Jim S. Gregory

Winter Fisheries Research and Habitat Improvements on the Henry's Fork of the Snake River

Abstract

*The rainbow trout (*Oncorhynchus mykiss*) population in the Henry's Fork of the Snake River from Island Park Dam to Riverside Campground is limited by recruitment of juveniles, with the bottleneck occurring during their first winter. Loss of juvenile trout from this area is appreciable—an estimated 188,000 individuals during some years. Fish loss during early winter is related to insufficient habitat that decreases survival and increases emigration. Loss of juvenile trout during late winter is related to loss of macrophyte habitat and low late-winter discharge. During late winter, emigration probably causes much of the loss. Some movement successfully occurs between Last Chance and Box Canyon and between all river sections and Pinehaven-Riverside. However, most of the loss remains unexplained. Habitat improvement projects developed to decrease loss of juvenile trout through this critical winter period have been largely unsuccessful, primarily because of sediment deposition in the structures. One exception may be the installation of a fish passage structure on the Buffalo River that allows spawning rainbow trout from the Henry's Fork to access the spring-influenced Buffalo River, thus giving juveniles the opportunity to spend the winter in warmer water, where woody debris provides habitat throughout the winter.*

Key words: winter, rainbow trout, brook trout, Henry's Fork, Buffalo River, survival, movements, cover, macrophytes, sedimentation, habitat, fish passage.

Introduction

The Henry's Fork of the Snake River from Island Park Dam to Pinehaven supports a world-famous rainbow trout (*Oncorhynchus mykiss*) fishery. However, angling success in this reach has varied over the years from the so-called "glory years" of the 1970s and early 1980s to the leaner years of the late 1980s and early 1990s. Reduced population abundances (Van Kirk and Gamblin this issue) and catch rates (Van Kirk *et al.* 1999) have caused individuals, groups, and agencies to forward an array of explanations and hypotheses (Van Kirk and Griffin 1997). Management strategy changes, such as termination of stocking and implementation of catch-and-release regulations, have undoubtedly played a role in shaping the rainbow trout population abundance and structure in the Henry's Fork (Van Kirk and Gamblin this issue). However, development of management strategies and habitat conditions that will sustain population abundances and catch rates similar to those of the past continues to be a goal.

Increasing abundance of a given population involves identifying the factor that limits that population's abundance and then manipulating that factor (Bailey 1984). Identifying limiting factors is not an exact science, but rather involves forming a "best guess" hypothesis and then testing that hypothesis. In the past, the Henry's Fork sustained artificially high abundances of adult fish, which resulted from stocking

Jim S. Gregory, Gregory Aquatics, 5306 Zollinger Road, Mackay, ID 83251

of catchables and reservoir drawdowns (Van Kirk and Gamblin this issue). Therefore, habitat conditions are presumably adequate for maintaining high abundances of adults. This leaves as possible limiting factors spawning habitat availability or quality, survival of eggs and fry, juvenile rearing habitat, juvenile overwintering habitat, and predation on juvenile trout. Based on unpublished data collected in the mid-1980s, Griffith (1988) hypothesized that winter habitat for juvenile rainbow trout may limit trout production on the Henry's Fork. Limited winter habitat along the banks (Contor 1989), loss of macrophyte habitat over the winter (Griffith and Smith 1995), and low apparent survival estimates (Meyer 1995, Mitro 1999) support this hypothesis. Winter survival in other rivers (compiled by Smith and Griffith 1994) averaged 49.8 percent (SD = 18.0%), whereas in-river apparent survival in the Henry's Fork downstream from Box Canyon is much lower (Meyer 1995, Mitro 1999). Winter survival of juvenile trout in the Henry's Fork is a function of size as fish enter winter (Smith and Griffith 1994, Meyer and Griffith 1997a), amount of adequate habitat through winter (Griffith and Smith 1995), effect of discharge on habitat (Mitro 1999), and water temperature (Smith and Griffith 1994, Meyer and Griffith 1997a).

Winter on the Henry's Fork has been defined as the period during which juvenile rainbow trout adopt concealment behavior (Smith and Griffith 1994). This typically occurs in the Henry's Fork at water temperatures <8 °C (Contor 1989). Despite air temperatures that drop below –30 °C, releases from the hypolimnion of Island Park Reservoir and the spring-fed Buffalo River, which enters the Henry's Fork near the top of Box Canyon, keep the Box Canyon and Last Chance reaches relatively warm (Smith 1992). Therefore, anchor ice is rare and surface ice is usually limited to areas along the bank, except during years of very low discharge (Snyder 1991, Griffith and Smith 1995). However, water temperatures in Harriman East remain near 0 °C for much of the winter (Smith 1992), and surface ice there can be extensive (Snyder 1991).

Questions that have provided direction for much of the research conducted in the Henry's Fork since the mid-1980s have been 1) what aspect of winter ecology of juvenile trout limits winter survival, and 2) how can that factor be manipulated so that it is no longer limiting? The purpose of this paper is to 1) review in somewhat chronological order winter fisheries research and habitat improvement projects on the Henry's Fork, 2) discuss individual research findings as they relate to each other including parallels and discrepancies, and 3) portray an overall hypothesis of the response of the Henry's Fork fishery to winter conditions. All geographic locations identified in this paper appear on the maps in Van Kirk and Benjamin (this issue).

Winter Ecology Of Juvenile Rainbow Trout In The Henry's Fork

Effects of Habitat Type, Temperature, Species, and Size on Survival

Juvenile trout and salmon conceal themselves during winter days in cobble or boulder substrates (Hartman 1963, Chapman and Bjornn 1969, Campbell and Neuner 1985) and in woody debris and undercut banks (Bustard and Narver 1975). In the Henry's Fork near Last Chance, juvenile rainbow trout have been observed to conceal in boulder substrate along the stream margins (Contor 1989) and, during the early part of the winter, in mid-channel macrophytes (Griffith and Smith 1995).

