Response to Frequently Asked Questions about the Henrys Fork Caldera Fishery

by
Jim Gregory
Gregory Aquatics
5306 Zollinger Rd.
Mackay, ID 83251

for
The Henry's Fork Foundation
P.O. Box 550
Ashton, ID 83420

June 2008

I. Executive summary

Over the past three decades, a substantial amount of research has been conducted on the Henrys Fork fishery in the Caldera Section (Island Park Dam to Riverside Campground). While researchers and managers have been quite effective at conveying this information among each other, they generally have been less effective in portraying it to the interested public. This document is an attempt to answer many of the questions frequently asked by the public, with information obtained through extensive research efforts. Additionally, compilation of this information provided an opportunity to systematically reevaluate research results with respect to concerns over perceived declines in fish populations on the Railroad Ranch. This progression also lends itself to identifying future research needs. Therefore, frequently asked questions were compiled and are addressed in this document under the categories of water quantity, water and habitat quality, fisheries biology and management, and watershed, riparian, and other aquatic ecology. Certainly, there are considerable interrelations among many of these categories, as is to be expected of a complex ecosystem.

Currently, there are two mechanisms influencing fish population size in the Caldera Section. First, fish population size is determined by the number of fish that survive their first winter (Section XI.f). When flow is high during late winter, more juvenile trout survive their first winter. Second, when Island Park Reservoir is drawn down and the gates at the base of the dam are opened (i.e. water flows through the gates instead of through the screened power plant intake) fish move from Island Park Reservoir into the Caldera Section of the Henrys Fork and become part of that population (Section XI.j). Based on my review of the Henrys Fork research, I believe that in the past (in the 1970s and early 1980s) there may have been a third mechanism, which was juvenile trout surviving their first winter at Last Chance, and possibly in downstream reaches, by utilizing macrophytes as winter concealment habitat through the winter (Section X.n), which no longer occurs (Griffith and Smith 1995). While several aspects of fish ecology in the Caldera Section are discussed in this document, this compilation of past research illustrated the previously unstudied potential affect that changes in the macrophyte community may have had on fish numbers, particularly in Last Chance and the Railroad Ranch reaches.

Beginning in the early 1980s and continuing through at least 1990, macrophyte density decreased and species composition shifted from those that provide substantial cover and habitat for fish to those that provide little of those same benefits (discussed in Section X.n). I think this change may have been related to changes in nutrients (Figure 8, discussed in Section X.o) and/or waterfowl (not just swans) grazing (Figure 7, discussed in Section XI.f), but Shea et al. (1996) think it may also be related to silt and flows (see Section X.n).

Reductions in macrophyte density likely reduced habitat availability for adult trout by causing reduced water levels at a given flow (Vinson et al. 1992) and by causing reductions in habitat complexity. Together these reduced habitat suitability and therefore adult fish numbers, particularly from Last Chance through Harriman East. More importantly to the Caldera trout population as a whole, the changes in the macrophyte community may have substantially reduced the number of juvenile trout surviving their first winter. This would be true if, prior to the changes in the macrophyte community, macrophyte beds remained dense enough to provide concealment for juvenile rainbow trout throughout the winter, instead of just through early winter (Griffith and Smith 1995). If this is the case, the fish population could have been affected throughout the Caldera Section.

Incidentally, Shea et al. (1996) also speculated that the robust macrophyte community that was present in the early 1980s may have been sufficient to provide habitat for juvenile trout through the winter, either by providing concealment habitat or by increasing water depths, making more of the bank area available for juvenile trout. Van Kirk (1996) called the Shea et al. (1996) speculation reasonable but did not believe it explained the population trend in Box Canyon.   However, we now know that the number of fish in Box Canyon is controlled by survival of juvenile trout through their first winter, and that those fish disperse throughout the majority of the Caldera Section. Therefore, if additional juvenile trout survived in Last Chance and/or the lower Caldera reaches as a result of additional winter habitat, fewer juvenile trout from Box Canyon would leave to fill available habitat in those other reaches. Therefore, the number of adult trout would increase in all Caldera reaches.

Changes in the macrophyte community could cause reductions in invertebrate density, as a result of reduced surface area available for attachment (Gregg 1981), and reduced levels of primary production. These changes may also cause changes in relative species composition of invertebrates.

Research and restoration alternatives are outlined in this document and include initiating studies to assess whether macrophytes can remain dense enough to provide winter habitat for juvenile trout throughout their first winter. Additionally, possibilities are outlined for providing additional winter habitat for juvenile trout in tributaries to the Henrys Fork.

II. Table of Contents

III. List of Figures

IV. List of Tables

V. Introduction

The Henrys Fork of the Snake River drainage in eastern Idaho provides one of the most important rainbow trout (*Oncorhynchus mykiss*) fisheries in the state (Idaho Department of Fish and Game 2007) and indeed, is famous across the country, having been selected as the most popular trout fishing stream in the country by Trout Unlimited members in 1998 (Van Kirk and Zale 2000). One of the most heavily-fished stream sections in the drainage is the 16 mile portion of the Henrys Fork between Island Park Dam and Riverside Campground (Coon 1977). This section of river is in the Island Park Caldera (volcanic crater), and is hereafter referred to as the Caldera Section. The popularity of this fishery is a result of several factors; most importantly, the spring creek nature of the river, which is a function of the volcanic geology of the basin (Whitehead 1978), and its productivity, a result of hypolimnetic releases from Island Park Dam (Ecosystems Research Institute 1996). The Henrys Fork was a notable fishery as early as the 1880s (Van Kirk and Benjamin 2000), but most of the research related to the fishery has been conducted since 1980. Much of this effort has been catalyzed, in one way or another, by the Henry's Fork Foundation (HFF), which has undertaken, funded, or cooperatively participated in many of these projects in this part of the watershed. Additional research and restoration projects have been undertaken by various universities, the Idaho Department of Fish and Game (IDFG), US Fish and Wildlife Service, US Forest Service, and others.

The HFF was formed in the early 1980s as a result of concern over hydroelectric power development proposals and cattle grazing damage along the banks of the Henrys Fork in the Caldera (Mickelson 1994). By the mid-1980s the HFF had helped to initiate research projects that led to habitat improvement efforts in the late 1980s (Gregory 2000a). Extensive research efforts have been completed in the drainage, with many of them focusing on the Caldera Section of the river. This research has greatly benefited managers, who now have important information to use in decision making. For example, extensive work by Dr. Jack Griffith and his graduate students (Contor 1989; Smith 1992; Meyer 1995) identified winter as being a critical period for juvenile trout survival, and a factor that appeared to regulate population size. A Montana State University dissertation by Mitro (1999) identified the effect that winter flow exerted on the juvenile trout population, and the specific time period when higher flows provided the most benefit. Fisheries managers are now able to work with water managers to ensure that any flexibility in water management benefits fish to the greatest extent possible.

Reports and studies on the Henrys Fork have been published in various peer-reviewed scientific journals, including an entire issue of the Intermountain Journal of Sciences (Van Kirk and Zale 2000) devoted to the aquatic resources of the Henrys Fork watershed, or are contained in "gray literature" reports. Gray literature reports completed prior to publication of the above referenced Intermountain Journal of Sciences are cited in an exhaustive bibliography within that issue (Van Kirk 2000). While it is important for resource managers to have the research information available to them, it is also important for resource users to be aware of the research findings. Additionally, summarizing what is known about a resource is a good forum for outlining what additional information is needed to make more effective resource management decisions.

VI. Objectives

The objectives of this document are as follows:

- Summarize the scientific knowledge base; the questions within are intended to provide an expansive and thorough coverage of the fishery, aquatic ecology, water management, etc. By doing so, the primary issues, concerns, and questions will be addressed in a single summary document that is accessible to a broad audience.
- Provide the foundational information for a summary brochure that will be produced and distributed to anglers, businesses, etc. in 2008 and beyond. The brochure is intended to provide outreach and education, links to this scientific summary document and references cited, and other sources of information about the river to interested parties.
- Assess opportunities for future aquatic research and restoration.

VII. Methods

The primary focus of this Caldera Assessment/Frequently Asked Questions (FAQs) is the wild rainbow trout fishery of the Henrys Fork from Island Park Dam downstream to Riverside Campground. While the focus of this document is on the wild rainbow trout fishery, it also includes all those features of the watershed that support the fishery, i.e., water flows, habitat, aquatic insects, etc. The substantive resource issues of concern within the Caldera Assessment/FAQs are categorized similar to those of the overall HFF Research and Restoration program, namely:

1) water quantity (including hydrology and geomorphology);

2) water and habitat quality (including invertebrate ecology);

3) fisheries biology and management (including creel and economic surveys); and

4) watershed, riparian, and other aquatic ecology (including land use).

All of the FAQs are placed under the above categories, dependent upon the primary subject matter. However, there are considerable interrelations among many of these categories, as is to be expected of a complex aquatic ecosystem. Questions are further grouped together within categories by topic in a logical sequence.

These objectives will be accomplished by addressing questions that have been or continue to be asked of resource managers. This list of questions was compiled by HFF staff, based on questions they repeatedly receive from members and anglers. The list of questions has undergone extensive review by state and federal resource managers and individuals who have fished the river for many years. A draft list of questions was e-mailed by Steve Trafton (HFF Executive Director) on February 26, 2008 to all current HFF board members, several past HFF board members, outfitter and guide representatives, known experienced anglers, and others seeking their input on the questions. Recipients were encouraged to forward the email to others who may be interested. Subsequently, the draft questions had a very wide distribution to interested parties, e.g., on February 27th, the original email and attachment was sent to the electronic mailing list (over 400 people, most of whom reside in Idaho and Utah) of the North Country Fishing Report, by Bob Springmeyer. In total, several dozen replies were received by HFF and suggestions and comments were incorporated into the question list.

The intent of this assessment was to focus on the Caldera Section of the Henrys Fork. Therefore, an expansive coverage of all literature related to fisheries and water management outside of the watershed was not within the scope of this document. Notably, several responses to HFF suggested a complete review of research related to fish stocking efficacy, effects on wild fish, results on other rivers, and other related topics. This type of information was beyond the scope of this document, but fish stocking as it relates to the Caldera Section of the Henrys Fork is covered herein.

The official name for the Henrys Fork (as designated by the US Board on Geographic Names) without the possessive apostrophe will be used in this document. However, when the apostrophe is part of a proper name, such as the Henry's Fork Foundation, or when someone who used the apostrophe is being directly quoted, the apostrophe will be used.

This document is intended for use by both scientists and non-scientists. Therefore, when possible, both metric and English units will be used. However, when doing so would be cumbersome, such as in graphs, only English units will be used. This convention will be deviated from for units of concentration and density where only metric units will be used, as English units of concentration and density are generally unfamiliar to all.

VIII. Study area

The Henrys Fork drainage is located in eastern Idaho and western Wyoming (Figure 1). It is dominated by volcanic features which are a result of the earth's crust passing over the "hot spot" that now lies beneath Yellowstone National Park (Hackett and Bonnichsen 1994) which left behind a caldera (volcanic crater), through which the Henrys Fork now flows (Figure 1). Due to the volcanic nature of the drainage, most of the streams have a substantial degree of groundwater influence (Van Kirk and Benjamin 2000). The hydrologic regime of these spring-influenced systems is altered in the Caldera Section of the Henrys Fork by water storage and delivery in Henrys Lake and Island Park Reservoir (Van Kirk and Burnett 2004).

Several distinct and well known stream reaches make up this section of the Henrys Fork, including the Box Canyon, Last Chance, the Railroad Ranch (or Ranch), Harriman East, and Pinehaven (Figure 1). Island Park Reservoir is not within in the focus section of this assessment. However, water flows, sediment, nutrients, etc, discharged from Island Park Dam are important factors influencing the fishery in the Caldera Section and Island Park Reservoir is covered with respect to these issues. Additionally, the reach below Riverside Campground sometimes known as "Cardiac Canyon" is often not thought of as part of the Caldera Section fishery, but nothing precludes movement of fish between this reach and upstream reaches. Therefore, where applicable information is available it will be included.

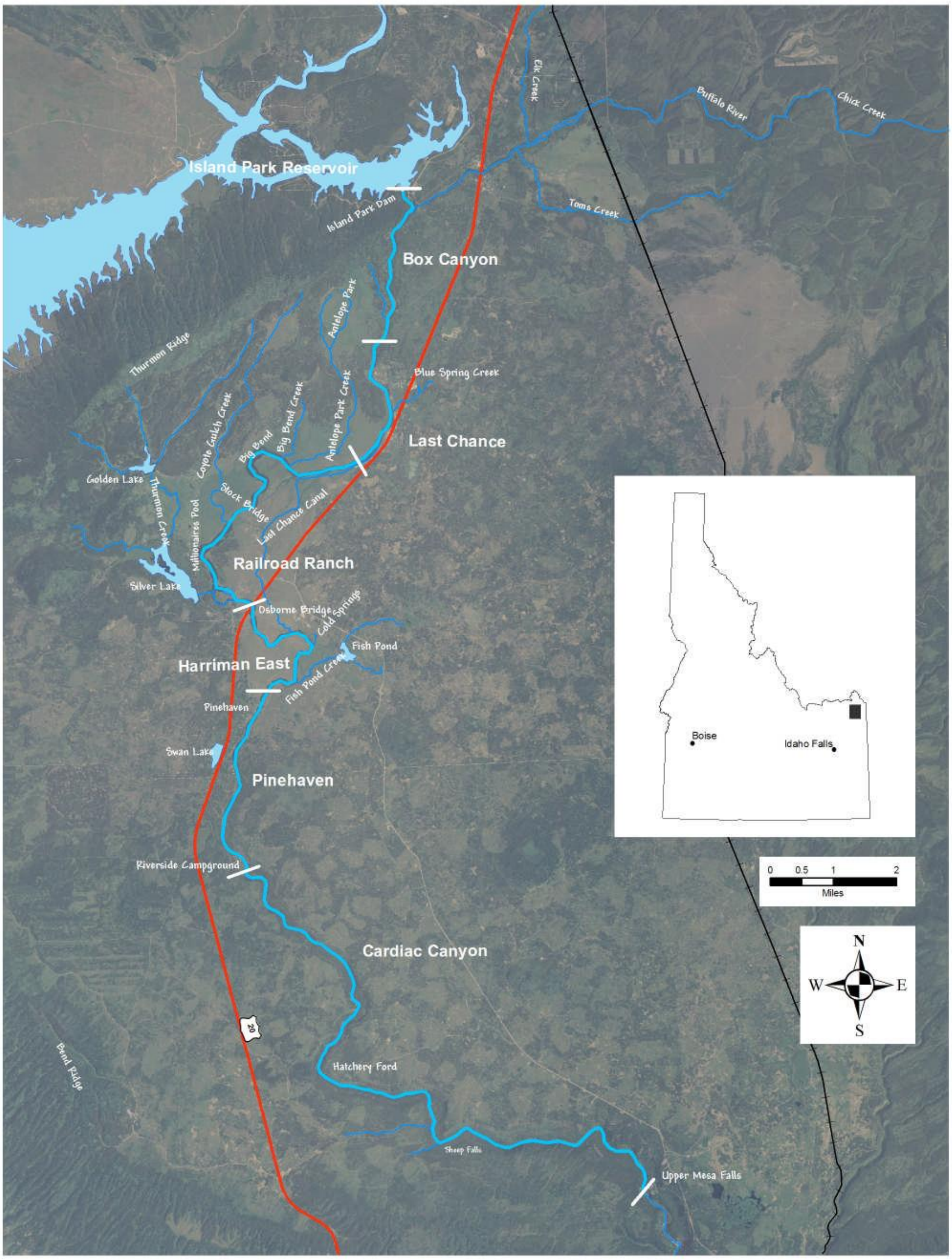

Figure 1. Henrys Fork reaches (between white lines) and notable features of the Caldera Section of the Henrys Fork.

a. Caldera Section reach descriptions

1. Island Park Reservoir

Island Park Reservoir is a 135,000 acre-foot (167 million cubic meter) irrigation storage reservoir that was completed in 1939, is owned and operated by the US Bureau of Reclamation, and stores water owned by the Fremont-Madison Irrigation District (and other water rights holders) as part of the Eastern Idaho Minidoka Project (Van Kirk and Benjamin 2000). The reservoir is contained by Island Park Dam, a 73 ft tall earth-fill dam that releases water from the lower level of the reservoir. These releases result in the discharged water being relatively warm in winter and relatively cooler in summer, thereby providing excellent growing conditions for fish. Additionally, the highly productive water released from the lower level of the reservoir provides nutrients which are transferred up the food chain and ultimately result in some of the highest fish growth rates in rivers or streams in Idaho (Schill 1991).

2. Box Canyon

Box Canyon is a basalt-lined canyon section of the Henrys Fork that starts at Island Park Dam and ends 2.8 miles downstream at the first streamside residential area. Gradient in this reach is relatively high (0.45%; Mitro 1999) and the substrate consists primarily of cobble and boulders. Large woody debris is abundant along the stream margins. Few macrophytes are present in this reach. Water temperature is moderated by bottom releases from Island Park Dam and by the spring-fed Buffalo River, which joins the Henrys Fork approximately 0.4 miles downstream from Island Park Dam. Because these two sources of water are slow to mix while traveling through Box Canyon, water temperature can vary laterally across the river during some times of the year. The only other tributary entering the river in this reach is an unnamed intermittent stream that pours off the west canyon rim and enters the Henrys Fork near the lower end of the reach.

3. Last Chance

The Last Chance reach extends from the base of Box Canyon 2.2 miles downstream past the community of Last Chance and ends at the upstream boundary of Harriman State Park. Gradient in this area is intermediate (0.3%; Mitro 1999) and the substrate consists primarily of embedded cobble and gravel. Some unembedded cobbles and boulders are present along the bank, and the only substantial woody debris in the reach is present in a log jam at the lower boundary of the reach. Macrophyte growth is dense and extensive throughout the reach (Griffith and Smith 1995). There is seldom any ice formation in this reach except during very cold weather or cold weather combined with low flows.

4. Railroad Ranch

The Railroad Ranch reach extends 5.2 miles from the upper Harriman State Park boundary downstream to Osborne Bridge, where US Highway 20 crosses the Henrys Fork. Gradient through this reach is generally low (0.1%; Mitro 1999) with two short riffle sections, one immediately downstream from the “Stock Bridge” and one near the lower end of the reach. Macrophyte growth is dense in areas but absent from other areas. Substrates are gravel and finer material, and woody debris is essentially absent. Ice is intermittently present in this reach throughout the winter. Notable features in this area are Big Bend, the Stock Bridge, Antelope Creek, Millionaire's Hole, and Thurmon Creek (Figure 1).

5. Harriman East

The Harriman East reach extends from Osborne Bridge 3.2 miles downstream to the lower Harriman State Park boundary, which is also the upstream boundary of the community of Pinehaven. This reach is very low gradient, and the substrate is mostly fines. Macrophytes are present but are sparse and generally patchily distributed. Ice in this section forms intermittently but is present through more of the winter in this reach than in the Railroad Ranch. Large woody debris is absent from this reach. Cold Springs and Fish Creek both enter the Henrys Fork from the east side in this reach. Cold Springs is a shallow pond adjacent to the Henrys Fork which was, in the past, part of a fish hatchery operation. The water in the springs is shallow but is slightly deepened by a short wall of rock that has been placed across its mouth. Fish Creek enters the Henrys Fork downstream from Cold Springs and comes from a small dammed pond. It travels almost a mile between the dam and its confluence with the Henrys Fork, and it is often ice-free during winter.

6. Pinehaven

The Pinehaven reach extends from the lower boundary of Harriman State Park, past the community of Pinehaven 3.2 miles downstream to just past Riverside Campground. The river in this area becomes more confined and higher gradient than upstream reaches. Substrate in this reach is typified by cobble and boulders, and large woody debris and boulders line the banks. Ice often forms along the bank areas of this reach during winter (Mitro 1999).

7. Cardiac Canyon

Downstream from Riverside Campground the river gradient increases and travels through a canyon, eventually dropping off the Island Park Caldera at Mesa Falls (11.3 miles downstream). Sheep Falls, a smaller waterfall that may be passable to some fish at some flows, is located 4.2 miles upstream from Mesa Falls. Little research has been conducted in this area, and it is generally ignored as a component of the Caldera fishery. Anchor ice may be extensive in this area during the winter (Gregory and Van Kirk 1998).

IX. Water quantity (including hydrology and geomorphology)

a. Flow management

What is the history of water management below Island Park Dam? What, if anything, changed in 1972 (with the MOU between irrigation interests and power production interests)? What changed in 2003 with the advent of the Henrys Fork Drought Management Plan? Isn't there a minimum flow requirement for the Henrys Fork?

The Henrys Fork in the Caldera Section is highly influenced by spring flows, which account for 80% of the total annual discharge in the Henrys Fork at Island Park (Van Kirk, Pers Comm.). However, Island Park Dam alters the natural flow regime such that median flows from October to May (1972 – 2002) were about 25 – 50% less than they would be naturally, and were about twice as high during July and August as they would be naturally (Van Kirk and Burnett 2004, Figure 2). But alteration is not as severe as it has been in the past.

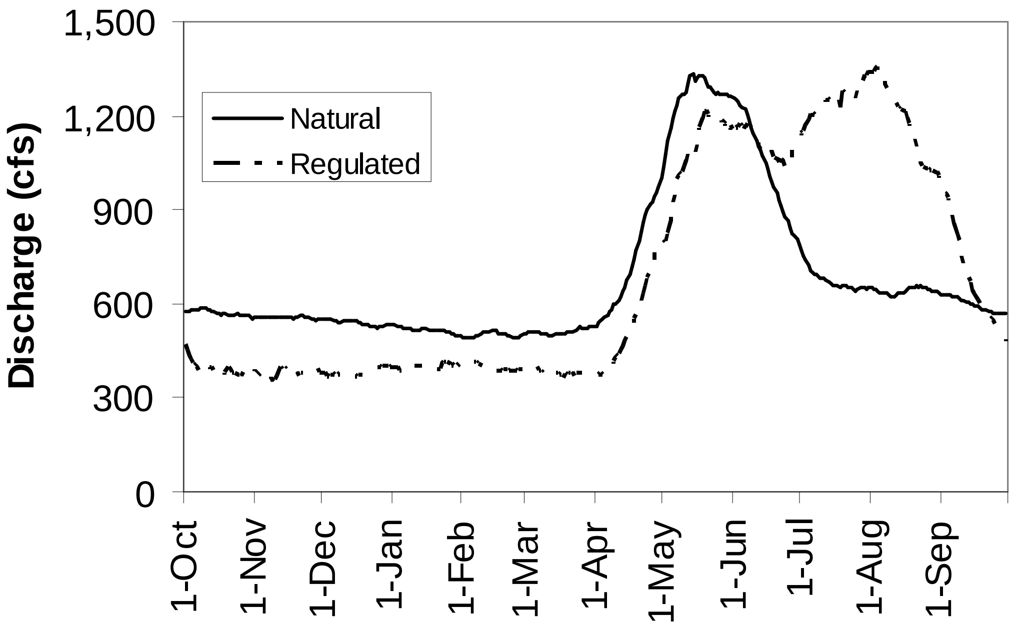

Figure 2. Mean natural and regulated flow at Island Park Dam, 1972 - 2003 (from Van Kirk and Burnett 2004).

From the time the dam was completed until the mid 1970s the most common strategy for filling the reservoir was to simply turn off flow at the dam on 15 November (Benjamin and Van Kirk 1999). Beginning in 1972, the onset of irrigation storage was moved up to 1 October so that flow could be stored over a longer period of time, which allowed for passage of some water for power production downstream. This arrangement was later formalized between the cooperators, including the Fremont-Madison Irrigation District, the City of Idaho Falls, Utah Power and Light, and the US Bureau of Reclamation (Benjamin and Van Kirk 1999). From that time through the winter of 1993-1994, winter discharge from the dam often remained higher than it had been during the previous period. However, flow from the dam was still often reduced to very low discharges (Figure 3). Water years with above average discharge in the mid and late 1990s enabled the release of unusually high winter flows for several years in a row. However, the drought of the early 2000s again brought lower winter flows, but not as low as prior to 1972.

