessened by extending the monitoring area upstream to Island Park Dam. However, additional monitored length could introduce other problems.

Acknowledgments

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Literature Cited

Anderson, W. G., R. S. McKinley, and M. Colavecchia. 1997. The use of clove oil as an anesthetic for rainbow trout and its effects on swimming performance. North American Journal of Fisheries Management 17:301-307.

Benjamin L. and R. W. Van Kirk. 1999. Assessing instream flows and reservoir operations on an eastern Idaho river. Journal of the American Water Resources Association 35:899-909.

Binns, N. A. 1994. Long-term responses of trout and macrohabitats to habitat management in a Wyoming headwater stream. North American Journal of Fisheries Management 14:87-98.

Chisholm, I. M., W. A. Hubert, and T. A. Wesche. 1987. Winter stream conditions and use of habitat by brook trout in high-elevation Wyoming streams. Transactions of the American Fisheries Society 116:176-184.

Cunjak, R. A. 1996. Winter habitat of selected stream fishes and potential impacts from land-use activity. Canadian Journal of Fisheries and Aquatic Sciences 53 (Suppl. 1):267–282.

Erman, D. C. 1986. Long-term structure of fish populations in Sagehen Creek, California. Transactions of the American Fisheries Society 115: 682-692.

Garren, D., W. C. Schrader, D. Keen, and J. Fredericks. 2004. Regional fisheries management investigations Upper Snake Region, (Subprojects I-G, II-G, III-G, IV-G). 2003 Job Performance Report, Program F-71-R-28, Idaho Department of Fish and Game, Idaho Falls.

Garren, D., W. C. Schrader, D. Keen, and J. Fredericks. 2008. Fishery management annual report: Upper Snake Region 2006. Idaho Department of Fish and Game, Idaho Falls.

Gatz, A. J., Jr. and J. M. Loar. 1988. Petersen and removal population size estimates: combining methods to adjust and interpret results when assumptions are violated. Environmental Biology of Fishes 21:293-307.

Gido, K. B. 2000. Stream-channel position of adult rainbow trout downstream of Navajo Reservoir, New Mexico, following changes in reservoir release. North American Journal of Fisheries Management 20:250–258.

Gregory, J. S. 2000. Winter fisheries research and habitat improvements on the Henry's Fork of the Snake River. Intermountain Journal of Science 6:232-248.

Gregory, J. S. 1998. Henrys Fork Habitat Assessment Island Park Dam to Warm River. Gregory Aquatics, Mackay ID for the Henry's Fork Foundation, Ashton, ID.

Gregory, J. S. and J. S. Griffith. 1996. Winter concealment by subyearling rainbow trout: space size selection and reduced concealment under surface ice and in turbid water conditions. Canadian Journal of Zoology 74:451-455.

Griffith, J. S. and R. W. Smith. 1995. Failure of submersed macrophytes to provide cover for rainbow trout throughout their first winter in the Henrys Fork of the Snake River, Idaho. North American Journal of Fisheries Management 15:42-48.

HabiTech. 1994. Flushing flow investigations; Henry's Fork of the Snake River, 1993-1994. Report of HabiTech, Inc., Laramie, WY, to State of Idaho, Department of Environmental Quality, Idaho Falls.

Hartman, G. F., T. G. Northcote, and C. C. Lindsey. 1962. Comparison of inlet and outlet spawning runs of rainbow trout in Loon Lake, British Columbia. Journal of the Fisheries Research Board Canada 19:173-200.

Heggenes, J., O. M. Krog, O. R. Lindas, J. G. Dokk, and T. Bremnes. 1993. Homeostatic behavioural responses in a changing environment: brown trout (*Salmo trutta*) become nocturnal during winter. Journal of Animal Ecology 62:295-308.

Henry, A. 2010. Aquatic Macrophytes at the Henrys Fork of the Snake River during 2009. Prepared for the Henry's Fork Foundation, Ashton, ID.