As light levels decrease, juvenile trout emerge from concealment to feed (Contor and Griffith 1995). The following studies were conducted to assess the importance of these habitat types and their effect on survival and retention of juvenile rainbow trout in the Henry's Fork.

Winter habitat use and availability in the Henry's Fork was studied by Contor (1989), who observed that at night, juvenile trout were associated almost exclusively (96%) with bank areas containing boulder clusters, undercut banks, and submerged willows. This type of bank habitat was present along all of Box Canyon, 20.0 percent of Last Chance, none of Harriman, 1.4 percent of Harriman East, and 2.3 percent of Pinehaven. Boulders and cobbles inundated by fine sediments did not have fish associated with them.

Given that Contor (1989) had found that cobble and boulder substrates were an important winter habitat component in the Henry's Fork and Hunt (1969) had found that brook trout (*Salvelinus fontinalis*) survival was greater at higher water temperatures, Smith and Griffith (1994) held fish in cages containing or lacking cobble substrate at four locations along a thermal gradient during the winter of 1989-1990. Survival in the cages ranged from 63 percent at the coldest site (mean water temperature 0.8 °C) to 100 percent at the warmest site (mean water temperature 6.5 °C). Survival was 11-24 percent higher in cages that contained cobble substrate than those with silt or gravel bottoms. Also, survival was size dependent, with significantly fewer smaller fish (<125 mm in total length) than larger fish surviving. Early winter was identified as a critical survival period, as 95 percent of the mortality occurred before 8 December. This was consistent with the metabolic-deficit hypothesis proposed by Cunjak *et al.* (1987).

During the winter of 1993-1994, juvenile trout were smaller (mean total length 86 mm) than in 1989-1990 during the Smith and Griffith (1994) study, in which mean total length of juvenile trout was 125 mm. Low summer water temperatures during 1993 likely caused this. Because overwinter survival was size-dependent in 1989-1990, it was hypothesized (Meyer and Griffith 1997b) that when most of the cohort was small (<125 mm as in 1993-1994), survival of the age class would be low, inferring that winter survival was dependent on summer growth conditions. Meyer and Griffith (1997a) assessed winter survival during 1993-1994 for rainbow trout as it related to fish size (given the smaller mean length, fish <90 mm were defined as small) and water temperature. They also assessed differential survival of brook trout and rainbow trout. Juvenile rainbow and brook trout of varying sizes were placed in cages at Last Chance and Harriman East in November. When mortality data from all cages were combined, 68 percent of the mortality occurred during early winter, and 4 percent occurred during late winter (Meyer and Griffith 1997a). No significant difference existed in survival of fish longer than 90 mm versus shorter than 90 mm at the Last Chance site (the warmer location). Statistical analysis of survival at the colder site (Harriman East) was not possible because of loss of some cages to ice damage. However, in the single cage that completed the winter intact, all five of the large juvenile rainbow trout survived, whereas only one of the five small trout survived. Meyer and Griffith (1997a) concluded that where habitat is suitable and temperatures are relatively high, energy reserves in even the smallest members of a cohort may be adequate to allow them to successfully survive their first winter. However, low temperatures at Harriman East may have reduced survival of the small rainbow trout there.

Brook trout survival averaged 60 percent and was significantly lower than for equal-sized rainbow trout, whose survival averaged 87 percent (Meyer and Griffith 1997a). Brook trout that died were smaller than those that survived. Meyer and Griffith (1997a) hypothesized that the lower survival rate of brook trout may have been a function of the type of winter habitat (cobble and boulder substrate) offered to them, which may have been more suitable for rainbow trout (Campbell and Neuner 1985, Smith and Griffith 1994, Meyer and Griffith 1997b) than for brook trout, which select undercut banks, woody debris, pools, and vegetation during winter (Cunjak and Power 1986). Brook trout comprise a low percentage of the fish assemblage in the Henry's Fork despite the possibility of emigration from the Buffalo River (Meyer 1995, Gregory 2000a), which supports an abundant brook trout population. Differential habitat selection and habitat availability may be responsible for this.

If survival is size-dependent and lower at sites with lower water temperatures, then winter mortality may be negligible even for small fish near groundwater springs, where winter water temperatures are high. Data from Chick Creek (a spring-fed tributary to the Buffalo River) support this hypothesis, as fish densities there remained stable during winter in contrast to those in the Henry's Fork (Griffith *et al.* 1996), despite juvenile rainbow trout in the Henry's Fork being larger than those in Chick Creek.

In cages with cobble and boulder substrate present, survival of juvenile rainbow trout did not differ greatly between the winters of 1989-1990 (Smith and Griffith 1994) and 1993-1994 (Meyer and Griffith 1997a), despite the fact that during the latter study, average length of test fish was 40 mm less than in the previous study. Meyer and Griffith (1997a) hypothesized, as did Lindroth (1965), that "smaller fish within a year-class are inferior to the average fish in the same year class but, compared between year-classes, a smaller size does not necessarily reflect inferiority in general viability." As stated by Meyer and Griffith (1997b), "this reasoning contradicts the argument that winter mortality is a direct function of size-related metabolic rates (Shuter and Post 1990)."