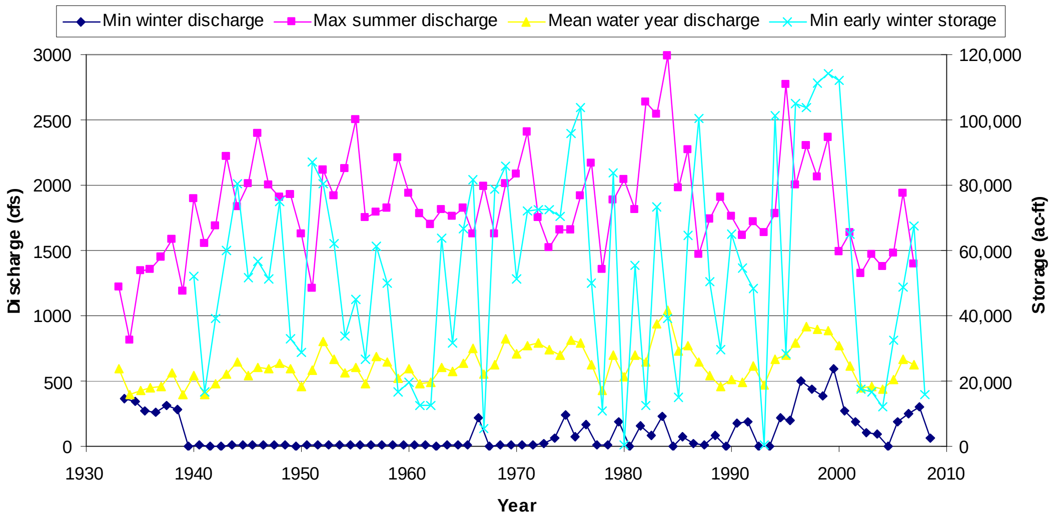

Figure 3. Minimum early winter (September - December) storage volume in Island Park Reservoir, along with minimum winter (October - March), maximum summer (April - September) and mean water year (October - September) discharge in the Henrys Fork downstream from Island Park Dam (mean discharge for the period of record is 620 cfs).

In September 2003, drought management was initiated in the Henrys Fork Basin as a result of the Fremont-Madison Conveyance Act (Public Law No. 108-85) which also directed, among other things, the transfer of title of the Cross Cut (Chester) Diversion Dam, Cross Cut Canal, and the Teton Exchange Wells from the Bureau of Reclamation to the Fremont-Madison Irrigation District. Section 9 of the act, which addresses Drought Management Planning, directs the Bureau of Reclamation to initiate and coordinate the drought management plan and to provide an avenue of communication, cooperation, and consultation to serve the cause of conservation (Joint Planning Committee 2005): "Within 60 days of the enactment of this Act, in collaboration with stakeholders in the Henrys Fork watershed, the Secretary shall initiate a drought management planning process to address all water uses, including irrigation and the wild trout fishery, in the Henrys Fork watershed."

However, the only way to ensure that water stored in Island Park Reservoir belongs to Fremont-Madison Irrigation District right holders is to have the reservoir full by 1 April (Benjamin and Van Kirk 1999). If the reservoir is not full by that time, senior water right holders in Twin Falls may request delivery of their water and make fill unachievable. Additionally, there are conditions under which Island Park Reservoir can fill after 1 April but the water does not belong to the Fremont-Madison Irrigation District right holders (Benjamin and Van Kirk 1999). Because of these water right dynamics and because inflow prior to 1 April is relatively constant, the amount of water that must be stored to fill the reservoir is determined each year, based on the initial reservoir content and the date storage begins and ends. Therefore, there is a given quantity of water that can be passed downstream during the winter, which is primarily dependent on reservoir carryover, and still leave enough to fill the reservoir. As stated by Rob Van Kirk (Pers. Comm.), "this isn't going to change under any sort of plan. The only thing that the planning can do in this case is determine when the water not needed for storage will be released."

Since 2003, representatives from the Henry's Fork Foundation, Trout Unlimited, The Nature Conservancy, Idaho Department of Fish and Game, Bureau of Reclamation, North Fork Reservoir Company, and Fremont-Madison Irrigation District have met several times annually to determine how these releases can be made to balance the needs of the wild trout fishery with those of the irrigators. One aspect that has changed dramatically with drought management is that early winter flows have been curtailed to achieve higher late winter flows (Figure 4). This scenario has been seen to benefit trout populations by increasing the number of juvenile rainbow trout that survive their first winter (discussed in section XI.f), and it is also a favorable scenario for the irrigators, because more water can be stored early in the winter – providing better assurance that the reservoir will fill.

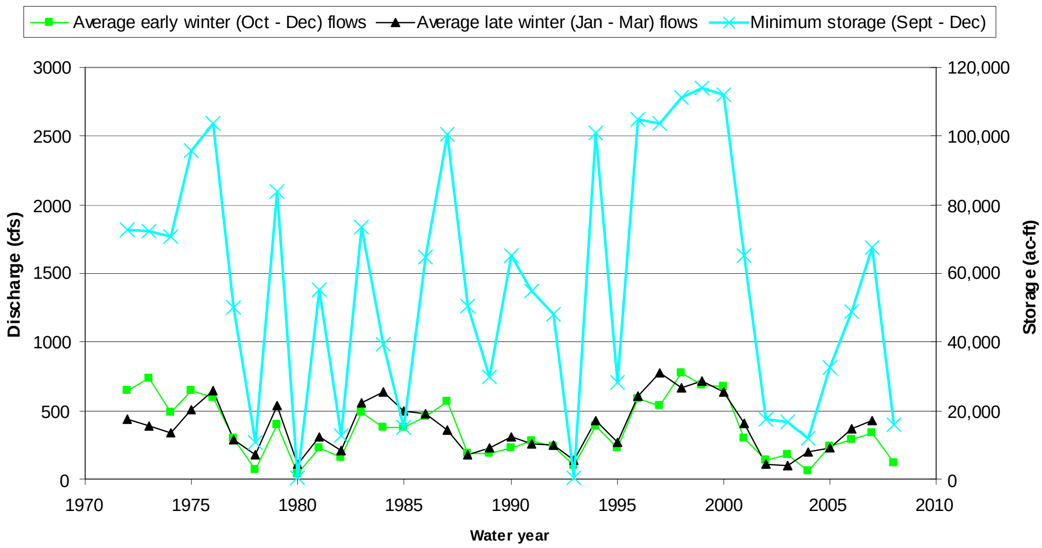

Figure 4. Winter flows and minimum early winter storage for water years 1972 - 2008.

While winter flow conditions have vastly improved over historical conditions, it is important to understand that Island Park Reservoir is an irrigation storage facility which is still managed to ensure that storage water rights are filled. It is also important to keep in mind that the benefits of having a tailwater fishery have some associated drawbacks, as well.

There is a 300 cfs minimum instream flow right on the Henrys Fork (water right number 21-7282) from the mouth of the Buffalo River downstream to below Mesa Falls. However, it has a priority date of 1981, which is junior, and therefore subordinate, to the storage rights in Island Park Reservoir, which have 1921 and 1935 priorities. In addition, the right specifically states that the right "…shall be limited to 300 cfs, or the rate of flow provided by the Buffalo River …. whichever is less." It also states that, "The right shall not be deemed to impose any conditions or requirements upon the operation of Island Park Dam." Therefore, in the final analysis the right simply precludes the storage of Buffalo River flows (base flow of ~ 200 cfs).

b. Options for obtaining improved flows

Outside of the current Drought Management Planning process, are there any other water management options, within the bounds of Idaho water law, to obtain improved water flows to support the wild rainbow trout population?

Eight potential alternatives for increasing flows were screened in the drought management plan (Joint Planning Committee 2005). These alternatives for the Caldera Section of the Henrys Fork included constructing a storage reservoir on the Teton River to allow more flexibility in water management at Island Park Reservoir, stocking juvenile trout in the Henrys Fork to mitigate low winter flows, initiating a mitigation fund to either reimburse water-users who voluntarily forfeit some of their storage allocation or who take land temporarily or permanently out of production or reduce their water use in other ways, and injecting some water from the Buffalo River into the Henrys Fork immediately below Island Park Dam. The preceding alternatives were either rejected by the drought management committee or require additional analysis to address their feasibility. The most physically possible alternative was adaptive management of Island Park Dam which "…focuses on different approaches to moving and accounting for water out of Island Park Dam. One possible component of adaptive management includes institutionalizing last year's approach: increasing flows out of Island Park and storing the water in American Falls when there is a minimal risk that American Falls Reservoir will fill (so that [Fremont-Madison Irrigation District's] proportional share on April 1 is not reduced or at risk)."

c. Ramping rate

Does Island Park Dam have an allowable ramping rate, i.e., how much can water flow releases increase or decrease per a period of time? Does ramping rate affect fish or macroinvertebrate hatches? If flows and ramping rates affect fish or insects during the angling season, especially during the first few weeks of the general season or the Ranch opener, is there any means to provide flows more conducive to angling?

The ramping rate for changing flows at Island Park Dam is no more than 50 cfs (1.4 cms) in 30 minutes (Ecosystems Research Institute 2007). The Fall River Rural

Electric Cooperative submits a compliance report to the Federal Energy Regulatory Commission (FERC) annually to verify that this ramping rate is not exceeded.

The effect on fish or invertebrates of changing flows at this rate is likely minimal, though it may occur and probably relates to slight temperature changes that they encounter. If the changing flows alter the behavior of fish and invertebrates, the alteration is likely only temporary.

Flow releases are determined by irrigation demand and weather conditions. Often the reservoir is full, or nearly full, at the beginning of the fishing season (general season opening on the Saturday of Memorial Day) (Figure 5) and therefore inflow to the reservoir is simply being passed through the dam, resulting in flows that reflect inflow. However, later in the summer as adjustments are made to fill irrigation calls for storage water, flow patterns change and no longer reflect inflow. Island Park Reservoir is an irrigation storage facility, and water management is a function of water rights. The timing of irrigation demand is dependent on climatically-driven conditions. Therefore, adaptive winter water management through the drought management planning process (see section IX.a) is the only means to mitigate flow variability due to irrigation demand.

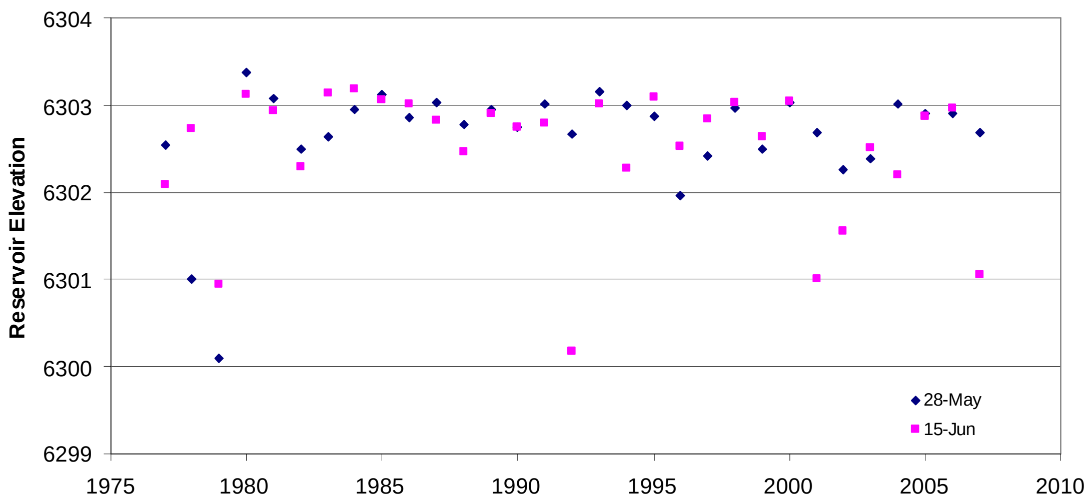

Figure 5. Reservoir elevation on 28 May (near the beginning of the general season opener) and 15 June (opening day of fishing season in Harriman State Park) from 1977 - 2007. Elevation 6302 is the top of the spillway (without the inflatable rubber collar) and elevation 6303 is the fill height of the reservoir.

d. Climate change and flows

What are the potential effects of climate change on water supply, delivery, and timing in the Henrys Fork?

Van Kirk investigated the effect of climate change on large rivers in Idaho and concluded that extreme effects of climate change in headwater streams are attenuated in large rivers, the effects of climate change on ground water systems will be minimal, and direct hydrologic and temperature effects from climate change will be much smaller than changes already caused by dams and diversions (Van Kirk, presentation given at the

Idaho Chapter of the American Fisheries Society, February 2008). Given that the Caldera Section is maintained primarily by ground water and is downstream from Henrys Lake and Island Park Reservoir, which already substantially influence discharge patterns (IX.a) and water temperature (XI.i), it is likely that hydrologic changes due to climate change will be minimal compared with alterations of the natural hydrology that are caused by water management in the two storage reservoirs.

e. Flows and geomorphic changes

What about flows at times of year apart from the winter – have they changed over the years (volume/timing)? What effects might this have had on the hydrology and geomorphology on the Railroad Ranch section of the Henrys Fork, a.k.a, the Ranch? Are there other "tailwater effects" of Island Park Dam, in terms of water, geomorphology, and hydrology?

As with most irrigation storage facilities, Island Park dam serves to alter flows through lowering winter discharge, increasing late summer discharge, lowering peak discharge, and shifting peak discharge to slightly later in the year (Van Kirk and Burnett 2004). In snowmelt- or runoff-driven stream basins, the lowering of the peak discharge has implications for preventing channel changes and flooding that ultimately result in healthy riparian areas. However, in the Henrys Fork there is only slight alteration to peak flows (Van Kirk and Burnett 2004), primarily because water managers attempt to fill the reservoir by 1 April (Benjamin and Van Kirk 1999), prior to run-off. When the reservoir is full by this date, peak flows are simply passed with the same magnitude and timing. Often however, the reservoir is almost full by this date and therefore peak flows are slightly lower and slightly later than would occur naturally. Furthermore, because the Henrys Fork is highly influenced by springs, channel-altering flows are very rare even without regulation. Therefore, geomorphic changes to the river channel downstream from Island Park Dam are essentially unaffected by hydrologic alteration due to the dam.

One of the most significant changes in flow management, one that ultimately eliminated some negative effects to the geomorphology of the Henrys Fork channel, was the elimination of "fill and spill" management that occurred prior to 1972. During this era, ice would form downstream from Island Park Dam (at Last Chance and further downstream) and then be flushed out when storage increased to spill level and resulted in increased flows. The movement of this ice downstream likely caused mechanical damage to the stream banks, macrophytes, and possibly to the stream bottom.

However, more subtle geomorphic changes may have occurred as a result of water storage and flow management at Island Park Dam. For example, the altered hydrograph has two distinct peaks, as opposed to one in the natural hydrograph (Figure 2), and the second one is higher than the natural one and longer in duration. So, the peak flow regime of the hydrograph has changed substantially. The second peak occurs when macrophytes are most dense, which means that water level at a given discharge is much higher during the irrigation peak than during the natural peak. The presence of macrophytes slows water velocity in the center of the channel and reduces bed scour and sediment transport during the later peak. However, the higher water level during the second peak, combined with slowing of velocities in mid-channel may actually accelerate bank erosion during the second peak. With annual sediment delivery reduced by the reservoir, there is no sediment to replace that being eroded. It is possible that since Island Park Dam was completed, the channel has been widening as a result of this second flow peak and loss of sediment to rebuild banks. Rather than down-cutting, the river has widened because this second peak occurs when macrophyte growth prevents scour of the bed mid-channel. Willow removal (section XII.a) and cattle grazing (section XII.b) may have made the banks more susceptible to erosion. Regardless of hydrologic regime type, the channel will adjust to the "bankfull" flow, which occurs every 1.5 – 3 years, depending on climate and geology. Under the managed regime, peak flows are a function of irrigation demand and not natural flows. Therefore, hydrologic alteration may play a role, although a less perceptible role, in altering channel morphology (Van Kirk, Pers Comm.).

f. Sediment and Island Park Reservoir

What was the amount of sediment released from Island Park Dam in 1992? What is the nature/composition of that sediment? Is there anything chemically harmful in the sediment? What do we know about the conditions under which sediment mobilizes in the reservoir and passes through Island Park Dam? Where did the sediment go then, where does it go now? Are water flows or channel characteristics affected by sediment deposition in the Henrys Fork?

During September 1992, Island Park Reservoir was drawn down very low to satisfy irrigation demand. The Idaho Department of Fish and Game took advantage of situation by planning a rotenone project for the reservoir in order to reduce the rough fish population. As the remaining reservoir pool was being drained, the river began to cut down into the accumulated sediment at the bottom of the reservoir and to transport the material downstream (Van Kirk and Griffin 1997). Before the reservoir gates were shut in late September, an estimated 50,000 – 100,000 tons of sediment had been mobilized and moved out of the reservoir (Minshall et al. 1993; Van Kirk and Griffin 1997). Both organic and inorganic sediment was observed in the river below the dam during late October 1992, but given the lack of an adequate control, the portion of either sediment type that could be attributed to the 1992 event could not be assessed (Minshall et al. 1993). No tests to assess the chemicals contained in the sediment were conducted.

Undoubtedly, sediment from the reservoir has been mobilized into the Henrys Fork in the past, and it is likely that it will happen again in the future. During annual run-off events, sediment is mobilized by streams that feed into Island Park Reservoir. As the sediment enters the reservoir pool, the ability of the water to transport the sediment decreases, and the sediment falls to the bottom of the reservoir. Sediment that is deposited into the submerged river channel is mobilized again as the reservoir is drawn down to a level at which the water velocity in that portion of the submerged channel increases. By this process, the sediment is transported further and further into the reservoir until the reservoir begins to fill with water again and the sediment remains at that location. When this happens over several years, a large amount of sediment ends up being deposited at about the elevation to which the reservoir is normally drawn down. If the reservoir is drawn down below this elevation in subsequent years, then, that sediment is mobilized. If the reservoir pool is small enough, then the sediment will not settle within the reservoir, but instead will be transported downstream into the river. Therefore, the reservoir elevation at which sediment will be mobilized and transported into the Henrys Fork changes over time and is related to the minimum pool elevation over the past several years.

In 1992, the reservoir pool reached a minimum elevation of 6,242.42 ft which corresponds to a pool volume of 270 ac-ft (0.33 million cubic meters). Prior to this drawdown, the lowest pool level occurred during 1979, when the pool elevation dropped to 6,243.55 ft and a pool volume of 430 ac-ft (0.53 million cubic meters), and resulted in sediment being flushed into the Henrys Fork downstream from Island Park Dam (Ball and Jeppson 1980). The only other drawdown that resulted in a minimum pool of less than 10,000 ac-ft (12.34 million cubic meters) occurred in 1966 when pool elevation reached 6,261.30 ft with pool volume being 5,540 ac-ft (6.84 million cubic meters; data from USBOR website). Based on these data, lowering the reservoir pool to 10,000 ac-ft (12.34 million cubic meters; ~6268 ft elevation) should not cause excessive mobilization of sediments. Even if the reservoir is not drawn down to this elevation for several years, a pool of 10,000 ac-ft (12.34 million cubic meters) should retain water in the pool long enough to cause the sediment to settle in the reservoir. Given that the recent sediment event flushed much of the sediment from the lower portion of the reservoir, it is likely possible to draw the reservoir down below 10,000 ac-ft (12.34 million cubic meters) without causing significant sedimentation. However, if the reservoir remains above 10,000 ac-ft (12.34 million cubic meters) for several years, then drawing it down below that level could mobilize some sediment.

In 1997, HabiTech (1998) evaluated sediment transport through the Caldera Section and found that most of the transported material was moving as suspended sediment and that most of it was transported during high spring flows (~2,000 cfs when transport was assessed in the spring). In fact, in June an estimated 50 tons/day of sediment was being transported at Last Chance while 109 tons/day were being transported at Osborne Bridge. This indicates that sediment was being mobilized and removed from lower Last Chance and the Railroad Ranch at these high flows. However, in July, as flows decreased and macrophyte growth decreased stream bottom shear stress, transport at Last Chance dropped to 14 tons/day at Last Chance and 6 tons/day at Osborne Bridge, indicating sediment deposition in lower Last Chance and/or the Railroad Ranch. By September, transport of sediment had reached a "steady state" with sediment transport averaging 9 tons/day in both locations. Because low flow conditions occur over a longer period of time than do high flow conditions, net transport of silt out of the Railroad Ranch may have been relatively low or even experienced a net import of sediment during the HabiTech (1998) study. However, as fine sediment levels continue to decrease in the Last Chance Reach, less sediment will be mobilized into the Railroad Ranch Reach and then sediment levels in that reach will begin to decrease, although the timing for this process has not been determined.

One feature in this reach that has provided substantial adult trout habitat in the past is "Millionaire's Pool" (Figure 1). Anecdotal information indicates that, in the past, this pool had extreme depths although there is some speculation as to whether or not the pool was formed naturally (HabiTech 1998). HabiTech (1998) evaluated this area and noted that, "Much of the right side [looking downstream] of the Millionaire's Pool channel can currently be classified as a sluggish backwater with substrates predominated by silt/clays, fine sands and aquatic vegetation. Due to this filling with finer sediment, portions of the area appear to be progressing through a successional sequence from riverine to marsh/wetland habitat." Another thing that may have caused Millionaire's Pool to decrease in depth relates not to fill by sediment but, but rather to the water surface elevation dropping. This could have happened due to a reduced density of macrophytes (discussed in section X.n) and their ability to increase water depth at a given discharge (Vinson et al. 1992).

Invertebrate studies conducted following the sediment event were unable to assess the effect of the sediment due to lack of any invertebrate collections prior to the event (Minshall et al. 1993). However, Meyer and Griffith (1994) cited Hampton (1981) as having collected some invertebrate samples in the Henrys Fork from Last Chance to Pinehaven during 1979 and 1980. Data from this sampling should be reviewed and compared with data from subsequent studies.

The effect of the sedimentation event on adult trout was also indeterminable, as adult trout populations increased substantially as a result of fish from the nearly empty reservoir moving downstream into the Henrys Fork. However, Gregory (2000a) hypothesized that the reduced juvenile trout density along stream banks at Last Chance observed by Griffith and Smith (1995) from the winter of 1992-1993 (0 trout/m²) compared to 1989-1990 (70 trout/m²) was a result of sediment filling the spaces between rocks, which made them ineffectual as concealment cover for juvenile trout. Assuming this hypothesis is accurate, one way to assess whether the effect of the sedimentation event has passed is to again evaluate juvenile trout densities along the bank at Last Chance through the winter.

g. Flushing flows and Railroad Ranch geomorphology

Would it be possible to increase high flow releases from Island Park Dam to mobilize and remove sediment from the Ranch? What could be the benefits and drawbacks of such water management? Is dredging, specifically on the Ranch, a viable option for achieving long-term channel benefits?

Following the sedimentation event of 1992, HabiTech (1994) conducted studies on the Henrys Fork to evaluate the amount of fine sediment in the stream substrate and the flow necessary to mobilize substrates and therefore flush sediments from gravel and cobble. They concluded that "While no pre-sediment release data are available to show conclusively that substrate quality of the Henry's Fork near Last Chance, Idaho, was reduced as a result of the September 1992 incident, the quantitative and observational evidence gathered during the course of this study strongly suggest that the streambed is quite highly embedded with fine sediment and that natural recruitment of salmonids is likely being limited." HabiTech (1994) also evaluated whether or not fine sediment could be scoured from spawning gravel and from the interstitial spaces between cobbles at the stream margin by mobilizing those substrates. They concluded that "…it is doubtful whether the release of a flushing flow regime from Island Park Dam could 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." While it takes much less energy to scour silt than to mobilize cobbles and boulders, silt in the interstitial spaces present in these substrates create low velocity areas that can not be cleaned without mobilization of that substrate. However, mobilizing the gravel to scour fine sediments was deemed to be a viable management option (HabiTech 1994). To mobilize the gravels and remove fine sediment, HabiTech (1994) recommended a peak flow of 2,600 cfs (73.7 cms) for at least 9 hours during late March or early April. Average daily flow exceeding 2,600 cfs (73.7 cms) occurred on 4 consecutive days in May of 1995, when Island Park Dam was full and inflow was passed. These flows likely caused gravel scour and removed some sediment from the spawning gravels. However, these flows occurred later in the year than recommended by Habitech (1994). This likely made flushing flows less effective because of increased macrophyte growth, which reduces shear stress on the stream bed (Vinson et al. 1992). Flows of this magnitude have not occurred between that time and the time of this writing (February 2008).

However, HabiTech (1994) did observe transport of fine sediment even at lower flows. This occurred because much of the sediment transported from the reservoir during 1992 was deposited on the surface of the gravel and therefore could be mobilized without flows sufficient to mobilize the gravel. In fact, they observed transport rates of 40 tons/day at flows of 525 cfs (14.9 cms) and 449 tons/day at flows of 1645. While transport rates were certainly not constant at a given discharge from that time forward (as the easiest particles to mobilize were probably still being mobilized in 1994 when the study was conducted), it is useful to note that had they been constant, 450,000 tons of sediment could have been mobilized from October 1992 to February 2008. Of course, other factors, such as macrophyte growth, can reduce the ability of a given discharge to transport fine sediment. Conversely, some factors increase the ability of a given discharge to transport fine sediment, such as waterfowl grazing, macrophyte sloughing, and salmonid spawning. These actions cause movement of materials that are larger than would normally be mobilized by flow alone but also help entrain small particles into the water column that are then transported out of the area. These mechanisms are not sufficient to scour sediment from interstitial spaces between cobble and boulders along the stream margin where sediment effects may still be impacting winter habitat for juvenile rainbow trout.