Jakober, M. J., T. E. McMahon, R. E. Thurow, and C. G. Clancy. 1998. Role of stream ice on fall and winter movements and habitat use by bull trout and cutthroat trout in Montana headwater streams. Transactions of the American Fisheries Society 127:223-235.

Lindstrom, J. W. and W. A. Hubert. 2004. Ice processes affect habitat use and movements of adult cutthroat trout and brook trout in a Wyoming foothills stream. North American Journal of Fisheries Management 24:1341-1352.

McKinney, T., D. W. Speas, R. S. Rogers, and W. R. Persons. 2001. Rainbow trout in a regulated river below Glen Canyon Dam, Arizona, following increased minimum flows and reduced discharge variability. North American Journal of Fisheries Management 21:216-222.

Mackenzie, D. I. and W. L. Kendall. 2002. How should detection probability be incorporated into estimates of relative abundance? Ecology 83:2387–2393.

Meka, J. M., E. E. Knudsen, D. C. Douglas, and R. B. Benter. 2003. Variable migratory patterns of different adult rainbow trout life history types in a Southwest Alaska watershed. Transactions of the American Fisheries Society 132:717–732.

Meyer, K. A. and J. S. Gregory. 2000. Evidence of concealment behavior by adult rainbow trout and brook trout in winter. Ecology of Freshwater Fish 9:138-144.

Meyer, K. A. and J. S. Griffith. 1997a. Effects of cobble-boulder substrate configuration on winter residency of juvenile rainbow trout. North American Journal of Fisheries Management 17:77-84.

Meyer, K. A. and J. S. Griffith. 1997b. First-winter survival of rainbow trout and brook trout in the Henrys Fork of the Snake River, Idaho. Canadian Journal of Zoology 75:59-63.

Mitro, M. G. and A. V. Zale. 2002. Seasonal survival, movement, and habitat use of age-0 rainbow trout in the Henrys Fork of the Snake River. Transactions of the American Fisheries Society 131:271-286.

Mitro, M. G., A. V. Zale, and B. A. Rich. 2003. The relation between age-0 rainbow trout (*Oncorhynchus mykiss*) abundance and winter discharge in a regulated river. Canadian Journal of Fisheries and Aquatic Sciences. 60:135-139.

Simpkins, D. G., W. A. Hubert, and T. A. Wesche. 2000. Effects of fall-to-winter changes in habitat and frazil ice on the movements and habitat use of juvenile rainbow trout in a Wyoming tailwater. Transactions of the American Fisheries Society 129:101-118.

Smith, R. W. and J. S. Griffith. 1994. Survival of rainbow trout during their first winter in the Henrys Fork of the Snake River, Idaho. Transactions of the American Fisheries Society 123:747-756.

Sutton, R. J., C. A. Caldwell, and V. S. Blazer. 2000. Observations of health indices used to monitor a tailwater trout fishery. North American Journal of Fisheries Management 20:267–275.

Swanberg, T. R., D. A. Schmetterling, and D. H. McEvoy. 1999. Comparison of surgical stables and silk sutures for closing incisions in rainbow trout. North American Journal of Fisheries Management 19: 215-218.

Van Kirk, R. W. and L. Benjamin. 2000. Physical and human geography of the Henry's Fork watershed. Intermountain Journal of Science 6:106-118.

Van Kirk, R. W. and M. Gamblin. 2000. History of fisheries management in the upper Henry's Fork watershed. Intermountain Journal of Science 6:263-284.

Van Kirk, R. W. and R. Martin. 2000. Interactions among aquatic vegetation, waterfowl, flows, and the fishery below Island Park Dam. Intermountain Journal of Science 6:249-262.

Winter, J. D. 1996. Advances in underwater biotelemetry. Pp. 555-590 *in* B. R. Murphy and D. W. Willis, editors, Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, MD.

Young, M. K. 1998. Absence of autumnal changes in habitat use and location of adult Colorado River cutthroat trout in a small stream. Transactions of the American Fisheries Society 127:147–151.

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