The second major habitat type selected by juvenile trout for winter concealment in the Henry's Fork is submerged macrophytes, which are present primarily in the Last Chance and Harriman reaches. During the winters of 1989-1990 and 1992-1993, Griffith and Smith (1995) assessed the importance of macrophytes in providing cover to juvenile trout by marking and recapturing fish and by monitoring macrophyte abundances and juvenile trout densities in macrophyte and bank habitats. Macrophyte density decreased as winter progressed because of senescence and grazing by waterfowl (Van Kirk and Martin this issue). Of the 372 juvenile rainbow trout marked, 63 (17%) were recaptured in either January or February 1990. Ninety-two percent of recaptured fish originally captured and released in mid-channel macrophyte habitat were recaptured along the bank; the remaining eight percent were recaptured in macrophyte habitat. No fish marked in bank sections were recovered in macrophytes. Density estimates corroborated the movement results, as over both winters, fish abundances decreased in mid-channel areas. Telemetrized juvenile rainbow trout moved to cobble and boulder cover when macrophyte densities in the Big Horn River, Wyoming, declined as winter progressed (Simpkins *et al.* 2000). During the winter of 1989-1990, Griffith and Smith (1995) observed a progressive increase in fish density in bank areas, but a decrease occurred in 1992-1993. They hypothesized that the decrease in

1992-1993 was a function of low winter flows and low macrophyte biomass, which caused some of the bank habitat to become dewatered. High macrophyte biomasses in the Henry's Fork increased channel roughness and resulted in deeper water levels at a given discharge than those present at lower macrophyte densities (Vinson *et al.* 1992).

Water levels may have been partially responsible for the reduction in juvenile trout density in bank habitat during the winter of 1992-1993. However, Island Park Reservoir was drawn down to minimum pool during the autumn of 1992 and held there for several days. This caused 50,000-100,000 tons of sediment to be mobilized from the reservoir bottom and deposited in the Henry's Fork (HabiTech, Inc. 1994). Sediment was deposited in low-velocity areas including those along the banks. This sediment affected the bank habitat in Last Chance by filling spaces between rocks making them ineffectual as concealment cover for juvenile trout (Contor 1989). Despite the fact that macrophytes do not retain fish throughout the winter, they may play an important role in providing habitat through early winter, particularly because mid-channel habitat comprises a much larger percent of total habitat than does bank habitat.

Emigration of Juvenile Trout During Winter

Smith and Griffith (1994) and Meyer and Griffith (1997a) showed that survival of juvenile trout in cages in the Island Park Dam to Harriman East section of the Henry's Fork ranged from 57 to 100 percent. These relatively high survival rates could have been caused in part by protection from predation afforded by the cages. However, the high survival rates combined with greater observed losses of free-ranging juvenile trout in the river (Griffith and Smith 1995) led to the hypothesis that loss of juvenile trout through the winter in the Henry's Fork below Island Park Dam was caused primarily by emigration, rather than mortality. Meyer and Griffith (1997a) studied juvenile rainbow trout emigration at Last Chance by placing varying densities of trout in test enclosures with (treatment) and without (control) cobble and boulder substrates. Three treatments were tested: 20 rocks with none touching each other, all 20 rocks touching each other arranged in a single layer, and all 20 rocks touching each other arranged in a double layer. Fish were placed in the enclosures and given 48 hours to acclimate, after which a downstream funnel trap was opened allowing fish to emigrate from the enclosure. After another 48 hours had passed, fish still in the enclosure were considered residents and those that had moved into the trap were considered emigrants. Significantly more residents remained in the enclosures with complex cover (Meyer and Griffith 1997a). There was no significant difference in the number of residents between the treatments using single or double layers. This study demonstrated that rainbow trout vacate areas lacking adequate winter concealment habitat and implied that decreasing densities of juvenile trout over winter, both along the bank and in mid-channel macrophytes, may be caused by emigration.

Meyer (1995) monitored densities of juvenile trout at reference locations in Box Canyon, Last Chance, and Harriman State Park through the winter of 1993-1994 to further examine possible movement of juvenile trout in the Henry's Fork. Densities in all three locations decreased through the winter, with densities nearing 0 fish/100m^2 in Harriman State Park and Last Chance during mid- and late winter, respectively. However, density of rainbow trout in Box Canyon decreased between early and mid-winter and remained stable between mid- and late winter (Fig. 1). Meyer (1995) concluded