It is generally considered that the effect of filling interstitial spaces was minimal in Box Canyon, due to the higher gradient and therefore greater transport capacity of that reach. Sedimentation of interstitial spaces in the Last Chance Reach may be evaluated by assessing juvenile trout use of these areas during winter but has not been done for nearly a decade. Sedimentation of interstitial spaces in the Railroad Ranch and Harriman East is somewhat of a non-issue because of the lack of cobble and boulder habitat in these reaches, and the effect is unknown in the Pinehaven reach due to a lack of data relating to use of those areas by juvenile trout prior to the sedimentation event.

The changes in spawning success due to the sedimentation event are also unknown. However, given the number of juvenile trout produced each spring in both Box Canyon and Last Chance in the late 1990s (158,000 – 306,000 juvenile trout; Mitro and Zale 2002), it is evident that any reductions in spawning success have had no effect on the fish population.

The current status of the sediment deposited during the 1992 event is unknown. Again, the easiest way to assess the effects of the event on the rainbow trout population may be to evaluate juvenile trout densities during the winter along the bank of the river at Last Chance. This should provide a meaningful assessment since it was evaluated before and after the sedimentation event (Griffith and Smith 1995), was suspected of being significantly affected by the event (Gregory 2000a), and directly affects juvenile trout survival (Smith and Griffith 1994) and therefore populations (Mitro 1999).

It seems that natural processes of macrophyte grazing by waterfowl, macrophyte sloughing through senescence, trout spawning, and flows of sufficient magnitude to scour silt and occasionally mobilize gravel may have moved much of the sediment through the Last Chance reach. However, it likely will take much longer for it to move through the Railroad Ranch and Harriman East reaches. In those reaches sediment is likely to be deposited in low velocity areas, particularly in areas where the channel is wide and shallow. Deposition will likely continue in these areas until they aggrade to the point that they eventually turn into bank, effectively narrowing the channel (although changes in channel width will likely be small). This is a natural process in streams, and particularly in spring-fed streams, which do not have the peak flows necessary to scour their channels. This is also the process that forms islands when spring-fed streams become too wide. As the channel narrows by forming new bank or islands, or expanding existing islands, the power of the remaining active channel increases, allowing it to transport material through it. However, this process may be reversed by waterfowl grazing, which may mobilize enough material from these depositional areas that they do not aggrade and turn into bank or islands but instead eventually reach the same deposition/transport equilibrium that was present prior to the sedimentation event.

Sediment is part of natural river and stream systems. While sediment regimes have been altered substantially in the Caldera Section and while it is difficult to see the effect of lack of sediment outlined in section IX.e, the sudden deposition of years of retained sediment in one year can cause visible impacts that will take years to reach an equilibrium that we do not fully understand at this time.

Waters (1995) discusses sediment and its removal from streams and outlines three processes, which do not include natural stream narrowing, by which this can occur: flushing flows, small instream structures to scour and maintain sediment-free sites, and gravel cleaning machines. As outlined by Waters (1995) the success of these projects depends on the elimination of the sediment source. In the case of the Railroad Ranch and Harriman East reaches, this does not simply mean preventing another sediment event from Island Park Reservoir, but includes the sediment from that event that will still be mobilized from upstream and transported into those reaches.

As discussed above, it is likely that it will take some time for sediment in the Railroad Ranch and Harriman East to flush out naturally. Use of instream structures and gravel cleaning machines is very expensive relative to the area treated. In certain situations, such as where spawning habitat is unavailable (which is not the case in the Caldera Section, see section X.i), it may be warranted. However, treating enough of the affected reaches to realize a population level effect in either invertebrate or fish density would be cost prohibitive as well as very intrusive.

X. Water and habitat quality (including invertebrate ecology)

a. Overwintering habitat

What is overwintering habitat for rainbow trout, and why is it available in some places and not in others? Where is the existing overwintering habitat? How does it change in relation to flow volumes, time of year, and other factors?

Winter habitat for juvenile rainbow trout has been studied extensively in the Henrys Fork (Contor 1989; Smith 1992; Meyer 1995; Mitro 1999). During the winter, as water temperatures decline below about 50° F (10° C), juvenile trout began to conceal during the day and come out at night as light levels decrease (Contor and Griffith 1994). This behavior appears to be related to predator avoidance (Gregory and Griffith 1996a) rather than seeking shelter from the current (Valdimarsson and Metcalfe 1998). Concealment cover consists of dense macrophyte beds (Griffith and Smith 1995), interstitial spaces between cobble and boulders (Contor 1989), or woody debris (Schrader and Griswold 1992). When these habitats are available to juvenile trout, they are more likely to survive (Smith and Griffith 1994), and where it is not available or not complex enough, they are likely to emigrate (Meyer and Griffith 1997). Emigration also occurs when the habitat becomes less suitable over time, such as when macrophyte density decreases through senescence or waterfowl grazing (Griffith and Smith 1995).

The best winter habitat for juvenile trout is located in Box Canyon (Mitro 1999), where cobble-boulder habitat and woody debris are plentiful and high water velocities keep interstitial spaces clear of sediment. Macrophytes in Last Chance provide habitat for large numbers of fish during early winter but over the winter become less suitable (Griffith and Smith 1995) and stream sections containing macrophytes contain few juvenile trout by the end of the winter (Mitro 1999). However, in Chick Creek (a tributary to the Buffalo River), where water temperatures remain relatively high throughout the winter, macrophytes do provide extensive habitat for juvenile trout throughout the entire winter (Griffith et al. 1996).

During winter, adult trout have been observed to aggregate in deep pools (Bjornn and Reiser 1991; Cunjak 1996) but also appear to use concealment habitat including woody debris, interstitial spaces in cobble-boulder habitat, and macrophytes (Meyer and Gregory 2000). While this has not been studied in the Henrys Fork, telemetry studies have indicated that adult trout winter in pool areas (J. Gregory, personal observation).

Thermal refuge is also a type of winter habitat. Gregory (2001) observed unconcealed juvenile rainbow trout in Thurmon Creek near a bottom release outflow pipe that released water from Silver Lake. Griffith et al. (1996) observed trout in Chick Creek, a spring-fed tributary to the Buffalo River, that were not concealed during the winter. These observations suggest that juvenile trout will forgo concealment during winter if water temperatures are warm enough (such as in Chick Creek) or if they can gain a substantial thermal advantage by doing so (39 °F [4 °C] downstream from the pipe in Thurmon Creek vs. 33 ° F [0.5 ° C] in adjacent areas where concealment habitat was available).

Late winter (~ December – March) flows have been shown to be positively correlated to winter survival of juvenile rainbow trout in the Henrys Fork (Mitro et al. 2003; Garren et al. 2004). Mitro et al. (2003) hypothesized this was because higher flows inundated more quality habitat along the bank. Additionally, since macrophytes provide cover through the first part of winter, interstitial space availability along the bank may be less important then, but become more important later in the winter as fish that were using macrophytes for concealment emigrate from those areas (Griffith and Smith 1995) and must search for unoccupied habitat or compete for occupied habitat (Gregory and Griffith 1996b).

b. Winter habitat in tributaries

Could overwintering habitat be provided in off-mainstem areas, e.g., tributaries, springs, etc? Would there be any benefit to providing upstream fish passage at Silver Lake? Can we make a reasonable estimate of true potential of these places (individually and collectively) to have a population-level impact on the Ranch fishery, and if so, what would be required?

Besides the Buffalo River, five perennial tributaries enter the Henrys Fork between Island Park Dam and Riverside Campground, including Blue Springs Creek, Antelope Park Creek, Big Bend Creek, Thurmon Creek, and Fish Creek (Figure 1). While assessment of each of these streams has been minimal, they may have the highest probability of success for significantly increasing juvenile trout winter survival in the Caldera Section of the Henrys Fork.

Blue Springs Creek originates on the east side of Highway 20 and flows into the Henrys Fork at Last Chance (Figure 1). It is small (11 cfs in July 1997; Gregory and Van Kirk 1998) and spring-fed and remains without ice through much of the winter. No research has been conducted on this stream during the winter, and a summer habitat assessment indicated that much of the stream substrate consisted of silt or embedded cobbles (Gregory and Van Kirk 1998). During the summer of 2006 the HFF conducted some additional assessment of the stream and found some juvenile rainbow trout and a few juvenile brook trout (*Salvelinus fontinalis*) but minimal winter habitat (J. DeRito, HFF, unpublished data). Therefore, concealment habitat is likely limited in this stream. The extent to which juvenile trout use this stream during winter is unknown and the thermal benefit it may provide has not been evaluated.

Antelope Park Creek and Big Bend Creek are small (~2 cfs, 0.06 cms), highly degraded (Gregory and Van Kirk 1998) streams that flow through the Railroad Ranch and flow into the Henrys Fork on the east side just upstream of Big Bend (Figure 1). While they are small enough that they may not provide substantial amounts of habitat, they are also small enough that they likely “snow bridge” (are completely covered by a layer of suspended snow), which may serve to keep the water temperature relatively high through the winter and may also make concealment habitat less critical for juvenile rainbow trout (Gregory and Griffith 1996a, Valdimarsson and Metcalfe 1998). Incidental observations indicate that a substantial number of age-0 whitefish (*Prosopium williamsoni*) currently spend at least part of the winter in these streams (J. Gregory, personal observation). It is unknown how many, if any, juvenile trout use them for winter habitat.

Thurmon Creek is also a spring-fed stream (34 cfs in July 1997; Gregory and Van Kirk 1998) that enters the Henrys Fork from the west, upstream of Osborne Bridge (Figure 1). This stream originates at springs at the heads of East, Middle, and West Thurmon creeks on the Targhee National Forest, all of which flow into Golden Lake. Thurmon Creek flows over the dam at Golden Lake, through the Railroad Ranch, through Silver Lake, and into the Henrys Fork. The only portion of this stream that is accessible to fish from the Henrys Fork is that section of stream between the Silver Lake Dam and the Henrys Fork, a stream reach of approximately 980 ft (300 m) in length. An estimated 2,000 juvenile rainbow trout, along with a comparable number of juvenile whitefish, were discovered in this section of stream during the winter of 2000 – 2001, after a single juvenile trout implanted with a radio tag at Last Chance was located there (Gregory 2001). This short section of stream contains little habitat that would typically be thought of as winter concealment habitat. However, most of the fish discovered in this section of stream were located downstream of a bottom-release pipe that was leaking 39° F (4° C) water and upstream from where that channel met the spillway channel, which was passing 33° F (0.5° C) water (Gregory 2001). Fish within this section, where concealment habitat did not exist, were selecting a thermal advantage over concealment habitat that was available in other areas.

Fish Pond Creek is similar to Thurmon Creek in that its waters flow from a man-made pond, "Fish Pond," into the Henrys Fork (Figure 1). However, it has a lower discharge than Thurmon Creek, the section of stream between the dam and the Henrys Fork is longer (> 1500 m), and the dam may be passable to fish (Gregory and Van Kirk 1998). Trout were not observed in this stream by an electrofishing crew during the winter but many trout of various sizes were observed in mid-July of that same year (Gregory and Van Kirk 1998). Gregory and Van Kirk (1998) speculated that these fish may move seasonally between the pond and the stream downstream from the dam.

Further evaluation of these streams is needed to assess their benefit, or potential benefit, to wintering fish. In all the spring-fed tributaries, it may be possible to increase over-winter habitat through standard habitat improvement techniques. Additionally, providing passage over Silver Lake Dam may provide a large block of winter habitat (Silver Lake) for juvenile trout. The benefits that may be realized by these projects are unknown but may be similar to those expected from the Buffalo River. However the mechanism may be through juvenile trout migrating upstream during early winter and returning sometime after late winter, whereas the Buffalo River project provides spawning and rearing habitat in addition to favorable winter habitat.

c. Winter habitat in the Last Chance Canal

Is there any fish habitat benefit to Harriman State Park's irrigation canal that begins in Last Chance? Could fish habitat in the canal be improved?

From September 1997 through May 2000 Gregory (2000b) evaluated juvenile trout use of the Harriman Canal, which draws water from the east side of the Henrys Fork at Last Chance (Last Chance Canal; Figure 1). As many as 1,750 juvenile rainbow trout were estimated to be present in the canal at the onset of one winter but fewer were present in successive winters. The canal did provide habitat for fish through the winter, but the amount of habitat created was related to the amount of macrophytes and small woody debris present in the ditch. Small woody debris in the canal was present in the form of a beaver dam and beaver cache, and the macrophytes were present in the backwaters of the beaver pond. Unfortunately, these things are incompatible with water delivery through the ditch, and prior to the end of the study the beaver dam was removed, which increased water velocities and caused the macrophytes to slough, effectively leaving the ditch with minimal concealment habitat for juvenile trout.

At the time the evaluation of the canal was conducted, Harriman State Park managers indicated that the canal was no longer used to deliver water for irrigation but was used to convey stock-water to Harriman East pastures. If the canal is ever abandoned as a water delivery facility, it could provide some habitat for juvenile trout during winter, particularly if beavers re-installed a dam. Water could flow through the canal for about one mile and then be routed back to the Henrys Fork, which would also prevent fish from becoming entrained further down the ditch and being unable to return to the river. In this way, it could function as an off-channel "reservoir," as was suggested by Jepson (1973), to provide habitat for rearing of juvenile trout. However, as long as the ditch is needed as a water delivery facility I believe its contribution as juvenile trout habitat will be negligible.

d. Winter habitat downstream from Pinehaven

What kind of overwintering rainbow trout habitat is found downriver of Pinehaven, downriver to Riverside, and below Riverside to Sheep Falls (upstream barrier to fish passage)?

Little fish research has been conducted either in the Pinehaven reach or downstream from Riverside Campground. Mitro (1999) indicated there were some fallen trees and large rocks along the banks, but very little winter concealment habitat suitable for juvenile rainbow trout was present along the banks at Pinehaven. He also indicated that much of the bank area was inundated with silt. Mitro (1999) caught few age-0 trout in this area, although spring estimates showed that apparent survival (includes immigration and emigration) was higher in this reach than any other reach he evaluated except Box Canyon. Nothing is known about the number of fish that survive the winter downstream from Riverside Campground, or whether or not these fish, or those from the Pinehaven reach, become a part of the fishery upstream from Pinehaven. Two telemetry studies on adult rainbow trout (Griffith and Smith unpublished; Gregory and Emery-Miller 2008) and one on juvenile rainbow trout (Gregory 2001) showed no movement of fish downstream from Riverside Campground. However, no fish downstream from Riverside Campground have ever been fitted with radio tags. Gregory and Van Kirk (1998) described this area as containing few gravel areas and abundant large woody debris and instream boulders, but speculated that anchor ice formation in the area may be extensive. However, given the similarities between this area and the Pinehaven area, and given the relatively high (compared to Last Chance and the Railroad Ranch) number of juvenile trout Mitro (1999) observed in the Pinehaven Reach following winter, further investigations of the river between Riverside Campground and Sheep Falls is warranted.

Sheep Falls may not be a complete barrier to upstream migration of fish (Gregory 2000c). However, additional falls in the general area (Upper and Lower Mesa

Falls), which are upstream migration barriers, ensure that any upstream migration from below Sheep Falls is probably minimal.

e. Winter habitat and ice

How does icing (shelf, frazil, or anchor) effect overwintering habitat for rainbow trout?

Water released from the hypolimnion (bottom of the reservoir) of Island Park Reservoir is a constant 39° F (4 °C) during the winter, preventing surface ice from forming on the Henrys Fork until the water has traveled a distance from the dam. However, this facilitates formation of frazil ice and anchor ice, particularly in the Last Chance and the Railroad Ranch area. Frazil ice (small ice crystals suspended in the water column) is formed when flowing water is supercooled to less than 32° F (0.0 ° C) by very cold air temperatures (Simpkins et al. 2000). These ice crystals move downstream with the water but may adhere to underwater objects such as rocks or macrophytes. In the Henrys Fork (Griffith and Smith 1995), as with other rivers (Simpkins et al. 2000), this process can cause rapid sloughing of macrophytes, effectively reducing concealment habitat for juvenile trout at a time when conditions for trout movement are most severe. Juvenile trout concealing themselves in the interstitial spaces of substrate may be less affected by frazil ice versus those using macrophytes (Simpkins et al. 2000). However, juvenile trout may be sealed into those spaces with unknown consequences when frazil ice forms into anchor ice. Simpkins et al. (2000) observed that frazil ice episodes coincided with substantial movements of ~9 inch wild fish and appeared to frequently force them to move long distances. Anchor ice formation can also cause habitat exclusion as the ice fills space in pools and ultimately causes trout to move (Jakober et al. 1998; Lindstrom and Hubert 2004). Conversely, shelf ice, also called surface ice, provides concealment habitat for juvenile and adult trout causing them to rely less heavily on other types of concealment cover (Gregory and Griffith 1996a; Jakober et al. 1998) such as macrophytes or small woody debris. Therefore, while hypolimnetic releases from Island Park Dam usually keep water temperatures in Box Canyon above freezing and therefore provide a thermal advantage to fish, the surface-ice-free water also provides an avenue for the formation of frazil ice and anchor ice that can be detrimental to fish in downstream areas.

During early winter of 2007, when flow from Island Park Dam remained very low from late October until late December, fisheries managers arranged with water managers to release water if air temperatures became extremely cold. While extreme cold weather did not materialize, this arrangement was a practical precaution because increased water releases may have helped prevent frazil ice and anchor ice formation.

Ice can also affect winter habitat through removal of macrophytes, which is discussed in section X.n.

f. Winter habitat improvements

Has there been any attempt to improve or enhance overwinter habitat "directly" with structures, etc? How successful were these attempts? What is there relative cost vs. benefit compared to water management?

Gregory (2000a) reviewed several attempts to increase winter habitat for juvenile trout in the Henrys Fork, including placing cobbles, boulders and conifers at Harriman East, placing conifers in the Buffalo River (Griffith et al. 1990), scouring silt from substrate at Last Chance and adding conifer trees (Gregory 2000b), adding cobble/boulder complexes at Last Chance (Gregory 2000a), adding artificial PVC structures at Last Chance (Gregory 1998b), and modifying and adding Christmas trees to the Last Chance Canal (Gregory 2000b). While all these efforts created, at least initially, some additional habitat for juvenile rainbow trout, most of them failed to provide habitat either throughout the winter or through multiple years. One reason for this is that most of them were directed at creating individual units of habitat. Projects of this type large enough to provide habitat for enough fish to elicit a population-level effect would be cost- or time- prohibitive (Gregory 2000a). While these projects are much more costly per unit of habitat created and much less effective than things like negotiating more water during late winter or ensuring that juvenile trout are able to pass the dam on the Buffalo River, they have substantial popular appeal. This is primarily because a large number of people can be involved, and because there is something to see on the ground, the benefit of which is perceived even if unsubstantiated. Therefore, the challenge for managers is to make resource users aware of the ongoing efforts to make more existing habitat available, and to constantly be looking for opportunities to get resource users involved in those efforts. Two habitat improvement projects have attempted to make large blocks of habitat available to juvenile trout. These projects are using the Last Chance Canal as off-channel habitat (Section X.c) and providing trout access to the Buffalo River (Section X.g).

g. Winter habitat in the Buffalo River

What are the habitat benefits to improved fish passage at the Buffalo River Hydroelectric Project? Can this project, and the fish passage improvements made, increase the number of rainbow trout in the Henrys Fork? Will improved fish passage benefit the fish and fishing in the Buffalo River?

In the fall of 1996, a fish ladder was installed on the dam of the Buffalo River. This ladder provided passage for sub-adult (the smallest rainbow trout observed to pass the fish ladder was six inches long) and adult rainbow trout (Gregory 2003). Managers anticipated that fish would move upstream to spawn, and their offspring would remain to rear in the spring-fed Buffalo River through their first winter. Subsequently, they would return to the Henrys Fork, having avoided the first winter survival limiting factor in the Henrys Fork (Gregory 2000a).

Initially there were concerns that adult Henrys Fork fish migrating into the Buffalo River may be caught and harvested by anglers. However, a creel survey which showed that few fish were being harvested in the Buffalo River (Van Kirk et al. 1997) and a telemetry study which showed that adult spawners moved downstream rather quickly after spawning (Gregory 2000d) alleviated these concerns, and in 2001 the ladder was left open all year (Gregory 2003).

Evaluation of the Buffalo River fish ladder benefit to the Henrys Fork was attempted but was ineffective, as out-migrating fish from the Buffalo River could easily avoid instream traps, and may have avoided a spillway trap by passing downstream through the ladder, through holes in the dam, or through the hydroelectric project (Gregory 2000e). Therefore, the effectiveness of making the Buffalo River available to spawning fish to increase winter survival of juvenile trout and contribute to the Henrys Fork population is not known.

As part of the re-licensing of the Buffalo River Hydroelectric Project, Fall River Rural Electric Cooperative (FRREC) screened the intake for the power plant, sealed the dam face, and installed an extension to the fish ladder in 2005. The fish ladder was designed to pass age-0 rainbow trout. Trapping records show that adult trout (age-3 and older) use the ladder in the spring, presumably to move upstream to spawn and juvenile trout (age-0 through age-2) use the ladder throughout the year, including ~ 2,000 age-0 and age-1 rainbow trout in October through December of 2006 and 2007 (Lee Mabey, US Forest Service, unpublished data).

HFF plans to trap out-migrants during 2008, which should be more efficient given that the dam has been sealed and the plant screened. That effort will concisely address the question of whether or not juvenile trout are successfully spending the winter in the Buffalo River or its tributaries. However, it is encouraging to note that juvenile trout are moving upstream into that river system during the fall and early winter, especially since winter survival appears better in that area (Griffith et al. 1996). While it is unconfirmed at this time, providing trout of all sizes with year-around access to the Buffalo River will very likely provide substantial benefits to the Henrys Fork trout population.

Van Kirk et al. (1997) speculated that some fish caught by anglers in the Buffalo River were from the Henrys Fork. Therefore, fishing may be improved in the Buffalo River, at least seasonally, by the presence of Henrys Fork migrants. However, fish populations are usually limited by space (Chapman 1966), so the resident population of adult trout in the Buffalo River may not actually increase.

h. Buffalo River habitat potential

What is the current condition of fish habitat in the Buffalo River, specifically for rainbow trout? Could habitat be improved or managed differently in the Buffalo River drainage, including tributaries, to improve rainbow trout overwintering capability?

The Buffalo River is a spring-fed stream that enters the Henrys Fork on the east side near the top of the Box Canyon (Figure 1). Three major spring-influenced streams, including Chick Creek, Toms Creek, and Elk Creek, are tributaries to the Buffalo River. Fisheries research in the Buffalo River has shown that in Chick Creek, juvenile trout densities remained relatively stable throughout the winter (Griffith et al. 1996) in contrast to fish densities in Last Chance (Griffith and Smith 1995). Juvenile trout in this stream use both woody debris and macrophytes for winter habitat. Because the stream maintains a relatively warm temperature throughout the winter and waterfowl grazing is minimal, macrophytes do not slough off during the winter, and therefore continue to provide habitat through the winter. Macrophyte coverage is extensive in Chick Creek, but is less so in the Buffalo River itself.

Much of Chick Creek and the upper Buffalo River contain large amounts of large woody debris (Gregory and Van Kirk 1998) that is available to fish for concealment. However, much of this wood does not have associated small woody debris, and therefore may be more suitable for adult trout than for juveniles. In the lower Buffalo River, juvenile trout density in habitat structures (Christmas trees) was relatively high during the year they were installed (Griffith et al. 1990), but decreased substantially after they lost their needles (Gregory 2000a), which shows the importance of small woody debris as juvenile trout concealment cover. However, Griffith et al. (1990) did observe trout using non-treatment natural bank areas (0.19 fish/m^2) too.

Streams in the Buffalo River drainage are relatively wide and shallow (width to depth ratios greater than 45) in all reaches, except upper Elk Creek and Lower Tom's Creek (Gregory and Van Kirk 1998). It is unclear whether this is a natural condition resulting from the rhyolite geology or a result of anthropogenic effects. Gregory and Van Kirk (1998) indicated that a local resident told their habitat assessment crew that in the 1920s, air boats were used on the lower Buffalo River and that upstream from the railroad crossing, railroad ties were cut and floated down the stream channel. Large woody debris was likely removed to facilitate both of these activities, and both activities would likely result in an over-widened channel. While these reports are unconfirmed, it is interesting to note that the two reaches where the streams are relatively narrow and deep (width/depth ratios less than 30) are both downstream from the railroad crossing (Gregory and Van Kirk 1998). If these streams were artificially widened as a result of these activities, they would not be expected to recover very quickly, since spring streams lack flushing flows to scour pools and build banks.