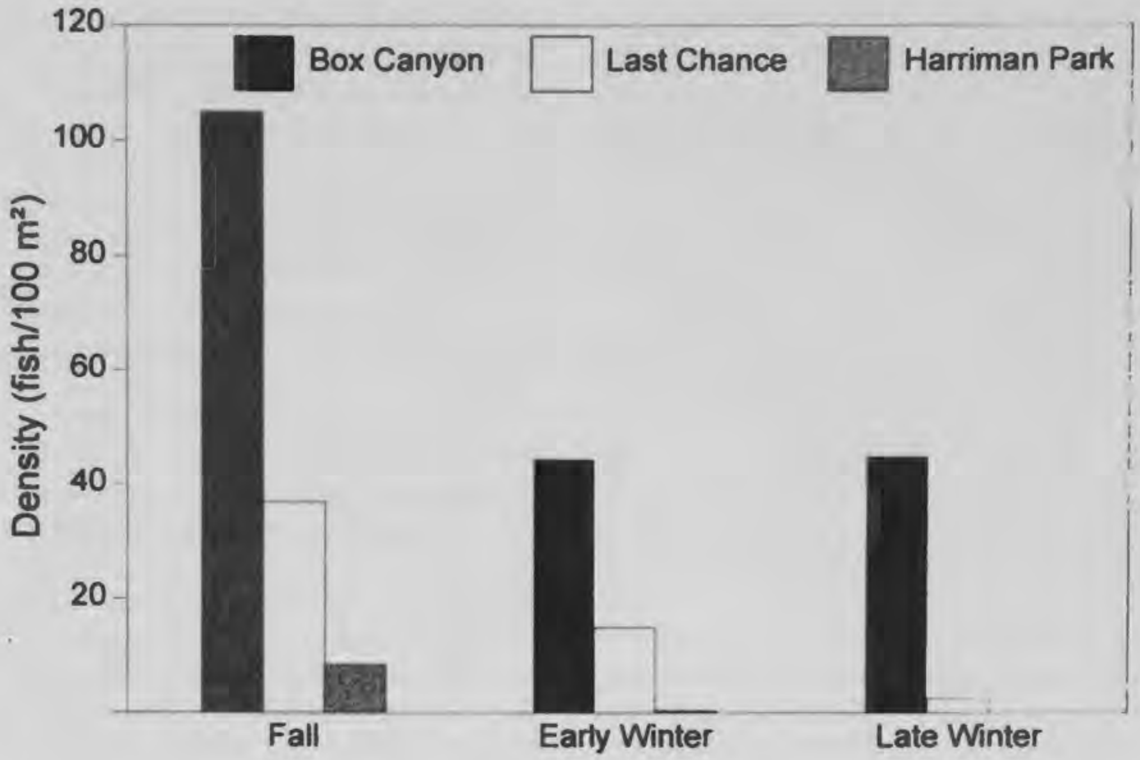

Figure 1. *Mean densities of juvenile rainbow trout along the stream margin at Box Canyon, Last Chance, and Harriman State Park during the winter of 1993-1994 in the Henry's Fork of the Snake River (From Meyer 1995; reproduced with permission from Idaho State University and the author).*

that few juvenile trout survived the winter in Harriman State Park and Last Chance but survival was higher in Box Canyon, which contains cobble and boulder substrates. The majority of fish loss observed by Meyer (1995) occurred during early winter.

Meyer (1995) observed direct evidence of movement of brook trout to Box Canyon, as their densities in that reach increased from 1.6 to 6.0 fish/100 m^2 over the winter. He hypothesized that brook trout were immigrating from the Buffalo River. This was later shown to occur, with most brook trout entering the Henry's Fork after the first of September (Gregory 2000a). During the winter of 1993-1994, mean length of rainbow trout increased significantly (from 86 mm to 126 mm) at Last Chance and slightly (from 83 mm to 90 mm) in Box Canyon. Meyer (1995) attributed these changes to size-dependent mortality or movement, with the magnitude of size-dependency related to harshness of conditions. Winter conditions are harsher at Last Chance than in Box Canyon because of lower water temperatures.

Population-Scale Studies of Juvenile Fish Loss

The above studies suggested only relative magnitudes of winter mortality and movement of age-0 trout in the Henry's Fork. Aside from a few unpublished extrapolations of density estimates, actual numbers of juvenile trout that survived their first winter in the Henry's Fork remained a loose approximation until Mitro (1999) extrapolated juvenile trout abundance in five river sections from Island Park Dam to Riverside Campground, based on a large number of density estimates in summer, autumn, and spring. Loss of age-0 trout between summer and autumn was minimal; the greatest loss occurred during winter. In autumn 1995, 1996, and 1997, an estimated 35,000-80,000 age-0 trout were present in Box Canyon and an estimated 90,000-150,000 age-0 trout were present in Last Chance. Spring abundance estimates in Box Canyon in 1996, 1997, and 1998 ranged from 8,000 to 15,000. Apparent winter survival rates of juvenile trout in Box Canyon were 23, 18, and 21 percent through those respective winters. Apparent survival in Last Chance, Harriman, and Harriman East, based on catch-per-unit-effort, was lower (0-11%) than in Box Canyon (Mitro 1999). Apparent survival for Pinehaven-Riverside was over 100 percent because fish migrated there from other river sections, but too few fish remained there after winter to calculate an abundance estimate (Mitro 1999). Space is the primary factor regulating stream fish populations in winter (Cunjak 1996). Fish located in suitable winter habitat remain through the winter, whereas those in areas with inadequate habitat tend to leave (Bjornn 1971, Cunjak and Randall 1993, Griffith and Smith 1995). Thus, low apparent survival rates in Last Chance, Harriman, and Harriman East supported the hypothesis that winter habitat in these areas is inadequate to support juvenile trout through their first winter.

Mortality (or emigration or both) in Box Canyon through the winter did not appear to be size-dependent although the median length of fish captured in Box Canyon increased by 8 mm during the winter of 1996-1997 and 3 mm during the winter of 1997-1998 (Mitro 1999). Similarly, average length increased 7 mm during the winter of 1993-1994 (Meyer 1995). These consistent increases in fish length over winter in Box Canyon may indicate slight size-dependent mortality or movement, or they may simply indicate growth during winter. This is possible in Box Canyon because of warm inflows from the spring-fed Buffalo River, which enters the Henry's Fork at the head of Box Canyon, and the relatively warm water released from the hypolimnion of Island Park Reservoir. Smith (1992) observed a three-percent increase in condition factor (Anderson and Neumann 1996) of fish in cages containing cover placed between Island Park Dam and the mouth of the Buffalo River.

Mitro (1999) found that loss of juvenile trout at Last Chance was primarily from mid-channel areas, whereas fish densities along the banks remained relatively constant throughout winter. Most of the loss of juvenile trout from the Last Chance reach occurred from November through February. These trends were similar to those reported by Griffith and Smith (1995). Mitro (1999) found that loss of fish from Last Chance occurred over a longer period than the early-winter period identified for mortality in cage studies by Smith and Griffith (1994) and Meyer and Griffith (1997a). Therefore, emigration, rather than mortality, probably caused much of the loss of fish from Last Chance. Loss may have been caused by mortality if predation was the primary cause of mortality (predators were excluded from the cages used to derive survival estimates) or if the cages actually enhanced survival during mid- and late but not early winter. Neither case is likely.