While there are undoubtedly some habitat issues in the Buffalo River drainage, the drainage is also undoubtedly capable of providing spawning habitat and juvenile trout wintering habitat for numerous fish. Habitat for adult trout is also abundant in the form of large woody debris and associated scour pools. One of the most important questions yet to be answered is that of whether juvenile fish from the Buffalo River move downstream into the Henrys Fork after successfully spending the winter in the Buffalo River and tributaries or whether they out-migrate as young-of-year. This question should be answered beginning in 2008 as the HFF conducts studies to trap trout out-migrating from the Buffalo River.

i. Spawning habitat

Is there enough rainbow trout spawning habitat in the river and/or its tributaries? Would improvements or increases in spawning habitat increase the number of fish in the population?

Spawning habitat is present throughout Box Canyon and Last Chance, and is present in reduced abundance in downstream reaches (Gregory 1997). Additionally, spawning quality substrate is present throughout the Buffalo River (Gregory and Van Kirk 1998). Gregory (1997) did not observe spawning in the portion of the Buffalo River he monitored for spawning activity, but spawning has been observed in other reaches (Gregory 2000d) of the Buffalo River. While the amount of spawning habitat in the Henrys Fork has not been quantified, it has been observed to be sufficient to produce 158,000 – 306,000 juvenile trout (Mitro and Zale 2002). Because the number of juvenile trout that survive their first winter is related to habitat availability, rather than the number of juvenile trout present at the beginning of the winter (Mitro et al. 2003), increasing availability of spawning habitat would have no effect on the population. In other words, the number of juvenile rainbow trout that survive their first winter is related to habitat availability and is not a percentage of the number of fish that are present at the beginning of winter. Therefore, even in the Railroad Ranch and Harriman East, where spawning habitat is present in limited abundance, increasing spawning habitat would not result in increased rainbow trout numbers, as any winter habitat contained therein would be easily filled with fish from other reaches of the river. This would occur because juvenile trout move both upstream and downstream during the winter in search of suitable winter habitat (Mitro and Zale 2002, Gregory 2001), and more than enough juvenile trout are produced in the available spawning habitat to fully seed all available winter habitat.

j. Flushing flows and habitat

Would "flushing flows" improve aquatic habitat for fish (spawning, overwintering, etc), macroinvertebrates, or macrophytes on the Ranch? Would other changes in water management (timing, frequency, duration, rates of changes, and magnitude) improve habitat for any of these aquatic organisms?

In 1997, five years after the 1992 sedimentation event and following a 1995 four day "flushing flow" event that exceeded the 2,600 cfs (73.7 cms) recommended by HabiTech (1994), HabiTech (1998) re-evaluated substrate conditions at Last Chance and sediment transport through the Caldera Section of the Henrys Fork. The results showed that substrate condition in Last Chance had improved overall, with decreases in fine sediment (from 28% of the total in 1994 to 16% in 1997), which also resulted in an increase in the median substrate particle size (from 0.5 inches [13 mm] in 1994 to 0.9 inches [23 mm] in 1997). Due to these changes, spawning gravel quality also increased over this time period. HabiTech (1998) stated that, "While these 1997 results are certainly encouraging and strongly suggest improvement over the conditions encountered following the 1992 sediment flow event from Island Park Reservoir, they should not be interpreted as license to continue the management practices which precipitated the 1992 event. The implementation and enforcement of a 'minimum pool' standard for the reservoir would likely prevent a future re-occurrence."

HabiTech (1994) estimated flushing flows necessary to mobilize, and therefore flush fine sediment from, spawning gravels at Last Chance. Flows to accomplish the same effect within the Railroad Ranch or Harriman East would be higher since the channel is both wider and of lower gradient. Spawning (which itself mobilizes and cleans gravel) has been observed at various locations throughout the Railroad Ranch (Rohrer 1984; Gregory 1997). However, creating additional spawning habitat would not increase fish populations, as production of juvenile trout in Box Canyon and Last Chance is more than adequate to seed all available winter habitat in the Caldera Section (See section X.a).

Winter habitat for juvenile trout is provided during early winter by macrophytes (Griffith and Smith 1995) and throughout the winter by cobble/boulder substrate (Contor and Griffith 1994, Smith and Griffith 1994, Meyer and Griffith 1997, Mitro 1999). As with spawning habitat, macrophytes present in the Last Chance reach are more than adequate to provide early winter habitat for juvenile trout and seed all the late winter habitat Not only would flushing flows likely be inadequate to flush the minimal amount of cobble and boulder habitat that is present in these reaches, but sediment would likely rapidly refill any spaces that had been cleaned, as it did to cobble/boulder habitat improvement clusters even prior to the 1992 sediment event (Gregory 2000a).

Adult trout habitat varies slightly between winter and summer, but consists of some type of cover for both seasons. Cover consists of water depth and/or concealment habitat. The difference lies primarily in the fact that during the summer adult trout need to have suitable habitat nearby into which they can move when threatened, and during the winter they spend the majority of their time actually in that habitat. During the summer, macrophytes provide concealment habitat and contribute to water depth by restricting flow, which ultimately increases the depth of the water (Vinson et al. 1992). During the winter, adult trout migrate to pool areas (Bjornn and Reiser 1991; Cunjak 1996) or conceal in cobble/boulder substrate, small woody debris (Meyer and Gregory 2000), or macrophytes (J. Gregory, personal observation). In the Railroad Ranch and Harriman East reaches, where small woody debris is not present and cobble/boulder substrate is rare and likely embedded with sediment, trout probably resort to wintering in deep pools. This behavior has been confirmed in this area with telemetry studies (J. Gregory, personal observation), which indicate that trout winter in deep pools such as those found at Big Bend, below the Stock Bridge, and near the mouth of Thurmon Creek. Anecdotal reports have indicated that some of these pools have filled with silt as a result of the sediment event of 1992. Filling of these pools would reduce the amount of habitat available to trout during both summer and winter.

It is unclear whether flushing flows could improve conditions for macrophytes. If conditions for macrophytes could be improved, it is likely that trout populations would respond positively (see section X.n).

k. Aquatic invertebrates

What is the current status of aquatic macroinvertebrates in the Henrys Fork? Have insect numbers and species declined -over the past few decades? Are aquatic insects affected by the current water management, specifically high summer flows and low winter flows?

The most recently analyzed macroinvertebrate data from the Henrys Fork (Gregory and Emery-Miller 2006) show that invertebrate density in the Caldera Section (at Last Chance and Big Bend) varies around 4,000 individuals/m² with about 60% of those being from the orders Ephemeroptera, Plecoptera, Trichoptera (mayflies, stoneflies, and caddis flies). Numbers have not changed significantly over the four years of repeated sampling in standardized areas (Gregory and Emery-Miller 2006). However, anglers have repeatedly indicated that aquatic invertebrate hatches have changed noticeably over the past 20 – 30 years. Anglers indicate fewer invertebrates hatching and changes in species relative abundance (Paini and Stiehl 1993a). These changes may be related to the changes in macrophyte abundance and species composition and phosphorus concentrations (discussed in sections X.n and X.o) that occurred through the 1980s.

Invertebrate production has been shown to be related to habitat availability, basal productivity (availability of nutrients, algae, bacteria, and organic mater) and predation (Kiffney and Roni 2007). Furthermore, Gregg (1981) showed that macrophytes produce substantially different conditions in microhabitat from un-vegetated substrate. These microhabitat changes, which are of primary importance to invertebrates, include changes in current velocity, substrate, surface area, and food. While the addition of macrophytes can increase the population density (invertebrates/surface area) of some invertebrates (*Enallagma, Gammarus, Gyraulus, Physa, Tubificidae, Pisidium, Helobdella*) it can decrease the density of others (*Hydropsyche, Simulium, Glossosoma, Baetis tricaudatus, Helicopsyche borealis, Optioservus quadrimaculatus, Brachycentrus, Hayalella azteca, Lepidostoma, Chironomidae, Oligochaeta*) and therefore can cause a change in species composition (Gregg 1981). However, given the substantial increase in surface area macrophytes provide, overall invertebrate density with the addition of macrophytes would be expected to increase (Gregg 1981).

Aquatic invertebrates can be affected by rapid changes in flow such as are common for "peaking power" flows (Cushman 1985). However, flow fluctuations of this type do not occur in the Henrys Fork.

I. Aquatic invertebrates and sediment

Did aquatic macroinvertebrates decline after the sediment release in 1992? Is there any data available prior to that event to compare to after? Ultimately, does or has this sediment made a difference, and is that a positive or a negative difference? Would sediment dredging improve habitat for any of these aquatic species? Are there any proven examples of such modifications?

Some of the first studies initiated to evaluate the effect of the September 1992 sediment release were directed at assessing its effect on invertebrates (Minshall et al. 1993; Meyer and Griffith 1994). Minshall et al. (1993) sampled invertebrates and measured sediment deposition in stream sections above and below Island Park Reservoir and in the Buffalo River during October 1992. They concluded that substantial deposition of sediments had occurred between lower Last Chance and Osborne Bridge, and that inorganic sediments and fine particulate organic matter levels were four to five times greater in these areas than they were in reference areas upstream from the reservoir and in the Buffalo River. They also found that invertebrate density and species richness just below the mouth of the Buffalo River was lower than at reference sites upstream. Based on these results they concluded that extremely poor habitat conditions were present in the Henrys Fork, especially between Last Chance and Osborne Bridge. However, due to the lack of pre-sedimentation data, Minshall et al. (1993) cautioned that they were unable to attribute those conditions to the sedimentation event.

Since that time, substantial invertebrate collections from 1995 – 2005 have been conducted in the Henrys Fork in the Caldera section (HFF, unpublished data; Gregory and Emery-Miller 2006; Gregory and Van Kirk 1997). A cursory comparison of metrics from those reports with metrics reported by Minshall et al. (1993) indicate that invertebrate populations have not changed significantly over that time period. However, sufficient data are available that an invertebrate expert analyzing the data carefully may be able to decipher trends in indicator taxa that are not readily apparent based on the indices.

Dredging of sediment, whether to benefit invertebrates or fish, is infeasible for several reasons. First, whether or not it could be done effectively is questionable. Second, it would be cost prohibitive to do it to an extent that population level changes could be expected. And third, continued transport of sediment (Habitec 1998), which occurred even before the 1992 sediment event (Gregory 2000a), would likely negate any benefits achieved.

m. Aquatic invertebrates and the Buffalo River

How does the Buffalo River affect aquatic macroinvertebrates in the Henrys Fork relative to the flow releases from Island Park Reservoir?

Water from the Buffalo River does not immediately mix with water from the Henrys Fork as it enters the river at Box Canyon, but rather mixes gradually as it progresses down river to Last Chance, as evidenced by differential lateral water temperatures through that reach (Gregory and Van Kirk 1997). This failure to mix creates an early spring thermal advantage on the east side of the Henrys Fork over that which occurs on the west side (Gregory et al. 2000). In the past, this thermal advantage could either become greater later in the spring (if cold surface water was spilled from Island Park Dam before the ice had melted) or less, possibly even becoming a thermal disadvantage (if warm surface water from Island Park Dam was spilled). However, the addition of an inflatable dam on the Island Park Dam spillway now makes it possible to somewhat regulate temperature when the reservoir fills to the point that it could spill. When it is possible to regulate temperature, spill is managed to avoid cold water releases and target a water temperature of 64° F (18° C) on the west side of the river near the outfall of the spillway until the reservoir bottom reaches a temperature of 59° F (15°C) (Gregory 2000f). Under these management criteria, the east side of the river likely will always maintain an early spring thermal advantage over the west side and likely will often continue that advantage throughout the spring. This affects invertebrates in Box Canyon by causing them (at least *Pteronarcys californica* [giant stoneflies]) to emerge about five days earlier and at a larger size (mean of 0.05 inches [1.2 mm] longer) than those on the west side (Gregory et al. 2000).

Because water from the Buffalo River does not immediately mix with that issuing from Island Park Dam, there are likely other effects besides temperature that vary laterally across the river. For example, sedimentation resulting from the mobilization of sediment from Island Park reservoir in 1992 and 1979 likely affected the west side of Box Canyon more than the east side (which presents an interesting comparison for evaluating the effects of the sediment on the substrate and invertebrates). Likewise, productivity likely varies laterally across the river, reflecting the differential inputs of nutrients that are delivered from the Buffalo River vs. Island Park Reservoir.

n. Macrophytes

How did the "ice outs", i.e., large icing events that occurred in past winters, especially in the late 1980s and early 1990s, affect the macrophytes? How did the

1992 sediment releases affect the aquatic macrophytes? If there were any negative changes to aquatic macrophytes how would this affect macroinvertebrates? What is the current status of macrophytes? How do swans affect macrophytes and then how may this affect rainbow trout? Is flow management for both swans and rainbow trout workable?

Macrophyte (rooted aquatic plants) abundance and species composition in the Henrys Fork have changed substantially over the 1958 – 1996 period of recorded studies (Shea et al. 1996). Several factors, most notably lack of standardization of methods between studies, confound precise comparisons of macrophyte abundance and species composition trends. However, extensive changes have occurred, as discussed by Shea et al. (1996), and these are reviewed below.

Macrophytes in the Henrys Fork were divided by Shea et al. (1996) into groups based on morphology. Group1 species were tall, robust, and erect species that thrive in low water velocity, silt – rich, high nutrient environments (*Potamogeton. pectinatus, P. richardsonii, Elodea canadensis, and Myriophyllum exalbescens*). Group 2 species were shorter, bottom dwelling species that are more tolerant of higher water velocities, prefer higher light intensity, and are capable of rapidly colonizing disturbed sites (*Callitriche hermaphroditica, Ranunculus aquatilis, and Zannichellia palustris*). The major species present on the Henrys Fork are characteristic of nutrient rich environments and are often among the most prolific, resilient, and persistent species present in disturbed aquatic systems. Several are even considered to be weedy or nuisance species and have a high potential for rapid increase in streams such as the Henry's Fork when conditions are favorable (Shea et al. 1996).

Macrophyte surveys from 1958 were rather cursory but describe a macrophyte community in which both Group 1 and Group 2 species were well represented. Macrophytes during this time period were subject to water management that often included very low early winter flows, resulting in formation of ice, and then increases in flow later in the winter that would cause the ice to break up and be mobilized, likely causing physical damage to macrophytes.

By 1977-1980, after winter flow management had changed (See section IX.a) and was more conducive to macrophyte growth than in previous periods, Group 1 species comprised > 95% of the biomass, while Group 2 had declined to trace quantities. Prolific beds of lush vegetation reached the water surface throughout much of the river. Biomass measurements and descriptions indicated that during the late 1970s, the plant community likely attained its peak biomass for the 1958-1995 period.

During the early 1980s, the macrophyte community experienced massive changes in both species composition and biomass. Shea et al. (1996) noted that this decline may have been initiated as early as 1979-1980 when Hampton (1981) noted a decline in the massive beds of *E. canadensis*, a Group 1 species, in Last Chance. By "1985/1987" (Shea et al. 1996) the dense beds of Group 1 macrophytes were totally absent from the Last Chance area and were replaced by Group 2 species. In 1986, macrophyte biomass had declined (~ 50%) from 1979 levels. By 1988, Group 2 species were more abundant than Group 1 species. In March 1990 aquatic macrophytes were nearly completely absent from the river; virtually all macrophytes had senesced or been consumed by waterfowl. However, winter grazing by waterfowl was not the only cause of macrophyte declines problem. Between October 1989 and October 1990, macrophyte biomass declined 78%, which showed the failure of macrophytes to recover to pre-winter grazing levels. Shea et al. (1996) also described the macrophytes of October 1990 as "stunted, stressed, and generally lacking in vigor." Plant height had also decreased approximately 68% from October 1989 to October 1990. Based on these data, Shea et al. (1996) concluded that, during the winter of 1989-1990, aquatic macrophytes within the Railroad Ranch "…experienced a massive decline from which they have not yet recovered." Extensive digging and herbivory by unusually large populations of Trumpeter Swans (*Cygnus buccinator*), Canada Geese (*Granta canadensis*) and ducks was believed to have contributed significantly to the decline. Shea et al. (1996) also indicated that continued heavy foraging by waterfowl appeared likely to impede recovery of the remaining sparse vegetation.

Patchy macrophyte recovery, in the form of increases in Group 1 species, plant cover, and plant height, occurred to some extent in 1991 and 1992. Macrophyte monitoring took place on 13 October 1992 and, although by that time the Island Park Dam gates had been shut, terminating the sediment release from the reservoir, "little sediment was noticeable along the transects" (Shea et al. 1996), which were located from Last Chance through Harriman East. Shea et al. (1996) hypothesized that the sediment may have been "perched" upstream in Box Canyon. By March of the next year, "huge quantities" of sediment had been transported into the survey area, settling in some areas in depths up to 1 m. Mean plant height decreased again in 1993 and by 1994 there was "patchy" recovery of macrophytes. In 1995, bare substrate again increased and plant height again decreased. By 1996, three of the four Group 1 species that dominated the macrophyte community in 1979 had declined by > 90% with two persisting only in trace amounts (Shea et al. 1996).

By 1999, macrophyte coverage had recovered to 1992 levels (Figure 6), although biomass was still lower than in the late 1970's. In 1999, transects at Last Chance and the Railroad Ranch still lacked massive beds of Group 1 species that dominated the area prior to 1990, but macrophytes had recovered substantially since the silt deposition of 1992 (Shea 1999). Shea (1999) also indicated that macrophytes were normal in color and vigor, in contrast to the stunted development and poor appearance observed in 1990 and 1991. Additionally, algae were abundant, except at Last Chance, and in some areas exceeded macrophyte biomass. These large algae mats were thought to affect water depth in a similar manner to macrophytes, by creating resistance to flow and increasing water level (Shea 1999).

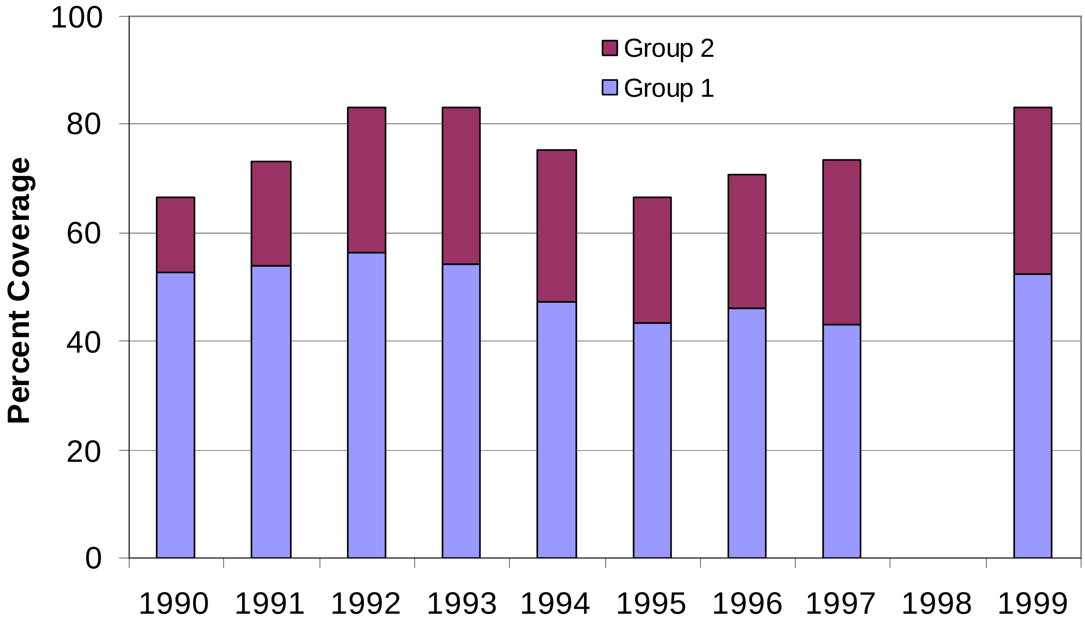

Figure 6. Percent coverage of the Henrys Fork by macrophytes observed during October surveys from Last Chance through Harriman East for the period of comparable records (Shea 1999).

While all species present in the 1970s and 1980s were still present in the Henrys Fork in 1996, they were greatly reduced in biomass, and individual plants were often unusually small (Shea et al. 1996). The areas around Big Bend and the Ranch houses had the tallest and most abundant vegetation in 1989 but the least abundant and shortest vegetation in 1995. Macrophyte recovery was best at Harriman East and worst in the Railroad Ranch at Big Bend and near the Ranch buildings.

The declines in macrophyte abundance occurred over a relatively long period of time, possibly beginning as early as 1979 and with abrupt declines in the late 1980s (from 1989 – 1990) and again after 1992. The cause of these declines is not clear, but Shea et al. (1996) indicated that several factors could contribute, including silt deposition from releases at Island Park Dam in 1979 and again in 1992, low winter flows and associated ice formation and breakup, high spring flows and associated scouring, and grazing by waterfowl. Additionally, reductions in macrophytes, particularly Group 1 macrophytes, cause what Shea et al. (1996) referred to as a "negative feedback loop" where macrophyte density is reduced, which causes increased water velocity, causing silt substrate in which other macrophytes are rooted to be scoured, which further reduces macrophyte density. Shea et al. (1996) also identified conditions which perpetuate the conditions that reduce Group 1 species and favor Group 2 species. These conditions include reduced macrophyte biomass, unstable fine sediments, and waterfowl grazing.

This reduction in macrophyte biomass/density altered many facets of the river's ecology, including channel roughness, flow velocity, water depth, patterns of sediment erosion and deposition, nutrient cycling, habitat quality and availability for fish and invertebrates (see section X.k), and food supplies for wintering waterfowl (Shea et al. 1996). Most notably for fish, changes in macrophyte density directly affect water depths

(Vinson et al. 1992) and winter habitat for juvenile trout (Griffith and Smith 1995). Macrophytes roughen the channel, causing resistance to flow and therefore increasing water depths. Vinson et al. (1992) showed that in the Henrys Fork water surface elevation dropped 1 – 1.6 ft (0.3 – 0.5 m) at a constant discharge as macrophyte coverage of the channel decreased from 60 – 90% of stream-bottom coverage to near 0%. This caused an associated 40 – 78% increase in water velocities and a 40 – 79% decrease in channel cross-sectional area. Since water depth is a habitat component for trout, both during summer and winter, these reductions in water depth and cross-sectional area reduce fish habitat availability and ultimately, at least locally, fish populations. Reductions in macrophyte abundance have also been seen to cause juvenile trout to emigrate from wintering areas as these reductions in abundance occur (Griffith and Smith 1995).

It is interesting to note that reductions in macrophyte density are not necessarily a function of time of year, as macrophyte density decreased more rapidly through the winter of 1992-1993 than during the winter of 1989-1990 (Griffith and Smith 1995). Resulting juvenile trout densities were therefore lower in mid-January of 1992-1993 than at the same time in 1989-1990 (Griffith and Smith 1995). Griffith and Smith (1995) concluded that macrophytes failed to provide habitat for juvenile trout through their first winter. However, their study was conducted after most of the massive reductions in macrophytes had already occurred. While at this point it is impossible to assess, it would be interesting to know whether macrophytes did persist at sufficiently high densities to provide habitat through the winter for juvenile trout prior to the reductions in macrophyte densities that occurred throughout the 1980s and early 1990s. If macrophytes can provide cover for juvenile trout through the winter, as they have been seen to do in the Last Chance Canal (see Section X.c) and Chick Creek (Griffith et al. 1996, re-establishment of macrophytes could cause a huge increase in survival of juvenile trout and ultimately increase the trout population throughout the Caldera Section.

Efforts to reduce impacts to macrophytes have included waterfowl hazing, which occurred throughout the 1990s, and transplanting of swans, which was last done during the winter of 2004-2005 (L. Hanauska-Brown, Pers. Comm. Idaho Department of Fish and Game). Additionally, the fishing season in the Railroad Ranch, which closed on 30 September as early as 1954, was extended to close with the general season on 30 November beginning in 2004. This change in season length was intended to encourage human disturbance of the Railroad Ranch area which, it was hoped, would result in passive hazing of waterfowl and cause them to continue fall migrations to other wintering areas. Shea et al. (1996) also experimented with grazing exclosures on the river. However, due to ice formation, the capture of senescent macrophytes by the posts that marked the plot perimeter (causing changes in flow and therefore scour and silt deposition), and the reluctance of swans to feed in the marked control plots, the experiment was terminated.

Returning macrophyte populations to the density and species composition of the 1970s will be difficult. However, Shea et al. (1996) suggested management actions that should aid in the recovery of Group 1 species. These included higher, stable winter flows, reduced variation between winter and early peak flows, delaying peak flows until June or later (which would shift peak flows even further from the natural flow regime –

see Figure 2), and reducing waterfowl herbivory. The most important of these may be reducing waterfowl herbivory. The number of swans counted in mid-winter surveys has increased substantially since the first surveys were conducted in 1972. This increasing swan trend has also been observed in the Henrys Fork (Van Kirk and Martin 2000), which is expected, as it is not unusual for 40% of the tri-state Rocky Mountain Population of Trumpeter Swans (Idaho, Wyoming, and Montana) to be on the Henrys Fork during the winter (Vinson 1990).

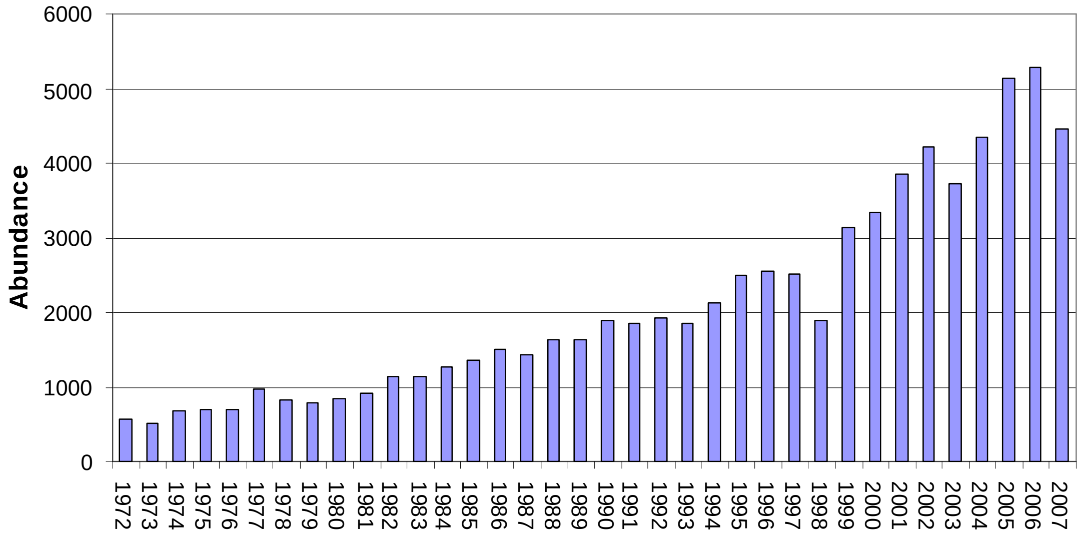

Figure 7. Counts of the Rocky Mountain Population (Idaho, Wyoming, and Montana) of trumpeter swans during winter, 1972-2007 (USFWS 2007). Counts are from the previous calendar year (e.g., the 2007 value is from the Fall 2006 survey).

One factor that Shea et al. (1996) specifically eliminated as a cause of macrophyte decline was lack of nutrients. They stated that, "Massive algal blooms and recent water chemistry data (Goodman 1994) indicate eutrophic conditions. Abundant sediment, and proliferation of *E. canadensis* in the downstream reaches provide no suggestion of nutrient depletion." However, over the period of macrophyte decline, there has also been a decline in nutrients (primarily phosphorus) in the Henrys Fork (See section X.o). This decrease in nutrients may cause decreased macrophyte density either directly (fewer nutrients available for macrophytes) or indirectly (by decreasing algae growth which covers macrophyte beds and protects them from grazing by waterfowl [Shea 1999]). Regardless of the cause, I believe that the relationship between the abundance and species composition of macrophytes and fish habitat is a key factor affecting Henrys Fork fish populations.

Swans and fish populations both benefit from higher winter flows. (Mitro et al. 2003; Vinson 1990). Swan populations benefit from high flows in early winter which prevent swan access to some macrophytes, thereby encouraging them to migrate to other areas, whereas low early winter flows cause more swans to remain on the Henrys Fork. This can result in consumption of the macrophytes before the end of winter, which can necessitate the emigration of swans during the winter. Conversely, rainbow trout benefit by high flows late in winter (See section X.a), which make additional habitat available after macrophyte habitat is no longer useable (discussed in section X.n). Unfortunately, winter flows are a limited resource and can not remain high throughout the winter. Therefore, addressing the needs of both species requires compromise.

o. *Water quality*

What is the current water quality (chemicals, nutrients, etc.), and are there any trends over time?

In 1974, nutrients in the Henrys Fork were measured (Forsgren et al. 1975) prior to the construction of centralized sewage treatment plants at Mack's Inn and Last Chance. The study found that fecal pollutants from human sources were entering the waters of the Henrys Fork at several communities from Henrys Lake to Last Chance (Forsgren et al. 1975). They found that phosphorus concentrations were high (~100 µg/l at Last Chance), "possibly due to the high phosphorous content of the geological formations in the study area." However, after installation of a centralized sewage treatment plant at Mack's Inn in 1982 and Last Chance in 1986, 1994 and 1995 phosphorus concentrations at Last Chance had dropped ~60 - 90% (to 41 and 10 µg/l). However, nitrogen concentrations remained similar over the same time period (Figure 8). Because the Henrys Fork is nitrogen limited (Idaho Water Resources Board 1992), macrophyte growth may be more dependent on changes in nitrogen levels than phosphorus levels.

While waterfowl undoubtedly have had an effect on macrophyte density and species composition, it is possible that reduced nutrients may also have played a role. This possibility needs to be investigated further.

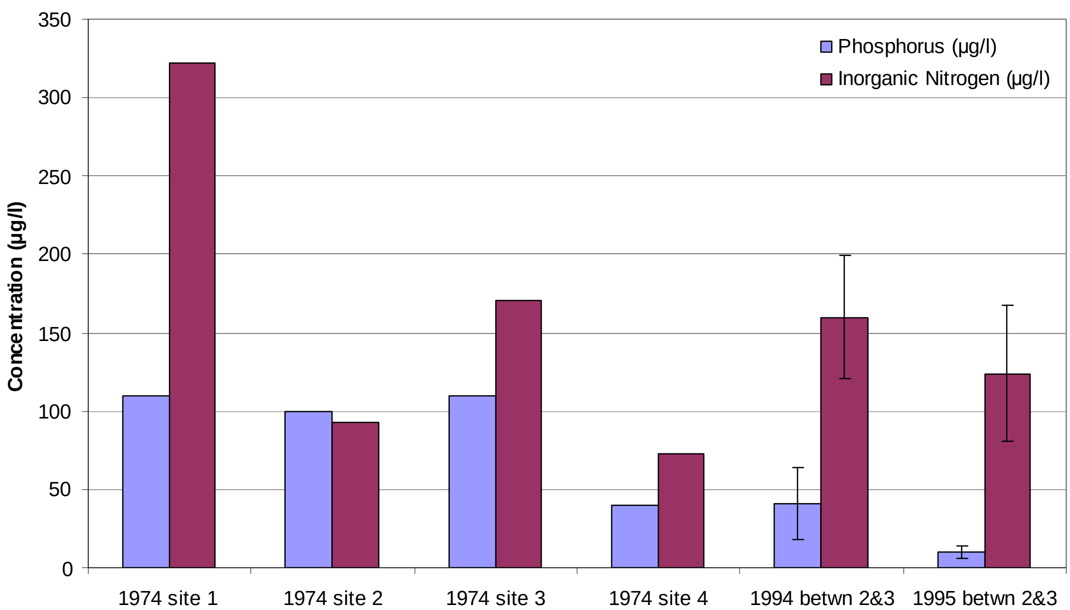

Figure 8. Average phosphorous and average total inorganic nitrogen (with 95% confidence intervals where available) measured at four locations in Last Chance throughout the summer of 1975 (Forsgren et al. 1975) and measured in an area between the 1974 sample areas 2 and 3 in 1994 (Goodman 1994) and 1995 (Goodman 1995).

XI. Fisheries biology and management (includes creel and economic surveys)

a. Rainbow trout history in the Henrys Fork

What is the history of the introduction of rainbow trout to the Henrys Fork? Is there a genetically distinct or distinguishable "Henrys Fork rainbow trout"? What hatchery strains have been stocked in the Caldera and when? Can the current rainbow trout in the Henrys Fork be traced back to the famous McCloud River strain? Are there genetically unique rainbow trout in Silver Lake?

It is unclear exactly when rainbow trout were first stocked into the Henrys Fork, or what the origin of those fish was, but Van Kirk and Gamblin (2000) reported that in 1891 a commercial rainbow trout fish hatchery was in operation on Henrys Lake, and by 1893 another hatchery raising brook and rainbow trout was functioning in the Shotgun Valley. Throughout the late 1800s, the US Commission on Fish and Fisheries (USCFF) was actively distributing eggs and fry of several trout species to individuals, agencies, and private companies throughout the country and probably supplied eggs to these first Henrys Fork hatcheries (Van Kirk and Gamblin 2000). Van Kirk and Gamblin (2000) reported that "Conventional wisdom has held that the origin of almost all rainbow trout beyond their native range is the McCloud River in northern California (e.g., Keil 1928, Wales 1939, Busack and Gall 1980), and that conventional wisdom has generally prevailed on the Henrys Fork to this day. However, historical records show that some rainbow trout eggs shipped to Bozeman, Montana, in the late 19th century were collected from steelhead in the Trinity River 150 miles west of the McCloud (USCFF 1897, and Behnke 1992)." Furthermore, Behnke (1992) states that "Redband trout of the McCloud River made only a minor contribution during hatchery operations there during 1877 – 1879 and from 1880 to 1888," and that "Exchanges of fish and eggs among state, federal, and private hatcheries mixed these rainbow trout stocks with little regard to their ancestry." This led Van Kirk and Gamblin (2000) to conclude that "the ancestor of the modern Henrys Fork rainbow was most likely a hybrid of many different rainbow stocks rather than a pure McCloud River fish."

Whatever the source of the original Henrys Fork rainbow trout, the rotenone treatments of Island Park Reservoir, tributaries, and the Henrys Fork downstream to Mesa Falls in 1958, and to Ashton in 1966 (Van Kirk and Gamblin 2000), effectively eliminated those fish, along with the native cutthroat trout. From those rotenone treatments forward until 1978, when hatchery fish stocking in the Caldera Section of the Henrys Fork was discontinued (J. Fredericks, IDFG, Pers. Comm.), rainbow trout were stocked using fish from IDFG hatcheries. Thus, the rainbow trout currently in the Henrys Fork are descendants and an admixture of Arlee rainbow, Mt. Lassen rainbow, Hayspur rainbow, domestic kamloops, and "unspecified rainbow," all of which were stocked by the IDFG after the rotenone treatments. Additionally, several rainbow and cutthroat strains including: Colorado River rainbow, Eagle Lake rainbow, Fish Lake rainbow, Hayspur rainbow, Mt Shasta rainbow, Mt Whitney rainbow, Troutlodge rainbow, Henrys Lake cutthroat, Lahontan cutthroat, rainbow/cutthroat hybrids, and unspecified cutthroat have been stocked in Island Park Reservoir and undoubtedly have passed Island Park Dam and interbred with rainbow trout in the Caldera Section.

The IDFG has not stocked fish in Silver Lake since at least 1967. Whether or not it was stocked before that time and what fish may have been stocked is unknown. It is also unknown whether the rotenone treatments in 1958 and 1966 included treatments of Silver Lake. Since the dam on Silver Lake is impassable to fish migrating upstream from the Henrys Fork it is possible that rainbow trout in Silver Lake are genetically similar to those that were in the Henrys Fork in the early 1900s. However, Henrys Lake cutthroat trout were stocked in Golden Lake in 2001 (Fredericks et al. 2003) and have likely hybridized with fish from Silver Lake to some extent.

b. Rotenone

How did the fish removal projects (Rotenone, etc.) in Island Park Reservoir and below affect the rainbow trout and other fishes?

Rotenone was used in 1958 and 1966 to remove non-game fish from Island Park Reservoir and native whitefish from the Henrys Fork. These treatments included tributaries upstream from Island Park Reservoir and the Henrys Fork to Mesa Falls in 1958, and the mainstem to Ashton in 1966 (Van Kirk and Gamblin 2000). These treatments removed nearly all fish, including native Yellowstone cutthroat trout, which were replaced with stocked rainbow trout (Van Kirk and Gamblin 2000). The effect of the more recent Island Park Reservoir rotenone treatments in 1979 and 1992 (Garren et al. 2008) was a function of the release of sediment (discussed in section IX.e) rather than the rotenone itself. Because the dam was completely shut off during the 1992 treatment, no detoxifying was conducted downstream of the reservoir. There were no incidents of fish kill due to the release of toxic water from the reservoir pool (Gamblin 1995).

c. Rainbow trout growth and survival

How well do rainbow trout grow in the Caldera? How long do they live? What are the mortality rates between year classes? How do these figures translate to fish/mile? Has the size of rainbow trout in the Caldera changed over time?

Rainbow trout in the Caldera Section of the Henrys Fork grow to about 17 inches (432 mm) by the winter of their fourth year (Table 1). This growth rate is faster than any reported for rainbow trout from 20 other rivers and streams across the state (Figure 9; Schill 1991). Growth is variable between years, particularly for juvenile trout (Meyer 1995), and between river sections (Angradi and Contor 1989). Trout have been seen to reach age-7 in the Box Canyon (Table 1; Garren et al. 2006a).

Table 1. Mean length (mm) at annulus formation (winter) for rainbow trout by reach in the Caldera Section of the Henrys Fork from 1981 (Rohrer 1983), 1986 to 1987 (Angradi and Contor 1989), 2002 (Garren et al. 2006b), and 2005 (Garren et al. 2006a).

		Mean length (mm) at annulus formation						
Year	Reach	1	2	3	4	5	6	7
1981	Box Canyon	129	211	297	369	458	555	
1986 – 1987	Box Canyon	155	277	364	431	493	532	
1986 – 1987	Railroad Ranch	120	231	355	435			
1986 – 1987	Pinehaven	112	235	367	482			
2002	Box Canyon	150	295	364	401	416	425	
2005	Box Canyon	122	296	348	432	422	458	494

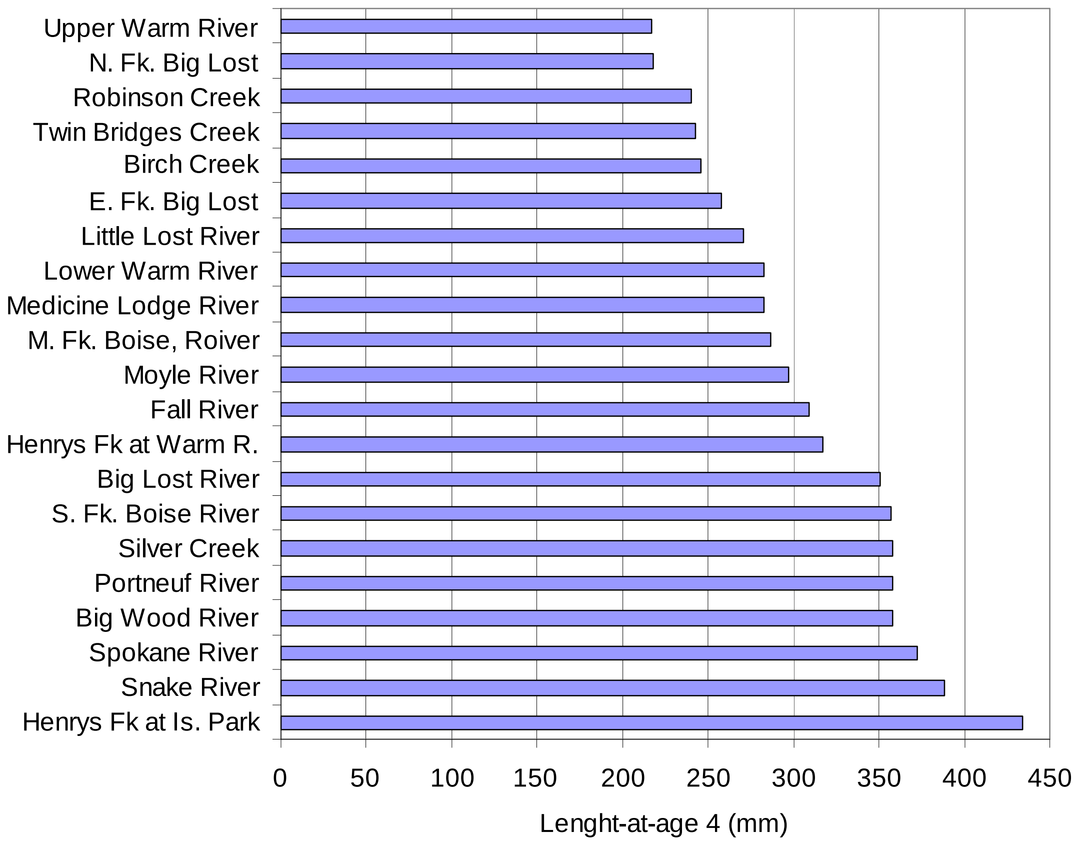

Figure 9. Length-at-age 4 for rainbow trout from rivers and streams across Idaho (data from Schill 1991; Henrys Fork data from Angradi and Contor 1989 collected at the Railroad Ranch).

Water management at Island Park reservoir also affects trout growth rate. Water released from the bottom of the reservoir is a near constant 39 °F (4° C) during the winter. At this water temperature, juvenile trout in Box Canyon upstream from the mouth of the Buffalo River have been shown to continue to grow through the winter (Smith 1992). Additionally, water from the Buffalo River enters the Henrys Fork at even warmer temperatures than water coming from the Island Park Dam (Gregory et al. 1995), which likely facilitates winter growth of fish throughout much of Box Canyon. However, by the time the water reaches Last Chance it has cooled enough that winter growth, at least of juvenile trout, has been shown to not occur in that area (Smith 1992). During the summer the cooler water sinks to the bottom of the reservoir and is released into Box Canyon. This prevents water temperatures from getting too warm, thereby creating optimal temperatures for trout growth in Box Canyon through much of the summer.

Mortality rates of age-0 rainbow trout in the Henrys Fork are much higher than that for older age-classes, and range from 77 – 100% depending on river reach (Mitro and Zale 2002). Extensive research has documented that the primary recurring factor influencing the number of fish present in the Caldera Section of the Henrys Fork is survival of juvenile trout through their first winter (Mitro and Zale 2002; Garren et al. 2004). Population size is also affected occasionally by recruitment from Island Park Reservoir by fish passing the dam either over the spillway or through the gates at the base of the dam (Van Kirk and Gamblin 2000), which is discussed section XI.j.

Average annual mortality for age 2 – 7 fish in Box Canyon during 2005 was estimated at 38% (Garren et al. 2006a). This mortality estimate is lower than the 53% average annual mortality rate for age 2 – 5 rainbow trout reported by Angradi and Contor (1989) for 1986 and 1987. However, some harvest (daily limit of 3 trout < 12 inches and 1 trout > 20 inches) was still allowed during that time period, which likely accounts for the higher mortality rate. Angradi and Contor (1989) also reported higher average mortality rates for fish from the Railroad Ranch (68%) and the area between Pinehaven and Hatchery Ford (82%). They speculated that winter anchor ice formation in the area downstream from Pinehaven may account for much of the natural mortality in that area. Schill (1991) reported that natural mortality in wild trout streams from across Idaho ranges from 31 – 64% per year (Schill 1991).

Interestingly, although growth rates appear to have remained relatively constant between the 1980s and 2005 (Table 1), Box Canyon contained proportionally more big fish in 2006 and 2007 than in the 1980s (Figure 10). This increase in the number of big fish corresponds to the decreased annual mortality rate that changed from 53% (Angradi and Contor 1989) to 38% (Garren et al. 2006a) over the same time period.

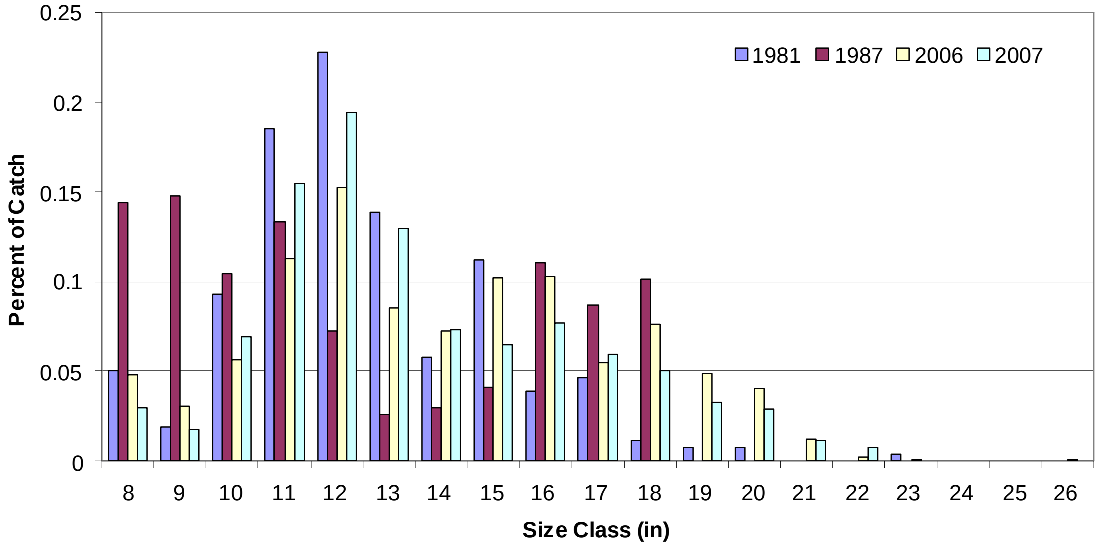

Figure 10. Length frequency distribution for rainbow trout captured in Box Canyon in 1981 (Rohrer 1983), 1987 (Angradi and Contor 1989), 2006, and 2007 (Dan Garren IDFG. Personal Communication).

d. Adult Trout and Winter Flows

Are adult rainbow trout negatively affected by low winter flows, in terms of mortality, feeding, etc.?

Adult trout survival appears to be unaffected by low winter flows, as evidenced by high survival rates of radio tagged adult rainbow trout during the winter of 2003 – 2004 (Gregory and Emery-Miller 2008). In late October 2003, radio tags were surgically implanted into 22 adult rainbow trout captured by electrofishing from the Last Chance and the Railroad Ranch reaches and 18 adult rainbow trout salvaged from the area between Island Park Dam and the mouth of the Buffalo River. Flow from Island Park Dam was terminated at that time and salvaged fish were released downstream from the mouth of the Buffalo River. In spite of stress associated with fish collection, handling, surgery, and low flows (discharge at the dam remained off until 25 December), only two tagged fish (5%) died between tagging and mid March (Figure 11). Thereafter, stress associated with spawning likely caused the increased mortality.

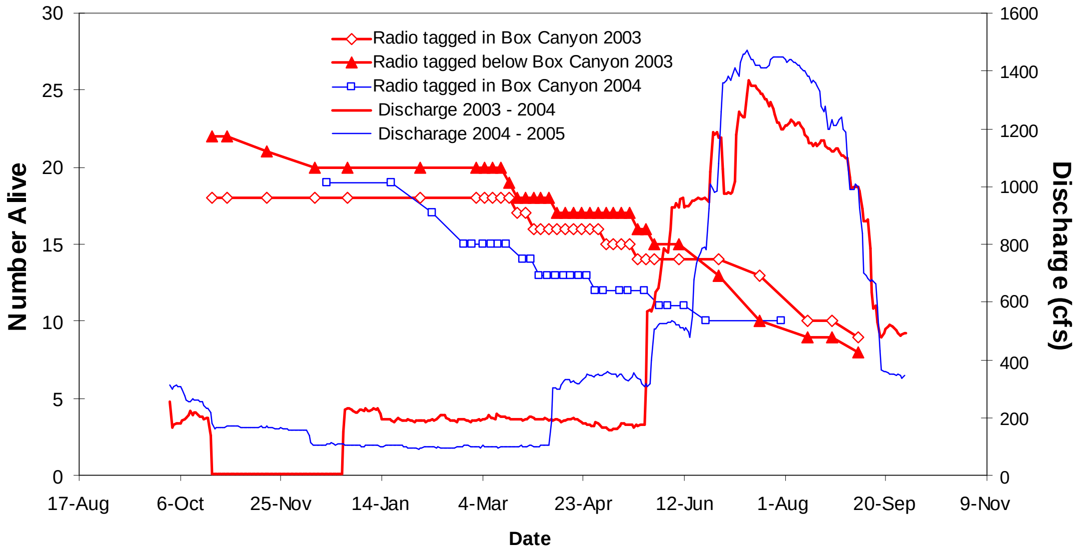

Figure 11. Survival of radio-tagged adult rainbow trout in the Henrys Fork compared to discharge at the USGS gage at Island Park over that same time period.