Mitro (1999) marked 11,881 juvenile rainbow trout and subsequently recaptured 245 (2%) of them in an attempt to quantify movement of juvenile trout in the Henry's Fork between Island Park Dam and Riverside Campground. Most (210) of these were age-0 fish, and the remainder (35) were age-1 fish (fish in this study were not considered age-1 until their second summer). Overwinter movement of juvenile trout from all sections to Pinehaven-Riverside was observed. Additionally, two juvenile trout moved from Last Chance to Box Canyon between autumn of one year and spring of the following year. This was the only upstream over-winter movement observed. No juveniles marked prior to winter in Last Chance, Harriman State Park, or Harriman East were recaptured after winter in the same river section. Most (31 of 35) of the fish that were recaptured at age 1 were marked at age 0 in the same river section in which they were recaptured. The remaining four age-1 recaptures had all moved downstream (two from Box Canyon to Last Chance, and one each from Box Canyon and Last Chance to Pinehaven-Riverside). Based on recaptured age-0 trout, the probability of movement from upper river sections to Pinehaven-Riverside was calculated at 0.0092.

Based on this movement probability, Mitro (1999) calculated, for example, that during the winter of 1997-1998, 1,841 age-0 trout would be expected to move to Pinehaven-Riverside from upriver sections. In all upriver sections except Box Canyon, too few juvenile trout remained in spring to derive an estimate of abundance; an estimated 9,730 survived the winter in Box Canyon. Therefore, more than 188,000 juvenile trout died or emigrated from the river reach between Island Park Dam and Riverside Campground during the winter of 1997-1998. Mitro (1999) equated emigration downstream from Riverside Campground with loss from the population. If these fish migrated farther downstream and over Mesa Falls, a barrier to upstream migration, then they would be lost from the population. However, over 10 km of river is present between Riverside Campground and Mesa Falls. Furthermore, this section is relatively steep (average gradient 0.71%) and contains cobble, boulder, and bedrock substrates (Gregory 1999a). Therefore, some fish migrating downstream of Riverside may possibly spend the winter in the canyon between Riverside Campground and Mesa Falls and possibly return to the study reach. This was not observed by Mitro (1999) based on recaptures of age-1 fish. However, recapture of age-1 fish was low and it is possible that fish that move to the canyon section might stay there until age 2 or later.

Although most mortality of juvenile trout occurs early in the winter (November; Griffith and Smith 1995, Meyer 1995, Meyer and Griffith 1997a), Mitro's (1999) results suggest that the time period of greatest emigration, and therefore loss, of juvenile fish from the Island Park Dam to Riverside reach occurs later in the winter (January). The disposition of most of the fish that leave Last Chance and Box Canyon remains unknown. Although whirling disease, presumably in combination with winter stresses, was a possible factor (Gustafson [1998] identified the Island Park Dam tailwater as a high-risk area for whirling disease), high winter survival of fish in cages (Smith and Griffith 1994, Meyer and Griffith 1997a) suggested this probably was not the case.

Effects of Winter Discharge on Survival and Retention

Mitro (1999) observed that abundances of juvenile trout present in Box Canyon in the springs of 1996, 1997, and 1998 were correlated with late-winter (15 January to 31 March) discharges. Based on this observation, the movement of juvenile trout out of the Last Chance reach in late winter, and the upstream movement of two marked fish from Last Chance to Box Canyon during the winter, Mitro (1999) reasoned that some fish from Last Chance move upstream to Box Canyon. If discharge was high following migration to Box Canyon, more bank habitat would be wetted and therefore more juvenile trout would be present in Box Canyon at the end of winter. From 22 January 1999 through the end of winter, discharge at

Island Park Dam was maintained at about 20 to 21 m^3/s. This discharge was greater than that of two of the previous three winters. Therefore, Mitro (1999) hypothesized that "the spring abundance estimate for Box Canyon would be correspondingly greater than that of two of the previous three winters." As predicted, spring juvenile trout abundance in Box Canyon was greater in 1999 than it had been in the previous two years, during which late-winter discharges were lower. Regression of spring-time abundances of age-0 rainbow trout in the Box Canyon against late-winter (15 January to 31 March) discharges at Island Park Dam showed a significant positive linear relationship (Mitro 1999). Data from Meyer (1995) for the winter of 1993-1994 conformed to this relationship.

This late-winter critical period for juvenile trout in Box Canyon conflicts with density estimates by Meyer (1995) who, during the winter of 1993-1994, observed a decrease in density of juvenile trout during early winter but no change between early and late winter (Fig. 1). However, during the winter of 1993-1994, average late-winter discharge was 11.5 m^3/s, which was lower than any discharge observed by Mitro (1999). Therefore, there may have been no net increase in fish abundance caused by upstream migration of juvenile trout from Last Chance during the winter of 1993-1994. If upstream migration of juvenile trout from Last Chance to Box Canyon during late winter indeed occurs, it lends further credibility to the idea that macrophytes in Last Chance provide important early-winter habitat. However, bank habitat in Box Canyon, increased by high discharge at Island Park Dam, provides the most important late-winter habitat in the Island Park to Riverside reach.

Rainbow trout also can emigrate to Box Canyon from the Buffalo River in late winter and, if conditions are suitable, survive and add to the Henry's Fork population. Meyer (1995) observed increases in brook trout densities in Box Canyon as winter progressed and Gregory (2000a) observed that both brook trout and rainbow trout emigrated from the Buffalo River until at least 1 February. Another possible explanation holds that there are still enough fish left that late-winter discharge creates the final adjustment to the population although much of the mortality and some of the movement may occur during early winter. However, if this were the case, I would have expected Meyer (1995) to observe at least a slight decrease in density between mid- and late winter, unless some other factor had coincidentally reduced fish abundances to that level already.

Juvenile Emigration and Mortality in Other Reaches of the Henry's Fork

The same processes that occur in the Henry's Fork from Island Park Dam to Riverside Campground also appear to occur upstream from Island Park Reservoir. Age-0 trout densities in the Henry's Fork between Coffee Pot Campground and Mack's Inn in early winter (10 November 1998) were 15,500 rainbow trout and 7,500 brook trout/km of stream (Gregory 1999b). Ninety-five percent of the juvenile trout were present in mid-channel macrophytes, and the remainder were along the bank. By late winter (31 March 1999) few macrophytes and no juvenile trout were present in mid-channel areas. Brook trout were the only species of juvenile trout collected along the banks, and their density was only 75 trout/km. Undercut banks and woody debris, which are selected at higher rates by juvenile brook trout than by juvenile rainbow trout (Cunjak and Power 1986), primarily provided cover remaining in this section. Gregory (1999b) hypothesized that, as in Last Chance, reductions in macrophyte densities through winter caused a concurrent reduction in juvenile fish habitat and therefore in fish abundance. Therefore, they either move downstream, presumably to the canyon section near Coffee Pot Rapids or to Island Park Reservoir, or die.

Research Summary

More than 15 years of research supports Griffith's (1988) original hypothesis that winter habitat for juvenile rainbow trout may limit trout production on the Henry's Fork. In Last Chance and Harriman State Park, habitat availability apparently is the primary limitation, especially during mid-to-late winter when macrophytes senesce or are removed by waterfowl and no longer provide adequate habitat for juvenile trout. Additionally, there appears to be a critical late-winter period in Box Canyon that probably is not related to macrophytes because few macrophytes occur in Box Canyon, but may be related to water depth and the associated amount of wetted or undercut habitat along the banks (Angradi and Contor 1989). Because most mortality occurs during early winter, but the greatest loss of fish occurs during late winter, emigration and not mortality probably is the primary cause of fish loss from Box Canyon, Last Chance, Harriman, and Harriman East. The Pinehaven-Riverside reach may be an exception to this trend, because fish migrate to this reach from the others.

Nevertheless, the fate of the majority of juvenile trout produced in the Henry's Fork between Island Park Dam and Riverside Campground is unknown. Because juvenile trout use of the Henry's Fork throughout this reach has been evaluated without finding concentrations of fish and because few tributaries enter the Henry's Fork between Island Park Dam and Mesa Falls, few possibilities exist for disposition of these fish. With the exception of the Buffalo River, tributaries are small and provide a limited amount of habitat for wintering juvenile trout. The Buffalo River was probably inaccessible to juvenile trout for much of the year prior to the installation of the fish ladder in 1996 (Mali 1998). Juvenile trout possibly emigrate successfully to "Cardiac Canyon" downstream from Riverside Campground. Many of these fish also may keep moving and eventually pass the series of waterfalls, which makes return impossible. The last possibility is that migration increases the risk of predation and other types of mortality, and therefore, movement-induced mortality is high. Additional research to examine these possibilities is needed.

Search For Additional Habitat

One way to avoid the unknown loss of juvenile trout is to increase the quality and quantity of habitat available to them in the Box Canyon and Last Chance sections of the river where the greatest abundances of age-0 fish are present at the beginning of winter (Meyer 1995, Mitro 1999). Such attempts to enhance retention of juvenile rainbow trout have been taking place almost as long as the winter research. Nearly every research project was followed by a habitat enhancement project that used the information obtained by the research to guide the design or implementation of the enhancement. Formal reports were seldom written for these projects, and analyses of their success often were cursory. However, in all cases some level of evaluation of project success was conducted, and the individuals involved have at least a subjective assessment as to their success.

Given Contor's (1989) observation that juvenile trout concealed in cobble and boulder substrate in Last Chance during winter, Contor directed the placement of cobble and boulder complexes and conifer trees in a 6.4-km section of Harriman East in 1988. The structures briefly provided habitat for a few juvenile trout and during some seasons a few adult trout. However, sediment rapidly accumulated in the structures, and during low flow, they were partially dewatered. Overall, the habitat they created was temporary.

To avoid the sediment problem in the Henry's Fork, small conifers were anchored along the banks of the Buffalo River to provide habitat for juvenile rainbow and brook trout during the summer of 1989. Electrofishing estimates during the winter of 1989-1990 showed that the aggregate density of rainbow and brook trout in the structures (1.65 fish/m^2) was eight times higher than in control areas (0.19 fish/m^2; Griffith *et al*. 1990). Although the data from the following year's evaluation have been lost, I was involved in the project and recall that when the trees lost their needles, juvenile trout almost completely stopped using them.

The draw-down of Island Park Reservoir in 1992 caused 50,000 to 100,000 tons of sediment to be mobilized from the reservoir bottom and transported down the Henry's Fork (HabiTech, Inc. 1994). Some of this sediment was deposited in the Last Chance reach and, based on winter trout densities before and after this event (Griffith and Smith 1995), the silt apparently affected juvenile trout winter habitat, presumably by filling substrate concealment spaces and making them either unavailable or unacceptable for juvenile trout. HabiTech, Inc. (1994) studied sediment transport in the Henry's Fork near Last Chance and concluded that it was "doubtful whether the release of a flushing flow regime from Island Park Dam will be successful in removing fine sediments trapped in the interstitial spaces associated with the cobble/boulder overwintering habitat along the lateral margins of the Henry's Fork. The flow needed to mobilize such coarse material would greatly exceed the historic peak discharge of record."

The U.S. Forest Service placed cobble and boulder clusters in the Last Chance reach of the Henry's Fork in 1993. In an effort to prevent siltation of the clusters, they were centered 1-8 m from the bank in relatively high water velocities. Kevin A. Meyer (Idaho Department of Fish and Game, Nampa, ID, unpublished data) evaluated the use of the structures by juvenile rainbow trout in early, mid, and late winter (24 October 1993, 1 December 1993, and 28 March 1994). At the onset of winter, use of the clusters by juvenile trout was related to their proximity to the bank, with all fish found in structures located within 2 m of the stream margin. Overall, juvenile trout use of the clusters was minimal, with the total number of juvenile trout captured in all clusters decreasing through winter from 34 to 17 to 11.