Fish feeding has not been evaluated at low winter flows but, because they are exothermic, fish have reduced food intake needs during winter and are likely not limited by reductions in food availability if, in fact, food availability is reduced at low winter flows.

Ultimately fish population size in a reach of river is a function of production, mortality, and movement. As indicated, radio-tagged adult mortality was minimal, but some upstream movement was observed during the winter (Gregory and Emery-Miller 2008). This was likely related to fish moving to deeper habitat. However, movements between reaches were minimal and included one fish that was released at Osborne Bridge and moved downstream to Harriman East. In most cases, fish moving between reaches were fish released at the Stock Bridge in the Railroad Ranch moving upstream to Last Chance. However, given that these fish were collected from the area between the Last Chance boat launch and the Railroad Ranch Stock Bridge, they could have been simply moving back to the areas from which they were captured.

e. Rainbow trout migration out of the Caldera Section

Do rainbow trout migrate downstream and out the Caldera by going over the falls (Sheep or Mesa)?

Two telemetry studies on adult rainbow trout with a total of 73 trout tagged (Griffith and Smith unpublished data; Gregory and Emery-Miller 2008) and one on juvenile rainbow trout where 44 fish were tagged (Gregory 2001) showed no movement of fish downstream from Riverside Campground. However, no fish downstream from Riverside Campground have ever been fitted with radio tags.

f. Juvenile rainbow trout and winter flows

Does water management (Island Park Reservoir storage and delivery) affect the wild rainbow trout population in the Caldera? What is the relationship between winter flows and wild trout numbers? Is it more important to have more water in the early part of the winter or the later part of winter? How does winter air temperature effect water temperature, fish movement, and survival in the caldera? If early winter flows and air temperatures are low, then should flows be increased sooner?

Water availability (drought vs. "good" water years) and water management at Island Park Dam, which are inextricably tied together, are probably the most important factors regulating fish populations in the Caldera Section of the Henrys Fork. Flows and/or water management affect trout population size and habitat availability through several factors outlined below.

The most well-documented relationship between flows and fish population size in the Henrys Fork is the relationship between winter flows and the survival of juvenile trout through their first winter (Mitro et al. 2003, Garren et al. 2004). In 1988 Griffith (1988a) stated that the factor that most limits fish populations in the Henrys Fork is first winter survival of juvenile trout. Several subsequent studies by Griffith and his graduate students documented the importance of winter habitat to the survival of juvenile trout (see Gregory 2000a). Based on these studies, primarily on observed high rates of mortality of caged fish at the onset of winter at Caldera sites (Smith 1992) and metabolic deficits during that time period as documented by researchers elsewhere (Cunjak et al. 1987), early winter was suspected as a critical period for survival of juvenile trout. While this is undoubtedly true, the effect of early winter survival on juvenile trout numbers in the Caldera Section is small compared to the effect of late winter emigration (Griffith and Smith 1995; Mitro 1999). In other words, emigration (fish leaving a river section), which occurs when sufficient winter habitat is not available (Griffith and Smith 1994, Meyer and Griffith 1997) and takes place in late winter (Griffith and Smith 1995, Mitro 1999), is such a large factor that the death of some fish during early winter is small in comparison. Mitro et al. (2003) found that there was a positive correlation between the number of juvenile trout successfully completing their first winter and flows during late winter (15 January – 31 March). This relationship has also been observed by Garren et al. (2004), who found that higher or lower late winter flows at the time fish were juveniles caused strong and weak year-classes in the population in subsequent years (Figure 12; Garren et al. 2004). Mitro et al. (2003) speculated that this relationship was a function of more bank habitat available at higher flows as more of the bank is wetted in late winter. Flows during this time period are a function of storage of water in Island Park Reservoir, which is primarily dependent upon reservoir carryover from the previous irrigation season (Section IX.a; Benjamin and Van Kirk 1999).

However, occasionally some other factor is responsible for increased or decreased winter survival of juvenile trout at a given flow, as evidenced by the outlying points from year classes 1997, 1998, and 2005. Additional analysis is needed to assess the factor that so substantially overrides the effect of late winter flow on year class strength. Possibilities include the relative size of juvenile trout at the onset of winter (Meyer 1995), the availability of bank habitat in Last Chance (which supported densities of 70 fish/m² in February 1990 but 0 fish/m² in 1993; Griffith and Smith 1995) and emigration of juvenile trout from the Buffalo River or Island Park Reservoir into the Caldera Section. Additionally, these points could be influenced by post first winter survival factors because age-2 fish are being sampled.

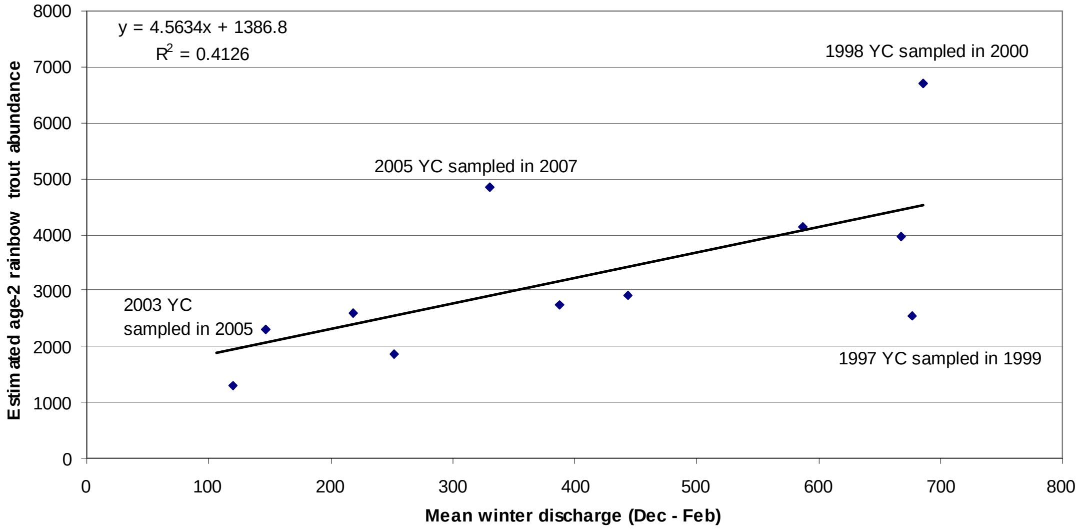

Figure 12. Relationship between mean late winter discharge (December through February) and year class (YC) strength of rainbow trout hatched the previous spring, as measured by estimates of age-2 rainbow trout abundance two years after hatching (Garren et al 2004).

During winter, discharge rates affect ice formation (Section X.e) and macrophyte grazing by waterfowl (Section X.n) both of which can affect fish habitat availability (Griffith and Smith 1995) and ultimately survival (Smith and Griffith 1994).

g. Rainbow trout and spring-time flows

Are rainbow trout affected by water management and hydropower production during the spring?

Water management at Island Park Dam has little effect on fish spawning and incubation except as it relates to temperature (discussed in Section IX.a) and silt (discussed in Section X.e). As outlined above, storage of water in the reservoir has the potential to cause spill with ice on the reservoir, which results in cold water moving through Box Canyon resulting in longer incubation times and ultimately slower fish growth. However, the inflatable rubber dam installed on the spillway to increase power production and management directives put in place for management of that rubber dam, make temperature controllable (within the bounds of reservoir surface and bottom temperature) negating this problem, and instead often making temperatures more favorable than background (inflow) temperatures.

h. Rainbow trout and summer flows

Are rainbow trout affected by water management during the summer?

Increasing late summer flows likely has a positive impact on fish populations by moderating late summer high temperatures (Gregory and Emery-Miller 2006). This occurs because water is drawn from the bottom of the reservoir and is relatively cool during summer. This effect can be reversed when the reservoir is drawn down to a low level such that warm surface water is passed through the outlet. While this likely has negative effects on fish growth and survival, the associated transfer of trout from the reservoir to the river downstream from the dam likely over compensates (increasing the fish population) for any negative affects the warm water may have. This is typically not much of a problem anyway because the reservoir usually becomes low late in the year (September), after warm summer temperatures have moderated.

i. Hydroelectric project

Did water management change in 1994 with the addition of the hydroelectric project on Island Park Dam? How does the hydroelectric project on Island Park Dam affect water quality and trout spawning and rearing?

In 1993, a 4.8 MW hydroelectric plant was retrofit to Island Park Dam (Van Kirk and Burnett 2004). This plant produces electricity by siphoning up to 960 cfs (27.2 cms) of water from the bottom of Island Park Reservoir and passing it through two turbines, which discharge the water into a bay at the base of Island Park Dam. The power plant does not alter flows in the Henrys Fork, as it only uses water that would otherwise be released from the dam anyway (Van Kirk and Burnett 2004). However, the hydroelectric plant does affect water temperature and water quality depending upon how reservoir water is moved downstream of the dam.

While the hydroelectric plant does not alter flows in the Henrys Fork, it does have some ability to alter Henrys Fork temperatures in the spring. Island Park reservoir is permitted to fill to a surface elevation of 6303 feet. This level is one foot higher than the spillway crest. Historically, this fill has been achieved by closing or partially closing the gates at the bottom of the reservoir until the reservoir reaches this elevation. At times, this meant that power production at the power plant had to be reduced or cease while water was still being passed downstream. When this occurred prior to the ice melting on the reservoir, near freezing water was passed downstream. If this occurred later in the year it sometimes meant that much warmer water was passed downstream than that which would have been released if water had been drawn from the bottom of the reservoir.

In the mid 1990s, the hydroelectric plant owners proposed to put a rubber dam on the spillway which could be inflated to a height of one foot (elevation of 6303 ft) so that water could continue to be routed through the power plant. Fisheries benefits included avoiding the passage of very cold or very warm water down the river, particularly when trout eggs were incubating. However, the drawback was that warmer spring water passage, that could increase the growth of young trout, would also be precluded. Trout egg and fry development is positively correlated to water temperature (Piper et al. 1982) and trout survival of their first winter has been shown to be positively correlated to their size at the beginning of winter (Smith and Griffith 1994; Cunjak et al. 1987). Therefore, the HFF and other stakeholders worked closely with plant managers to come up with an operating plan that allowed the rubber dam to be installed and used to increase power production while at the same time providing a thermal benefit to the fishery. This was accomplished by designating operating procedures that prevented spill prior to the ice melting on the reservoir, targeted a water temperature of 64° F (18° C) on the west side of the river near the outfall of the spillway, and allowed complete cessation of spill when the thermal advantage of doing so was less than 4° F (2° C) or the bottom of the reservoir reached 59° F (15°C) (Gregory 2000f).

The hydroelectric plant is also required to maintain the dissolved oxygen content of water released from the power plant at or above 7.0 mg/liter (Ecosystems Research Institute 2007). When water at the bottom of the reservoir is low in dissolved oxygen, this standard is attained by aerating the water in a basin at the plant outflow. Before the power plant was installed, this low-oxygen water was released directly into the Henrys Fork through the gates at the base of the dam.

j. Fish movement from Island Park Reservoir

Are fish (which species?) moving from Island Park Reservoir to the river below, and if so, how, when, and how many? Does reservoir management affect the number of fish moving to the river below? How does the current fish movement from the Reservoir compare to that prior to the Island Park Hydroelectric Project? What would happen if the screen to the hydroelectric power plant intake were removed? Are rainbow trout that move through Island Park Dam to the river below more likely to reside in the Box Canyon or below? What are the benefits and drawbacks from reservoir "by-stocking" of fish?

Prior to 1994, fish movement from Island Park Reservoir to the Henrys Fork downstream from the dam likely occurred both over the spillway and through the unscreened gates at the base of the dam. While fish likely pass the dam over the spillway, they may be somewhat unlikely to emigrate from the reservoir when spill is occurring simply because there is a large amount of space available in the reservoir when it is at spill elevation. As the reservoir surface elevation drops, the volume of water stored in the reservoir and therefore the space available for fish in the reservoir also decreases. As this occurs fish may be more likely to leave the reservoir by the only means possible at that time - through the unscreened gates. This downstream movement of fish at low reservoir volumes has been observed in other Idaho reservoirs (Jeppson 1975) and is apparent in the Box Canyon population estimates from 1993 (Van Kirk and Gamblin 2000). During 1993, rainbow trout population estimates in Box Canyon increased sharply from 1992 population estimates and reflected numerous fish from Island Park Reservoir that moved into the river when the reservoir was drawn down to about 270 ac-ft (0.33 million cubic meters) in September 1992 (Figure 13).

In 1994, a hydro-electric facility was installed on the dam. The facility uses a screened siphon to take water from the bottom of the reservoir through the dam and turbines. While the facility does not affect outflow from the dam (see Section IX.a), it does affect fish movement from the reservoir to the river below because much of the flow that now passes the dam, does so through a screen (Van Kirk and Gamblin 2000). However, when the water surface in Island Park Reservoir drops below about 6281.5 ft elevation (which corresponds to about 28,000 ac-ft [34.56 million cubic meters] of storage, or about 21% of reservoir storage capacity) the siphon that carries water through the power plant ceases to function (Brent Smith, Northwest Power Services, Inc., Personal Communication). This necessitates the opening of the unscreened gates under the dam, which facilitates the passage of fish from the reservoir downstream into the Henrys Fork. The power plant is also shut down, and the unscreened gates opened, when discharge from the dam drops below 180 cfs (5.1 cms). This also often occurs when reservoir levels are low and likely facilitates movement of fish from the reservoir into the Henrys Fork. Over the lifetime of the hydro-electric plant, electricity production has stopped because flow was too low or the reservoir elevation was too low, about 10% of the time (Figure 13).

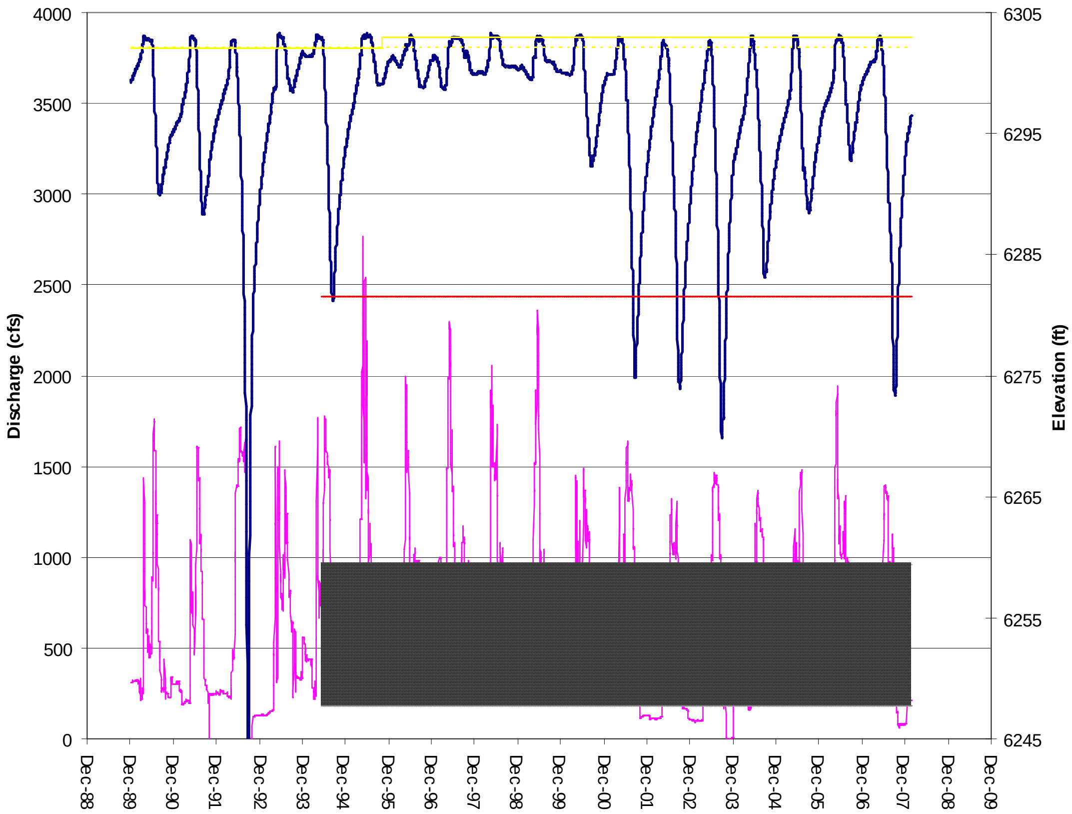

Figure 13. Island Park Reservoir water surface elevation (heavy blue) and discharge (magenta). Since it began operating in June of 1994, discharges between 180 and 960 cfs (gray rectangle) are passed through the Island Park Hydro-electric plant, except when water surface elevation drops below 6281.5 (red line) when the siphon ceases to function and all the water passes through the unscreened gates. At elevations above 6202 ft spill occurred prior to 1995, when a rubber collar was installed on the spillway and allows regulation of spill between 6302 and 6303 elevation (dotted and solid yellow lines).

Water is also passed through the unscreened gates when discharge from the dam exceeds 960 cfs (27.2 cms). However, this occurs at intermediate to high reservoir elevations and likely does not facilitate much trout movement from the reservoir into the Henrys Fork, because reservoir volumes are high.

Currently, there is also the possibility of transfer of fish from Island Park Reservoir to the Henrys Fork via the spillway. However, the number of fish using this route is unknown and likely always was fewer than was historically transferred through the gates at the bottom of the dam, simply because more space in the reservoir is usable by fish at the high reservoir elevations when spill takes place. If fish indeed were passed downstream over the spillway in the past, current fish passage via this route is likely reduced due to an inflatable rubber collar that was installed on the spillway in 1995. Although water is still spilled over the collar, use of the collar to increase power production reduces the amount of water, and therefore likely fish, passing over the spillway.

Because water still passes Island Park Dam through unscreened avenues, fish still move out of Island Park Reservoir into the river below. However, this movement does not take place to the extent that occurred before the hydro-electric facility was installed. Removal of the screen on the hydro-electric facility intake has been suggested, but is probably self defeating as mortality of catchable sized trout (7 – 12 inch) through a power generation facility (on the Buffalo River) has been shown to exceed 70% (Gregory 2000e). While mortality through power generating facilities can vary at each facility based on turbine type, design, number of blades, blade speed, head pressure, and others, high mortality of fish passing through the turbines is likely.

Fish that move from the reservoir into the Henrys Fork have been observed in the Box Canyon, as evidenced by the 1993 population estimate, and downstream in the Railroad Ranch (McDaniel 1994), although their relative abundance in each area is unknown. Fishermen initially indicated that these fish did not fight as well when hooked and were easier to hook than resident fish, but they adapted rapidly (Paini and Stiehl 1993a, McDaniel 1994).

Other species of fish besides rainbow trout are found in the reservoir including Yellowstone cutthroat trout, brook trout, mountain whitefish, Utah chub, and Utah suckers (Garren et al. 2006a), and these fish likely also enter the Henrys Fork via the same mechanisms described above, although numbers of these fish immigrating has not been evaluated. With the exception of anglers voicing some dissatisfaction with the fighting ability of immigrant fish (McDaniel 1994), no negative consequences of immigration of any of the above species has been observed.

k. Whirling disease

Is whirling disease present in the Henrys Fork within the Caldera? If so, does whirling disease affect the rainbow trout population, and why haven't similar affects been seen such as those in area watersheds, e.g., the Madison River? If not, what are the risks of whirling disease being spread to the Caldera, and how might it affect the rainbow trout population?

Whirling disease was first discovered in Henrys Fork trout at Macks Inn during the summer of 2001 (Gregory 2003). Since that time, juvenile trout abundance has not differed significantly in that area (Gregory and Emery-Miller 2006). Whirling disease has also been found in Howard Creek (http://www.esg.montana.edu/cgi-bin/fhhucd?01240700009295), which is a tributary to Henrys Lake.

Whirling disease does not cause fish population reductions in every area in which it is present. Spatial and temporal overlap in the release of sufficient numbers of

Triactinomyxons (TAMs) to contact a vulnerable fish species at a susceptible life state is critical for proliferation of the disease. This depends on the number of an oligochaete worm *Tubifex tubifex* (an intermediate host) present, number of TAMs produced, fish species present, and timing of fish emergence. One of the most important abiotic factors in transmission of *Myxobolus cerebralis* (the causative agent of whirling disease) to trout by *T. tubifex* is temperature, with the highest level of TAM production and infection of fish occurring between 50 and 59° F (10 and 15 °C) (Granath and Gilbert 2002, MacConnell and Vincent 2002, Vincent 2002).

The current widespread distribution of *M. cerebralis*, both in Idaho and throughout the country, is in part, a result of stocking infected hatchery fish (Andree et al. 2002). However, Bergersen and Anderson (1997) hypothesized that the parasite could also be transported by fish-eating birds, and on the equipment of anglers. This is possible, as the myxospore stage (spores that are transferred from dead fish to *T. tubifex*) of the parasite is extremely resilient. It can survive passage through the guts of birds and fish, can withstand freezing for at least 3 months (Kerans and Zale 2002) and has been reported to remain viable in a dry pond bed for twelve years (Wagner 2002). While whirling disease has not been documented to be present in the Caldera Section of the Henrys Fork it is likely that it either is present or will be eventually. At this time, the dynamics of whirling disease are not known well enough to allow prediction of how it will affect specific fish populations.

I. Rainbow trout carrying capacity

Do rainbow trout prefer the Box Canyon to other parts of the Henrys Fork? What is the relationship between rainbow trout numbers in the Box Canyon and those on the Ranch or other parts of the Henrys Fork?

The rainbow trout carrying capacity of the Caldera Section of the river is determined by overwinter juvenile habitat, which is primarily in Box Canyon but in the past was available in other locations. Once winter is over, the fish that have survived disperse throughout the Caldera section. Where those disperse to is a function of the available resources (food and cover). In areas where more resources are available more fish will be present. Therefore, whether or not rainbow trout prefer the Box Canyon over other Caldera reaches could be determined by assessing relative population densities between reaches. However, the correlation between fish population estimates in the Box Canyon and other reaches of the Caldera section of the Henrys Fork has not been well evaluated. The telemetry study outlined in section X.d (Gregory and Emery-Miller 2008) indicates that between 10 and 20% of fish radio tagged in other reaches of the river are present in Box Canyon during May, when the population estimate is conducted. Therefore, the Box Canyon estimate, to some extent, is an estimate of fish numbers from a larger portion of the river than just Box Canyon. As would be expected, fish originally radio-tagged further from Box Canyon were present in Box Canyon during May in lower numbers than those radio-tagged closer to Box Canyon (Gregory and Emery-Miller 2008).

Population estimates conducted by Angradi and Contor (1989) during 1987 indicate that fish densities (fish/length of stream) were similar among reaches (Figure 14). However, fish size structure varied among the different reaches (Figure 15).

Collecting fish, especially large fish, via electrofishing in slow water is difficult, and Angradi and Contor (1989) suggested that large fish, particularly in the Railroad Ranch section, were likely underestimated, which may account for the observed differences in size structure. In 1994, Gamblin et al. (2002) also assessed fish populations downstream from Box Canyon and found that population density (fish/length) was lower in downstream reaches than in Box Canyon (Figure 16). While these population estimates compared with those from 1987 seem to indicate a downtrend in trout numbers downstream from Box Canyon relative to those in Box Canyon, this relationship is tentative for the following reasons. First, the data from 1994 do not include confidence intervals, which indicate the level of precision of the estimate. Second, the downstream areas sampled are not consistent between years. In 1987, the Railroad Ranch was sampled from the Stock Bridge downstream to Millionaire's Pool, while the 1994 samples were conducted from the north boundary of Harriman State Park to the Stock Bridge. Additionally, an estimate was conducted in Pinehaven only in 1987 and at Last Chance only in 1996. The IDFG is planning to rectify this situation by conducting population estimates downstream from Box Canyon in 2008. The estimates they obtain will be useful to determine if habitat suitability has changed substantially in downstream areas relative to those in Box Canyon.

If fish habitat was equally suitable between reaches in 1987 and became less suitable in downstream reaches in 1994 because of sediment deposition, macrophyte reductions, or other factors, then a shift in relative fish density would be expected. This would cause the number of fish/stream length in more suitable areas to be higher than the number of fish/stream length in the less suitable areas. However, given the wide confidence intervals (Figure 14) reported for 1987 and the lack of confidence intervals for the 1994 data, conclusively identifying a change in suitability based on fish density may be difficult.

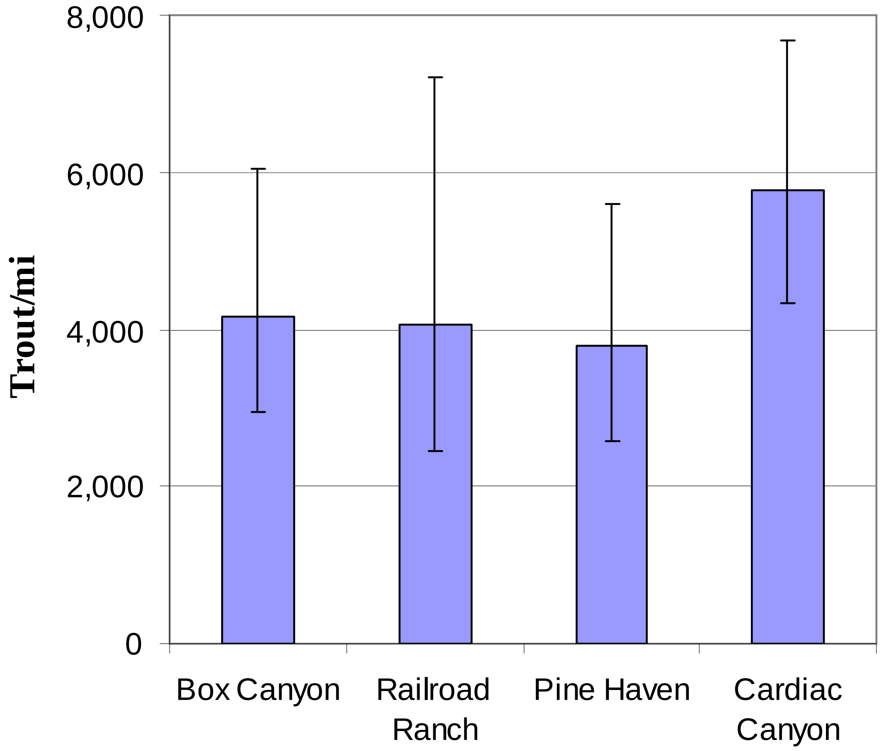

Figure 14. Rainbow trout population estimates (for all fish captured) and 95% confidence intervals for Box Canyon, Railroad Ranch (Stock Bridge to Millionaires Pool), Pinehaven, and Cardiac Canyon on the Henrys Fork during the summer of 1987 (Angradi and Contor 1989).

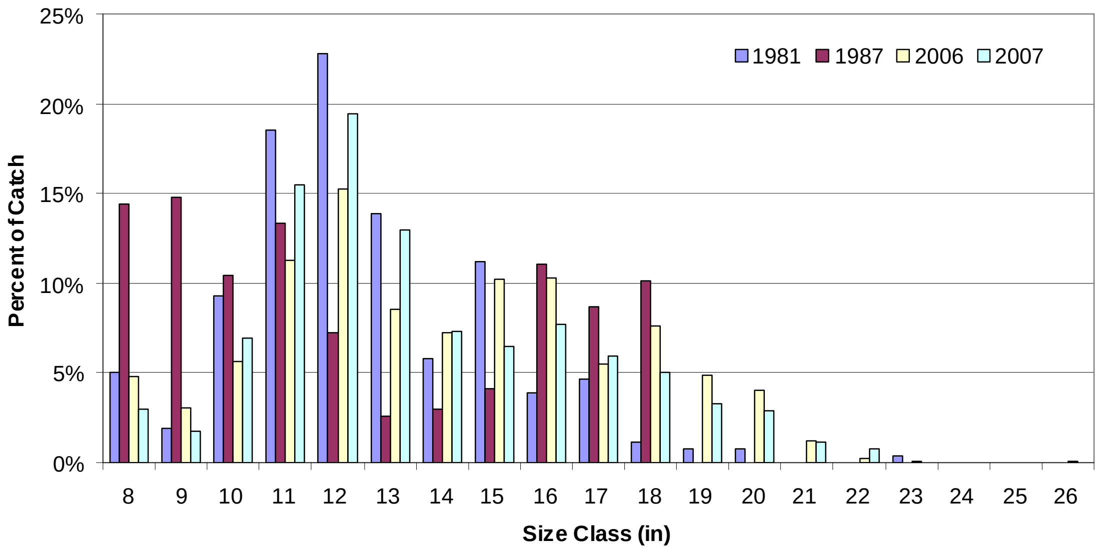

Figure 15. Length frequency distribution for rainbow trout collected at Box Canyon, Railroad Ranch (Stock Bridge to Millionaires Pool), Pinehaven, and Cardiac Canyon on the Henrys Fork of the Snake River during the summer of 1987 (Angradi and Contor 1989).

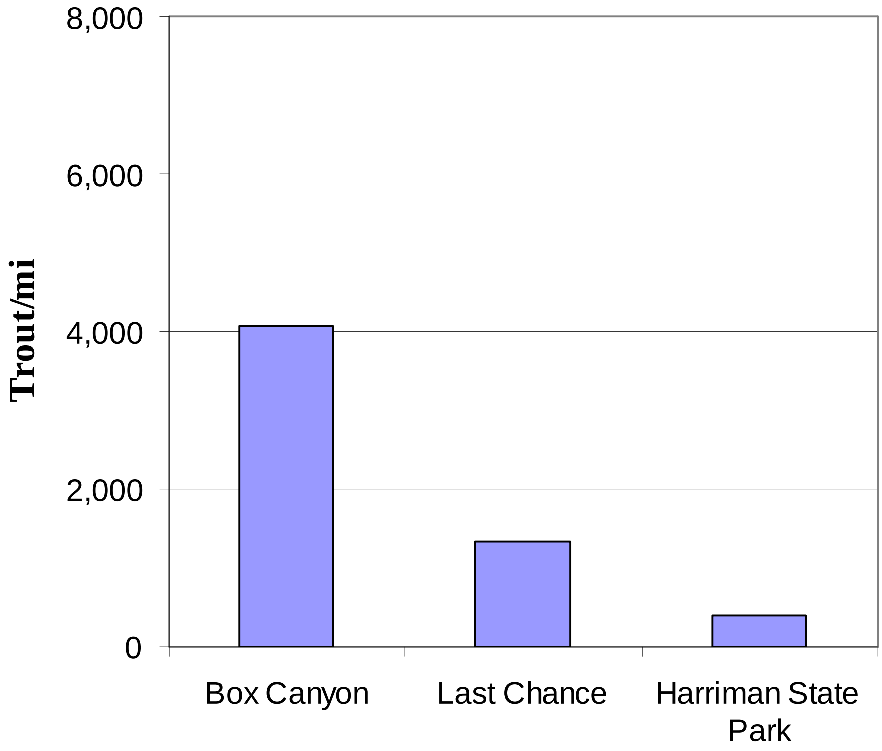

Figure 16. Rainbow trout population estimates (for fish > 150 mm in length) for Box Canyon, Last Chance, and the Railroad Ranch (HSP north boundary to Stock Bridge), on the Henrys Fork during 1994 (Gamblin et al. 2002).

m. Stocking

When did stocking end in the Caldera? What are the differences in fish numbers before and after stocking in the Caldera? Could stocking of juvenile rainbows (ie. 1-year-old and older) increase the numbers of fish?

Trout stocking by the IDFG in the Caldera Section of the Henrys Fork ceased in 1978 (J. Fredericks, Idaho Department of Fish and Game, Pers. Comm.). The only population estimate conducted in Box Canyon that would be influenced by fish stocking was done by Coon (1978) in 1978 (Figure 17). While Coon (1978) reported capture data he did not report an estimate because "…the low water created maintenance problems for our boat and electrodes and not enough fish could be marked and recaptured to make useable estimates." However, Angradi and Contor (1989) calculated an "extrapolation" of the 1978 data reported by Coon (1978) of 18,796 wild trout > 9.8 inches (250 mm) in the Box Canyon section. Van Kirk and Gamblin (2000) reported this estimate as fish per section on a graph that showed this estimate as being higher than subsequent Box Canyon estimates. However, Coon's (1978) electrofishing section extended from the Mouth of the Buffalo River to the mouth of Blue Springs (3.5 miles, 5.4 km), while subsequent estimates (1989 to present) only extended downstream to the riffle at the bottom of Box

Canyon (2.3 miles, 3.7 km). Additionally, while Coon (1978) captured fish as small as 150 mm, which is the smallest size class reported for most subsequent data, and reported capture data from wild fish, Angradi and Contor (1989) indicate that the extrapolation estimate is for fish > 9.8 inches (250 mm) and do not indicate if hatchery fish were included. When the extrapolation estimate is standardized to stream length, it is still one of the higher estimates but is similar to population data from 2000 (Figure 17). While the estimate can be standardized to section length, the uncertainties associated with it, related to the questionable lower size limit of fish included in the estimate and the inclusion of a portion of the Last Chance Reach, make interpretation of this data difficult. However, 1978 was preceded by several winters of above average late winter discharges (Figure 18) which would cause several strong year-classes in a row, resulting in good population abundance.

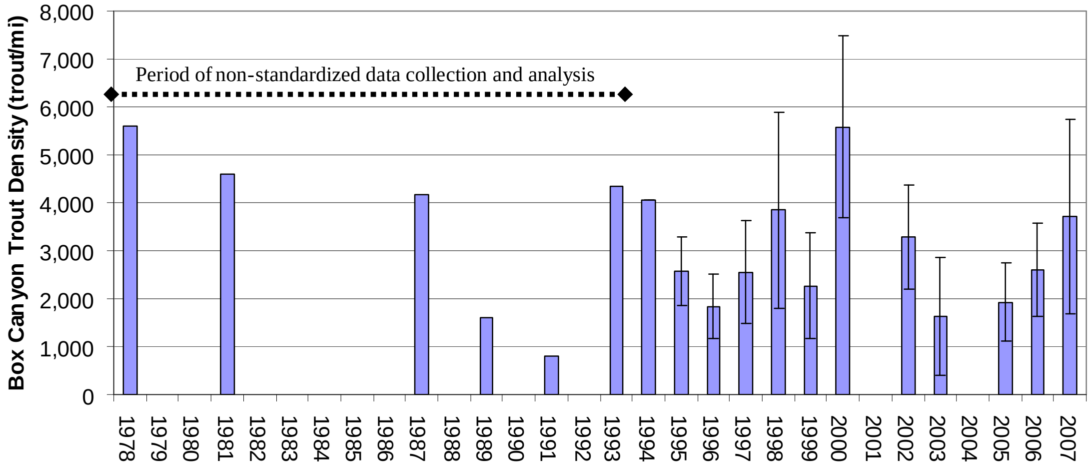

Figure 17. Box Canyon wild trout density (number of fish/mile) from 1978 - 2007.

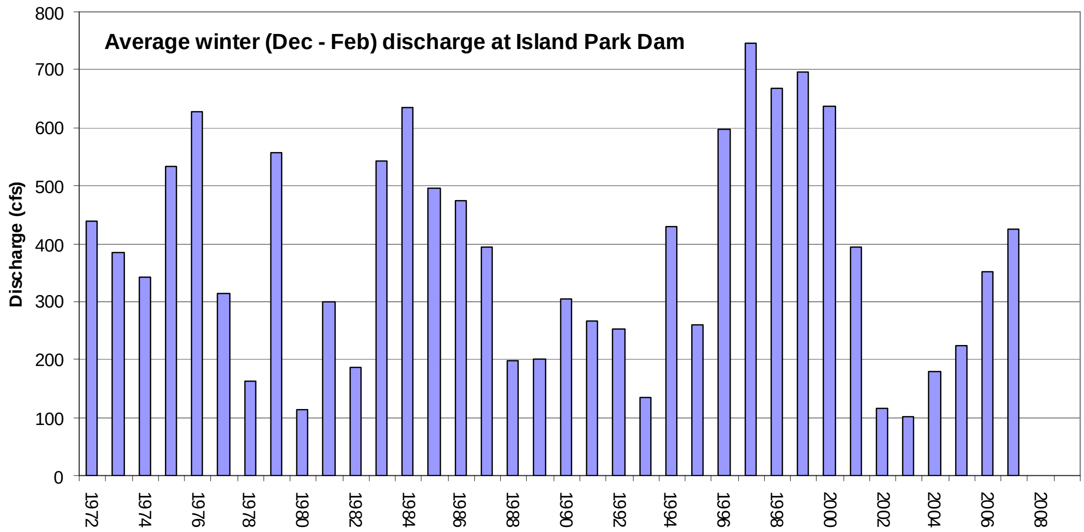

Figure 18. Average winter (December - February) discharge below Island Park Dam for a given water year.

In 1973, 31,400 catchable (8 - 12 inch) hatchery rainbow trout were stocked into the Henrys Fork between Island Park Dam and Riverside Campground. Creel census showed that 15% of them returned to the creel. In 1976, 34,740 catchable hatchery rainbow trout were stocked into the Henrys Fork in that same section and 11% of them returned to the creel. A review of hatchery trout harvest statistics in Wyoming (Wiley et al. 1993) showed that stocking of hatchery catchables in rivers should be done only where anglers can remove them quickly, as survival to the next season is low. Return-to-the-creel was lower in the Caldera Section of the Henrys Fork than the average of 27.5% but within the range (7.7-65.2) reported for Wyoming (Wiley et al. 1993) for stream stocked hatchery catchables.

Given that first winter survival limits the size of the fish population in the Caldera Section of the Henrys Fork (Mitro and Zale 2002, Garren et al. 2004), it has been suggested that stocking fish as fingerlings, after they have completed their first winter may be a viable alternative. The only fingerling stocking evaluation completed on the Henrys Fork was completed by Coon (1977), who stocked fingerlings (4 – 6 inch) in the spring of 1976 and evaluated harvest of those fish in 1977. He reported that by the end of the summer some of those fish had begun to be harvested, but by the end of the evaluation period (31 August), only 0.8% of the fingerlings planted had been harvested. Unfortunately, this does not adequately evaluate the question, as those trout were planted in the spring, before their first winter, and the evaluation period ended before they were fully vulnerable to angling and harvest.

In Wyoming, Wiley et al. (1993) reported average return-to-the-creel rates of 11% (range 0.6 – 23%) for sub-catchable trout planted in streams. He recommended that when sub-catchable trout are stocked in streams it should be done during the spring, in areas where hatchery and receiving water are of the similar quality (productivity), where water temperatures and flows are not limiting, and where few competing fish are present. The Henrys Fork certainly has competing fish present, even following low flow years when recruitment to the population is low. Additionally, after spring-spawned rainbow trout spend their first winter in the hatchery they are nearly catchable size and likely would have a survival rate more similar to catchables than true fingerlings. High and Meyer (in press) found that 87% of hatchery catchables released into the Boise River throughout the summer, where size limits precluded harvest of test fish, were dead within 30 days of stocking.

Interestingly, Van Kirk et al. (1999) reported that in 1996, 6% of the fish caught by anglers in Box Canyon were hatchery fish. This is comparable to earlier results from throughout the Caldera Section, which showed that 15% of the harvested fish were hatchery trout in 1973 (Jeppson 1973), and that 19% of the harvested fish were hatchery trout in 1976 (Coon 1977). This is somewhat surprising as more than 30,000 hatchery catchable rainbow trout were planted in that reach in the 1970s while none were planted in the reach in the 1990s. Van Kirk et al. (1999) hypothesized that these fish entered the Henrys Fork after being stocked in either Island Park Reservoir or the Buffalo River. Catch of hatchery fish in Box Canyon of 6% probably reflect multiple captures of some fish, as was calculated by Van Kirk and Giese (1999) for the Buffalo River.

n. Fishing regulations

When did fishing regulations change from a catch-and-keep fishery to catch-and-release? Did rainbow trout numbers and size increase as a result of the change?

The Henrys Fork from Riverside Campground to Island Park Dam was placed under catch-and-release regulation for the first time in 1988. However, a long series of progressively more restrictive regulations lead to this point. For example, the reduced season length on the Railroad Ranch was in place as early as 1954, when the season there ran from 10 July – 30 September and was enacted to protect waterfowl rather than fish. By 1969 the Railroad Ranch season had been changed to 15 June – 30 September. In 1972, the general trout limit was reduced from 15 to 10 trout, and in 1973 additional restrictions of no trout greater than 14 inches and fly fishing-only had been added to the Railroad Ranch regulations. In 1977, the general limit was restricted to 6 trout. In 1978 a “slot limit” was enacted throughout the Caldera Section which restricted harvest to 3 trout < 12 inches and 1 trout > 20 inches, and by 1980 the Caldera Section had been restricted to artificial flies and lures. Restrictive regulations seem to be working on the Henrys Fork as evidenced by a 1996 angler survey estimate which showed that fish in Box Canyon were caught an average of four times each (Van Kirk et al. 1999).

Comparison of changes in trout population size, as with macrophyte density and angler effort, is hindered by non-standard data collection and analysis techniques (Figure 17). Also, attributing changes in trout population size strictly to changes in regulations is problematic, as substantial other changes have occurred which also affect fish populations (Section X.n). However, restrictive regulations likely caused the decreased annual mortality of age-2 and older fish, which changed from 53% in 1987 (Angradi and Contor 1989) to 38% in 2005 (Garren et al. 2006a). However, the number of fish in the population did not increase (Figure 17). This likely indicates that recruitment (the number of fish that survive their first winter) has decreased, which I believe may be related to changes in winter habitat macrophytes may have provided for juvenile trout in the past (see section X.n). It is also apparent that in 2006 and 2007, the Box Canyon contained proportionally more large fish than in the 1980s (Figure 10), which is likely a result of restrictive regulations.

o. Year-round angling

What would be the effect on the rainbow trout population from a year-round angling season on the Henrys Fork in the Caldera (everything but the Railroad Ranch)?

The biological effect of year-round angling season on the Caldera Section of the Henrys Fork would likely be minimal. First, fishing effort is minimal at the end of the fishing season (Figure 19) and would likely be even lower from December through April due to difficult access and cold weather. Second, the population is not limited by production of fry, so even stress associated with hooking spawning fish and trampling of trout redds would have to be very large before it would begin to effect recruitment of young trout to the population. While increased mortality on spawning fish would not affect the number of young fish that ultimately are recruited to the population as age-2, it would cause some increased mortality to spawners, effectively removing those fish from the population. This could be avoided by simply managing this section with the existing winter stream season which goes from 1 December to 31 March. Although spawning in Box Canyon has been observed prior to this date (Gregory 1999a), due to reasons outlined above, fishing pressure would probably be light before 31 March.

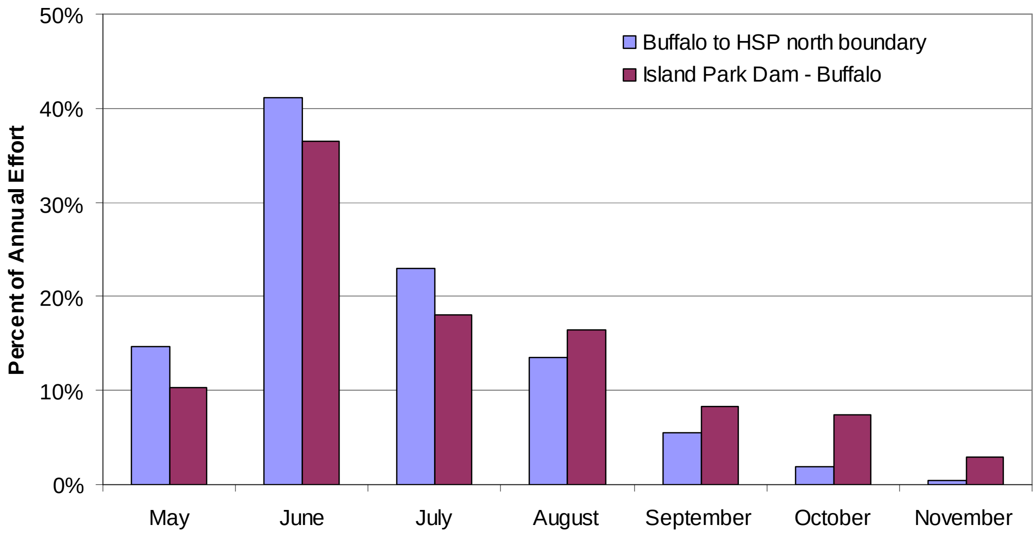

Figure 19. Percent of annual fishing effort for each month of the 1981 fishing season (data from Rohrer 1983).

p. Angler surveys and angling effort

When was the last time a "creel survey" was conducted for the Henrys Fork within the Caldera? What was angler effort?

"Creel" or angler surveys have been completed on the Henrys Fork in the Caldera Section throughout the 1970s, 1980s, and 1990s (Jepson 1973; Coon 1977;

Rohrer 1983; Rohrer 1984; Angradi and Contor 1989; Van Kirk and Beesley 1999; and Gamblin et al. 2002).

Table 2. Angler effort on the Caldera Section of the Henrys Fork 1973 - 1996.

Section	Section number	Length (mi)	Year	Effort, hours/mi May - 31 Aug	May - 30 Nov
IP Dam - Buffalo	11	0.4	1973		45,288
IP Dam - Buffalo	11	0.4	1976	7,930	
IP Dam - Buffalo	11	0.4	1981	11,833	14,563
IP Dam - Buffalo	11	0.4	1982	9,670	
Buffalo - HSP north boundary	10	4.7	1973		6,300
Buffalo - HSP north boundary	10	4.7	1976	3,719	
Buffalo - HSP north boundary	10	4.7	1981	6,841	7,422
Buffalo - HSP north boundary	10	4.7	1982	4,795	
IP Dam - Mouth of Box Canyon		3.2	1996	7,022	9,365
North boundary HSP – Osborne	9	5.3	1973		5,758
North boundary HSP – Osborne	9	5.3	1976	4,830	
North boundary HSP – Osborne	9	5.3	1981	7,747 [a]	8,565
North boundary HSP – Osborne	9	5.3	1982	5,861 [a]	
Osborne - south boundary HSP	8	2.5	1973		3,415
Osborne - south boundary HSP	8	2.5	1976	2,848	
South HSP - Riverside CG	7	3.4	1973		2,604
South HSP - Riverside CG	7	3.4	1976	1,935	
Pine Haven – Riverside CG		1.7	1987	2,415 [b]	
Riverside CG - Lower Mesa Falls	6	12	1973		269
Riverside CG - Lower Mesa Falls	6	12	1976	365	
Riverside CG - Hatchery Ford		5.3	1987	1,435 [b]	

[a] - Survey conducted 15 June – 31 August

[b] - Survey ended 7 September

Assessing changes in effort in the Caldera Section of the Henrys Fork is difficult because angler surveys were not always conducted over the same time period or section of stream. However, if effort is standardized by length (hours/mi) some general conclusions can be drawn. In 1973, effort between Island Park Dam and the mouth of the Buffalo River was over 3 times higher than was observed in any other period (Table 2). The latest angler survey, conducted in 1996, shows that effort in the Box Canyon area appears to have increased over time. However, this is hard to determine as earlier surveys included data from Box Canyon and Last Chance in the same section. It appears that effort can vary substantially, even between consecutive years (1981 – 1982; Table 2). Also, with the exception of 1982 (which seems to be a lower-effort year), effort appears to have increased over time. Two things are very evident based on the data: first, it has been a long time since an angler survey has been done, and second, subsequent angler surveys should be conducted in a manner that allows for comparison with as much past data as possible. The IDFG and the HFF are planning to conduct an angler survey in 2008.

q. *Angler catch and satisfaction*

What is angler catch and satisfaction for the Henrys Fork within the caldera?

Assessing change in catch and satisfaction in the Caldera Section of the Henrys Fork is difficult because angler surveys were not always conducted over the same time period or section of stream. However, catch rates were generally higher in the late 1970s and early 1980s, although catch rates were very high in the downstream portion of the Caldera Section in 1987 (Figure 20). Unfortunately, angler surveys were not conducted in upstream reaches during that same year. Catch rates during the most recent angler survey, which was conducted in 1996, are within the range of historical data, but generally lower than late 1970s and early 1980s catch rates. The IDFG does not have a catch rate objective for the Henrys Fork, but the five year plan (IDFG 2007) outlines the objectives and programs for the Caldera Section of the Henrys Fork. "Sustain high catch rates and a desirable size structure in the Henrys Fork on the catch-and-release section from Riverside Campground upstream to Island Park Dam. Continue long-term monitoring of trout population and angling success through regularly scheduled sampling surveys. Work for stream flow protection and enhancement, focusing on winter flow enhancements to optimize juvenile trout over-winter survival."

While angler satisfaction is a subjective measure, it appears to have been decidedly higher in 1981 than in subsequent years (Figure 21). This is not surprising, given that catch rate was also relatively high at this time (Figure 20).