Prior to the winter of 1994-1995, a small water-jet pump was used to flush silt from two 30-m sections of the Henry's Fork near Last Chance. Additionally, cobbles and boulders were added to two 30-m sections, and small conifers were anchored in two 30-m sections (Henry's Fork Foundation Newsletter, Fall 1994). By mid-winter enough sediment had been transported into the test areas that most of the habitat was unusable, and in early January four juvenile trout were collected from a cobble-and-boulder treatment section and four trout were collected from a conifer treatment section. Shelf ice precluded electrofishing in areas that had been cleaned with the water-jet pump. However, the amount of sediment that had been deposited at other treatment sites suggested that these sites would no longer be sediment-free (Henry's Fork Foundation Newsletter, Winter 1995).

Because of the sediment problem, structures were needed that could easily be removed and cleaned during the winter. Therefore, artificial structures made of PVC-pipe were placed along the bank in the Henry's Fork at Last Chance in the winter of 1997-1998. These structures were 51-mm diameter x 19.7-cm long pipes siliconed together 10 pipes wide and three pipes high. Juvenile trout in cages used similar structures during winter when no other habitat was provided (Gregory and Griffith 1996). Areas with structures were electrofished monthly and compared to bare-bank areas (no cobble or boulders present) and areas that contained cobble and boulder substrates (Gregory 1998). Although some juvenile trout did occupy the structures, no significant difference occurred between densities of fish in structures and bare-bank areas; densities of fish in areas containing cobble and boulder substrates were significantly higher. However, no juvenile trout remained in the cobble-and-boulder substrate areas by the end of April (Fig. 2).

Attempts to increase habitat availability and quality in the Henry's Fork by manipulating small blocks of habitat often provided habitat for a few fish for a short time. Projects of this type large enough to provide habitat for enough fish to elicit a population-level effect would be cost- or time-prohibitive. However, a large block of habitat could be made easily available to Henry's Fork fish if the dam near the mouth of the Buffalo River could be made to pass fish, given that winter conditions appeared to be good in Chick Creek (Griffith *et al.* 1996) and, presumably, in the Buffalo River. Therefore, Buffalo Hydro Inc. installed a fish ladder on the dam in autumn of 1996 (Mali 1998). The hope was that trout would move upstream out of the

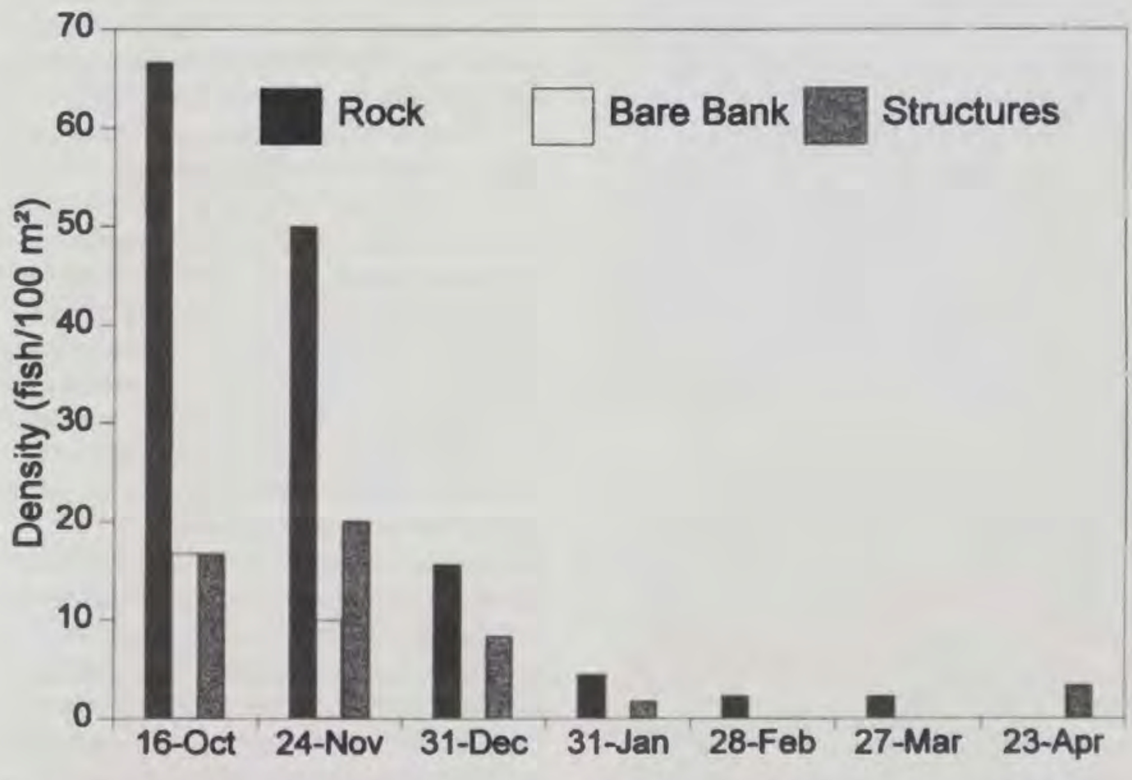

Figure 2. *Juvenile rainbow trout densities in control areas containing cobbles and boulders (rock), bare banks containing no cobbles or boulders, and artificial-cover structures (structures). From Gregory (1998).*

Henry's Fork to spawn, their offspring would spend their first winter in the warm spring waters of the Buffalo River and Chick Creek, and then juveniles would migrate downstream into the Henry's Fork as age-1 fish. The offspring would thereby avoid the first winter "bottleneck" in the Henry's Fork. Upstream migration of spawners (rainbow trout ≥ 406 mm in total length) was monitored during the springs of 1997 and 1998 with an underwater video camera at the fish ladder (Van Kirk and Beesley 1999). In 1997 and 1998, 171 and 98 spawners, respectively, moved through the ladder (Van Kirk and Beesley 1999).

A rotary screw trap was used during the summers of 1997 and 1998 to capture downstream migrating age-0 and age-1 trout in the Buffalo River (Van Kirk and Beesley 1999, Gregory 2000a). Captured trout were measured, marked, and transported upstream for release so that trap efficiency could be determined to allow estimation of the total number of downstream migrants. Because of the low recapture rate of marked trout during both years, estimates of total out-migration could not be calculated. However, trap efficiency based on other methods (discharge volume through the trap and capture rates of radishes) was estimated at less than 9 percent (Van Kirk and Beesley 1999). In 1997, 189 fry (trout <30 mm in total length), 504 age-0 fish, and six age-1 fish were captured in the trap. In 1998, 144 age-0, 34 age-1, and seven age-2 trout were captured. Peak migration occurred during September in both years. Most of the migrating trout exited the Buffalo River as age-0 fish instead of spending their first winter there. However, the trap turned slowly enough after high water receded that it probably was easily avoided by most age-1 and larger fish. Therefore, emigration of age-1 and older age classes probably was underestimated. In 1999, both the rotary screw trap and a spillway trap were used and 401 rainbow trout and 331 brook trout were captured (Gregory 2000a). Gregory (2000a) estimated that about 2,883 rainbow trout (95% CI, 1,547-5,817) and 700 brook trout (95% CI, 134-14,078) spent their first winter in the Buffalo River and then emigrated to the Henry's Fork.

Another relatively large block of bank habitat that was considered for providing winter trout habitat was the Harriman Canal (a 2-m wide x 20-50-cm deep irrigation ditch), assuming water could be left in it through winter and fish could exit the canal in spring. An assessment of juvenile trout use of the canal in autumn and winter was conducted in 1997-1998 when the canal headgate was left open (Gregory 1998). Juvenile trout were collected and marked weekly in a 200-m section immediately downstream from the headgate near the head of the canal. Trout abundance in the canal was estimated by electrofishing individual habitat types, quantifying the habitat, and extrapolating the estimates to the remaining area of that habitat type. The number of fish captured each week decreased progressively, and an average of 70 percent of the fish captured each week were unmarked, indicating that fish were moving either back upstream to the river or, more likely, further downstream into the canal. Abundance of juvenile rainbow trout in the canal was about 1,750 individuals (95% CI, 1,584-2,300) in early December, but had decreased to 246 (95% CI, 209-375) by early April. About 500 juvenile mountain whitefish (*Prosopium williamsoni*) were also present in early April. By July, when irrigation water was needed, 107 (95% CI, 97-116) juvenile trout remained in the canal. I concluded that some juvenile winter habitat did exist in the canal but it was insufficient to cause a large number of juvenile trout to remain or survive through the winter.

Headgate structures were installed

in the canal 2 km downstream from the head of the canal prior to the winter of 1998-1999. These structures allowed winter closure of the canal at that point and routed the water back to the river. A screen was placed in the headgate that routed water back to the river on 17 November 1998 so that fish would be trapped in the canal. The headgate at the head of the ditch was shut so that the only inflow into the canal was headgate leakage and inflow from an adjacent spring. Lowering the water level caused the macrophytes in the canal to slough off and clog the screen, which made its removal necessary. Because macrophytes were the primary habitat type used by juvenile trout, their sloughing caused the available habitat in the canal to decrease, which may have caused emigration of juvenile trout (Griffith and Smith 1995, Meyer and Griffith 1997b). Estimated abundance of juvenile rainbow trout in the canal in early December 1998 was 33 fish (95% CI, 33-36; Gregory 1999c), a substantial drop from the 1,750 fish present in the previous winter (Gregory 1998). Because so few fish remained, the canal headgate was re-opened and after Christmas about 50 discarded Christmas trees were placed in the canal. An estimated 97 juvenile trout (95% CI, 74-140) were in the canal on 30 March 1999 and by July, when irrigation water was needed, 45 remained (95% CI, 38-55). Although Christmas trees were in the canal only from January until April, they trapped enough sediment to eliminate about half of the habitat they originally provided.

The headgate remained open during the winter of 1999-2000 so that the macrophytes would persist until early January (Griffith and Smith 1995), when small conifers were added to provide habitat for the remainder of the winter (Gregory 2000b). However, macrophyte density in the canal was reduced prior to the onset of winter by removal of a beaver dam in the canal, which subsequently reduced water depths and increased water velocities. An estimated 177 trout (95% CI, 164-189) were present in the canal on 4 December 1999 (Gregory 2000b). Given the removal of the beaver dam, subsequent loss of macrophytes, and sedimentation, the canal was not expected to provide habitat for many juvenile trout and was therefore abandoned as a habitat improvement project.

Habitat Improvement Summary

For a habitat improvement project to be successful, it must not only provide additional habitat, but the habitat it provides must be limiting. It must also be extensive enough to create a substantial increase in the fish population. Most of the habitat improvement projects on the Henry's Fork were small in scale and experimental. With the exception of the Buffalo River fish ladder, none were cost effective on a large scale. Given the relationship between high late-winter flows and number of trout successfully completing their first winter in Box Canyon, it appears that the best option for habitat improvement at this point is to keep winter flows high during late winter. This should be done in association with continued monitoring to validate the mechanism responsible for this relationship. Habitat improvement measures that address this mechanism may be successful when drought conditions preclude high discharge.

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