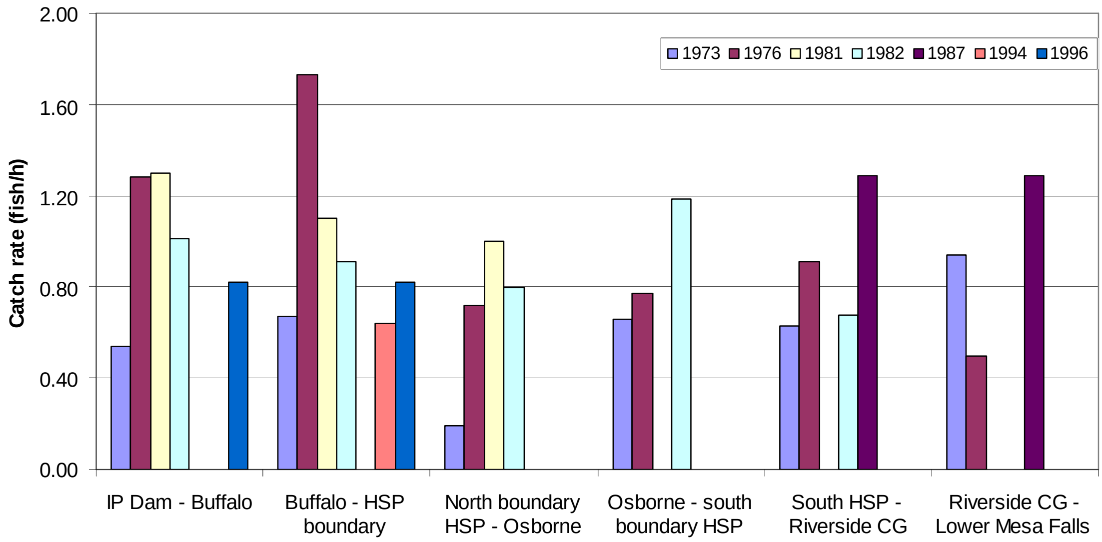

Figure 20. Catch rate (fish/h) for fish captured by angling in the Caldera Section of the Buffalo River. Data are from Jepson (1973) 1973 data, Coon (1977) 1976 data, Rohrer (1984) 1982 data, Angradi and Contor (1989) 1987 data, Gamblin et al. (2002) 1994 data, and Van Kirk et al. (1999) 1996 data.

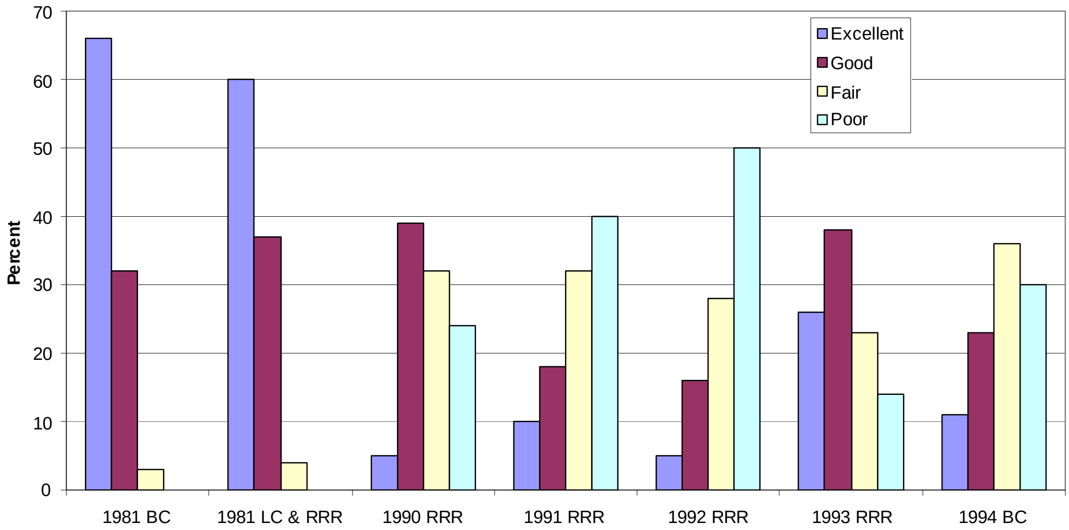

Figure 21. Angler satisfaction in reaches of the Caldera Section of the Henrys Fork (Data are from Rohrer 1983, Paini and Stiehl 1993b, and Gamblin et al. 2002).

r. Hooking mortality

How does catch-and-release angling affect mortality rates of fish and fish numbers?

A variety of factors affect the survival rates of fish captured by angling and then released. These factors include: hook and associated attractor - including whether or not the hook is barbed (Wydoski 1977; Schill and Scarpella 1997), hooking location (Mason and Hunt 1967; Wydoski 1977), playing time (Bouck and Ball 1966: Horak and Klein 1967), handling time (Schisler and Bergersen 1996), and water temperature (Shisler and Bergersen 1996).

In 1980 and 1981, Schill et al. (1986) examined hooking mortality in a wild cutthroat trout (*Salmo clarki bouvieri*) population located in a section of the Yellowstone River in Yellowstone National Park, which is managed under catch-and-release regulations (artificial flies and lures only – no restriction on barbed hooks). They found that the hooking mortality rate per single capture was 0.3%. Since cutthroat trout in this study were caught an average of 9.7 times during the season, Shill et al. (1986) estimated that 3% of the population died annually as a result of catch-and-release fishing. Van Kirk et al. (1999) estimated that fish in Box Canyon were caught an average of 4 times each. So, assuming the mortality rate is the same for rainbow trout from Box Canyon (artificial flies and lures only with a single barbless hook) as cutthroat trout from Yellowstone National Park, a 1.2% angling mortality rate can be calculated. This is very low compared to actual mortality, which Garren et al. (2006a) estimated at 38% per year. Furthermore, mortality is not necessarily additive; that is, some fish that die because of hooking mortality may have died from “natural” causes even if they had not been caught.

s. Economic value of angling

What is the economic contribution of the Henrys Forks in the Caldera? Is it possible to break this down by different sections of the river, e.g., the Box Canyon, the Ranch, etc.?

Paini and Stiehl (1993b) completed a qualitative survey of anglers in the Railroad Ranch reach of the Henrys Fork from 1990 through 1993 to evaluate fishing satisfaction, which they then related to the economic benefit of angling to the Island Park area. They concluded that "The economic impact to the Island Park area depends more on numbers of anglers visiting the area than on the amount of money those anglers as individuals spend. Comparisons between perceptions of angling quality and angler census proves that angling quality is the most important factor in attracting anglers to the area." They estimated the economic contribution of Ranch anglers to the Island Park areas was $115,033 in 1993 but was substantially lower in previous years when the fishing was poorer (Paini and Stiehl 1993b). Nowell and Kerkvliet (2000) indicated that the total annual value of the fishery between Island Park Dam and Hatchery Ford for recreational angling was ~5 million dollars. Loomis et al. (2005) calculated that in 2004, the economic value of fishing in the section from Henrys Lake Dam downstream to Riverside Campground was between $3.4 and $8.3 million (depending on whether the Contingent Valuation Method or Travel Cost Method was used).

t. Cutthroat trout

When were Yellowstone cutthroat trout displaced/replaced by rainbow trout in this part of the Henrys Fork?

Rainbow trout were introduced into the upper Henrys Fork as early as 1881, and angler descriptions of catches from the early- to mid-20th century indicate that most fish caught at that time were cutthroat-rainbow hybrids. Cutthroat trout tend to spawn in tributaries rather than in large rivers, whereas rainbow trout tend to spawn in mainstem areas. Construction of Island Park Dam and the Buffalo River Dam in the 1930s blocked access to the major spawning tributaries in the Caldera reach, which probably had a substantial negative effect on cutthroat trout populations downstream of Island Park Dam and allowed rainbow trout to replace them. The rotenone treatments of Island Park Reservoir, the tributaries, and the river downstream to Mesa Falls in 1958 and to Ashton in 1966 (Van Kirk and Gamblin 2000) effectively eliminated the native Yellowstone cutthroat and any descendant cutthroat-rainbow hybrids. Following these treatments, the reservoir and river were restocked with rainbow trout.

u. Whitefish

What is the status and trend of whitefish in the Caldera? How are whitefish affected by water management? Have whitefish numbers declined in recent years? Have whitefish benefited from improved fish passage at the Buffalo River Hydroelectric Project?

Mountain whitefish, which are native to the Caldera have, in the past, been thought to compete with trout. They were therefore the target of removal efforts in the

South Fork of the Snake River with dynamite (J. Fredericks, IDFG, Personal Communication) and in the Henrys Fork with rotenone (Van Kirk and Gamblin 2000).

In 1973, Jeppson (1973) stated that, "Most whitefish were eradicated in 1958 when Henrys Fork and some tributary streams above Mesa Falls were treated with rotenone. Whitefish are still relatively scarce above Mesa Falls…" By 1986 populations had recovered, at least somewhat, and a population estimate of whitefish in the pool downstream from the Stock Bridge in the Railroad Ranch yielded an estimate of 1,462 whitefish (Angradi and Contor 1986). However, Angradi and Contor (1986) cautioned that, "Because the river was partially dewatered at the time of the census (1, 2 October 1986), extrapolation of the population estimate riverwide may not be appropriate, as whitefish may have been concentrated from adjacent areas into the pool." The following year, Angradi and Contor (1989) estimated whitefish abundance at the Railroad Ranch section (Stock Bridge to Millionaire's pool) and Pinehaven at 92 and 99 adult whitefish/mi respectively.

In a 1994 HFF newsletter, John McDaniel noted that based on anecdotal observations he estimated that whitefish had declined by over 90% in the Harriman East Reach. He believed this decline was, in part, a result of the sedimentation event of 1992 but also noted that the decline appeared to begin before that time. To date, no whitefish estimate has ever been attempted in this reach.

In 2002, whitefish estimates were conducted in Box Canyon for the first time. Garren et al. (2006b) estimated 2,607 whitefish in this reach (95% CI = 895 - 4,319), which equates to 1,134 fish per mile (705 fish per km). Garren et al. (2006b) also collected otoliths from whitefish and calculated length-at-age for those fish (Table 3). During the 2005 population sampling in Box Canyon no estimate was conducted for whitefish but, it was noted that they were abundant (Garren et al. 2006a).

The benefit of improved passage of the Buffalo River dam to whitefish is unclear at this time, primarily because we do not know what limits whitefish in the Henrys Fork. However, what is clear is that substantial numbers of whitefish are using the ladder (over 11,000 in 2006 and over 3,000 in 2007 – primarily fish < 8 inches long), and that they likely benefit to some extent from the increased habitat area available and the relatively warm winter temperatures. Juvenile whitefish have been observed in other spring-influenced tributaries of the Henrys Fork during the winter, including Thurmon Creek (Gregory 2001) and Big Bend and Antelope Park Creeks (J. Gregory, personal observation). These streams, along with the recently available Buffalo River, may provide important wintering areas for juvenile whitefish.

Table 3. Average length at annulus formation (winter) for whitefish collected from Box Canyon of the Henrys Fork in 2002 (Garren et al. 2006b).

	Mean length (mm) at annulus formation									
Age	1	2	3	4	5	6	7	8	9	10
Length (mm)	234	310	---	380	405	---	432	440	440	455

v. Brook Trout

What is the affect of brook trout on rainbow trout in the Buffalo River, especially in regards to overwintering habitat, competition, predation, and increased upstream fish passage at the Buffalo River Hydroelectric Project?

The negative effect of brook trout on cutthroat trout populations has been well documented in the western United States, where cutthroat are native (Griffith 1988b; Young 1995). In the east, where brook trout are native, it appears that rainbow trout negatively impact brook trout populations (Larson and Moore 1985). In the Great Smokey Mountains National Park, rainbow trout eradication projects have been completed, which successfully increased brook trout populations (Lohr and West 1992), indicating that the rainbow trout were suppressing brook trout populations.

Predation on cutthroat trout fry by adult and juvenile brook trout has been observed during summer (Irving 1987) and suspected during winter (Gregory and Griffith 2000). While predation of brook trout on rainbow trout undoubtedly occurs, the earlier spawning time of rainbow trout and their fast growth rate make them less vulnerable to brook trout predation, or vulnerable over a shorter period of time, than cutthroat trout. It also likely makes them invulnerable to predation by brook trout of the same age class. For example, at the beginning of winter, Gregory and Griffith (2000) captured wild cutthroat trout and brook trout fry that averaged 1.8 and 3.2 inches (46 mm and 83 mm) respectively from tributaries of Henrys Lake. In the study that followed, only one wild cutthroat trout held over the winter in cages with brook trout survived the winter, indicating that brook trout have an advantage over cutthroat trout of the same age class. However, age 0 rainbow trout (3.0 inches (77 mm)) were nearly the same length as age-0 brook trout (3.8 inches (97 mm)) in Chick Creek, a spring influenced tributary to the Buffalo River (Griffith et al. 1996). Additionally, rainbow trout density in Chick Creek was over twice as high for age-0 rainbow trout as for age-0 brook trout (14.8 vs. 6.2 fish/100 m^2 respectively; Griffith et al. 1996). The length and densities of age-0 rainbow trout suggest that brook trout do not have the same advantage over rainbow trout as over cutthroat trout

Furthermore, survival of rainbow trout was higher than that of brook trout when held in the same cages (Meyer 1995). Meyer (1995) speculated that cobble-boulder substrate provided in test cages may be less optimal winter habitat for brook trout than for rainbow trout. This concurs with my own observations during winter; brook trout conceal more often in woody debris, whereas rainbow trout are more often found concealing in cobble-boulder substrate. In the Buffalo River, woody debris is much more plentiful than cobble-boulder substrate. However, water temperatures in the Buffalo River and its tributaries may be high enough through the winter that availability of winter concealment habitat is not a major factor in interactions between these two species.

Creel surveys and fish population sampling in Box Canyon over the past 35 years have documented a small population of brook trout (Table 4). Meyer (1995) speculated that these brook trout were coming from the Buffalo River during winter, as he observed an increase in brook trout abundance from only capturing one age-0 brook trout at Box Canyon sampling areas in early winter to capturing 1.6 brook trout/100m^2

(4.2% of the fish sampled) in mid winter to capturing 6 brook trout/100m² (12% of the fish sampled) by late winter.

Although no repeated population data are available for the Buffalo River, because of emigration of brook trout into Box Canyon, Box Canyon samples of brook trout may be used as an index of brook trout populations in the Buffalo River. For many years, brook trout have made up approximately 5 - 6% of the trout present in Box Canyon (Table 4). Recent reductions in Box Canyon brook trout populations (Table 4) may indicate that migrant rainbow trout from the Henrys Fork, or their offspring, negatively affect brook trout populations in the Buffalo River, not vice versa.

Interestingly, it appeared that in the mid 1990s brook trout populations increased by a factor of 12 in the Box Canyon over the winter because of immigration (Meyer 1995). Age-0 rainbow trout populations in Chick Creek, a tributary to the Buffalo River, have been seen to be over twice that of brook trout (Griffith et al. 1996). Therefore, if rainbow trout are emigrating from the Buffalo River in similar proportions and at similar times as brook trout, recruitment of rainbow trout from the Buffalo River may be important and may highlight the need for late winter flows to accommodate the additional migrants. The limited data and assumptions above highlight the need to evaluate out-migration from the Buffalo River through the winter, in addition to during the summer.

Table 4. Percent brook trout out of all trout and salmon sampled by various methods, 1973 - 2007.

Year	% brook	Assessment method	Source
1973	11%	Creel Survey	Jeppson 1973
1976	5%	Creel Survey	Coon 1977
1978	0.4%	Electrofishing sample	Coon 1978
1986	5%	Electrofishing sample	Angradi and Contor
1987	5%	Electrofishing sample	Angradi and Contor
1993	6%	Electrofishing sample	Gamblin et al. 2001
1994	6%	Electrofishing sample	Gamblin et al. 2002
1995	2%	Electrofishing sample	Schrader et al. 2002
1996	5%	Angler Survey	Van Kirk et al. 1999
2000	0.1%	Electrofishing sample	Dillon et al. 2004
2002	0.2%	Electrofishing sample	Garren et al. 2006b
2003	0.7%	Electrofishing sample	Garren et al. 2006c
2005	0 %	Electrofishing sample	Garren et al. 2006a
2006	0.8%	Electrofishing sample	Garren Pers. Comm.
2007	2%	Electrofishing sample	Garren Pers. Comm.

w. Predators

How do predators affect fish in the Henrys Fork? Have pelicans increased and what is their effect on fish?

Predation on fish in the Henrys Fork occurs from a variety of sources including otters (*Lutra canadensis*), mink (*Mustela vison*), eagles (*Haliaeetus leucocephalus*), king-fishers (*Megaceryle alcyon*), osprey (*Pandion haliaetus*), pelicans (*Pelecanus onocrotalus*), and possibly others. Many of these predator populations have increased across the west over the past 30 years as a result of reduced trapping pressure on furbearers and the banning of dichlorodiphenyltrichloroethane (DDT). However, in spite of increased predator populations and associated predation pressures, annual mortality rates for age-2 and older rainbow trout in the Henrys Fork have dropped over the past 20 years from 53% in 1987 (Angradi and Contor 1989) to 38% in 2005 (Garren et al. 2006a). While some harvest in 1987 likely accounts for the higher annual rainbow trout mortality rate, the increase in predation is apparently less than the decrease in harvest. Additionally, because fish populations tend to compensate for mortality (removal of some fish results in an increased survival probability for other fish) the effect of predation on the population is less than the actual number of individuals removed (McFadden 1977).

XII. Watershed, riparian, and other aquatic ecology

a. Riparian vegetation changes along the Henrys Fork

What is the history of riparian vegetation before and after cattle grazing was begun on the Ranch and adjacent areas? Were willows, shrubs, or trees commonly found along the Henrys Fork within the Ranch prior to cattle grazing and management? Did cattle grazing harm the streambanks and affect the river and fish? How does water management affect current riparian vegetation?

The type of vegetation historically present along the Henrys Fork in the past is largely unknown. In the late 1990s Bezzerides (1999) conducted field and historic photograph investigations to assess whether or not willows were historically present along the Henrys Fork at the Railroad Ranch. He found old photographs showing a fringe of shrubs and a few trees along the river near what is now Last Chance, and a 1915 photo which showed few willows along the banks of the river in the Railroad Ranch. However, since cattle grazing began ca. 1898 (Bezzerides 1999), he hypothesized that haying and grazing operations prior to 1915 may have already impacted willow communities. Bezzerides (1999) found heavily browsed (apparently by moose) willows on islands in the Railroad Ranch and determined that the area was likely capable of sustaining willows. He suggested that a mosaic of willows with 20 – 30% canopy coverage may be reasonable. He also suggested that if, in fact, willows were historically present, factors such as sediment capture by Island Park Reservoir, lack of flooding, and browsing by moose may be preventing their re-establishment. However, willows have become established along the Last Chance Canal. This area likely sustained the same grazing and browsing pressure as willows along the banks of the Henrys Fork. Willows often become established in disturbed areas, such as canals, but are less likely to become established in undisturbed areas such as along spring creeks. However, as pointed out by

Bezzerides (1999), other spring fed streams in the area, such as Thurmon Creek and the Buffalo River, support willow communities.

Establishment of willows along streams occurs under very specific conditions as outlined by Van Kirk (Pers. Comm.). Woody riparian vegetation establishes itself only on freshly deposited and/or exposed bank sediments. There are two mechanisms for this. The first is through deposition of sediment on point bars during high flow events. After the peak flow recedes, seeds are deposited on the bars, and germination and rooting take place, with the roots following the declining water table down through the remainder of the flow recession. Timing and flow recession rates are important in this process - the sediment must become available for seeding at the same time the plants are putting out seed, which is at the natural peak flow timing. Additionally, recession of the peak flow cannot be too rapid, or the water table declines too rapidly for the seedling roots to develop. Because the Henrys Fork is highly spring influenced, this entire mechanism probably played a minimal role in establishment of riparian vegetation along the Henrys Fork historically. Deposition of gravel bars typically do not occur in the groundwater-dominated system. The second mechanism is disturbance along the bank that removes grass and other terrestrial vegetation and exposes fresh soil. Historically, this mechanism may have been driven by ice and wildlife, with the latter probably being more important. Even in large streams such as the Henrys Fork, beavers could have caused substantial bank disturbance and local areas of sediment deposition, providing areas in which willows could become established.

There are two differences between these mechanisms. The first (sediment deposition by high flow events) provides colonization opportunities at regular intervals along the stream every 1.5 to 3 years, coinciding with bankfull flow events. This rapid establishment rate is offset by an equal erosion rate, which is the primary mechanism for recruitment of woody debris into the stream channel. This mechanism functions primarily in free-stone streams. The second mechanism provides opportunities only locally in space and only infrequently in time. Establishment and erosion rates balance in this case, but on a much longer time scale and in a much patchier, more variable spatial pattern. Human disturbance has occurred on a much faster time scale and a much wider spatial scale than the natural scales of establishment and erosion.

Water management affects woody vegetation establishment along the banks primarily by affecting flooding and flow recession rates outlined in the first mechanism. Additionally, Island Park Dam captures sediments that may have otherwise been deposited on the banks of the river and become available as a seed bed for willows. However, because the Henrys Fork is primarily spring-fed this mechanism of willow establishment may have played a minimal role, even before water management at Island Park Dam. Bezzerides (1999) pointed out that historic pictures showed over-bank flows, and that these events have not occurred recently. He hypothesized that the river may have down-cut, creating a deeper channel. However, he also pointed out that fewer islands existed in the Railroad Ranch during his study than were present in historic photos. A comparison of the 1953 and 2004 aerial photos shows that some small islands that were present in 1953 are not longer visible. Bezzerides (1999) suspected that sediment capture in Island Park Reservoir may have been responsible for loss of these islands, as sediment was not available to continue to build them or to replace eroded portions of them. I suspect that rather than down-cutting causing the lack of flooding, the reduction of islands and macrophytes (described in section X.n), both of which cause constriction of flow through the channel, may now reduce over-bank flows (disturbance), which may reduce establishment of woody vegetation. Van Kirk (Pers. Comm.) also suspects that the Henrys Fork through the Railroad Ranch has widened since construction of Island Park Dam. The loss of the islands, reduction in macrophytes, and channel widening has produced a more uniform, shallow, wide channel in this section.

b. Streambank fencing

What is the history of the riparian fencing within and adjacent to the Ranch? Has fencing improved riparian vegetation and bank habitat and decreased erosion? Does fencing assist with improving macroinvertebrate or fish habitat? What is the current status of fencing and streambank conditions?

Grazing by cattle can impact fisheries in many ways, as described by Platts (1991). In the Henrys Fork, the main impact was probably damage to the banks (Platts et al. 1989), primarily breaking down of undercut banks, thereby reducing the cover available to fish. Since the riparian fencing was installed in the mid 1980s by the HFF and others, cattle grazing along the banks of the river has been mostly eliminated, banks have recovered, and undercuts have been re-established (Gregory 1999b).

Currently, the river corridor is fenced wherever grazing occurs from Pinehaven to the upper end of Last Chance. Harriman State Park maintains the riparian fence within the park boundaries and the HFF maintains the fence on the national forest. The high tensile electric fence used generally has an expected life of about 15 to 20 years, after which a major rebuild is usually needed. In 2007, HFF and HSP began replacing 8 miles (12.8 km) of the electric fence with a new barbed wire fence.

c. Potential for vegetation planting

Would it be beneficial to plant willows, conifers, or other vegetation along the Henrys Fork? Would this improve habitat for fish, aquatic plants, or insects?

Riparian vegetation provides many benefits to the river and the fishery it supports. Some of the key benefits are protecting the banks from cattle grazing, anchoring the banks so they are not eroded at high flows, providing a source for large and small woody debris in the stream, and moderating high temperatures through shading. In the Henrys Fork these are unimportant relative to other issues because cattle grazing does not occur along the banks of the Henrys Fork, flows do not get high enough to rapidly erode banks, woody debris is a minimal component of habitat in spring streams, and shading of the river would be minimal even with extensive streambank woody vegetation because of the width of the river. In spring streams, macrophytes provide most of the habitat and other benefits (e.g. aquatic invertebrate attachment sites), and should be the focus of restoration efforts (as outlined in section X.n).

However, willows may be able to provide additional winter habitat for juvenile trout, particularly where beaver move them into the stream for dams or caches. If willows were historically present along 30% of the stream bank through the Railroad Ranch and Harriman East as hypothesized by Bezzerides (1999; Section XII.a), five miles of stream bank would be lined with willows. Schrader and Griswold (1992) found winter densities of juvenile cutthroat trout of 42 trout/100 m^2 in small woody debris habitat. If the same densities are applied to rainbow trout in the Henrys Fork five miles of small woody debris habitat could equate to habitat for 3,400 juvenile trout. This is a substantial number given that currently 7,500 to 15,000 juvenile trout survive the winter in Box Canyon (Mitro 1999). However, while willows standing along the bank provide benefits of erosion control and shading, juvenile trout winter habitat is only created by substantial willow recruitment to the stream either through inundation of the willows, senescence of the willow and subsequent recruitment into the stream, or beaver activity which results in willow movement into the stream.

d. Aquatic nuisance species

Are there any aquatic nuisance species, i.e., plants, macroinvertebrates, etc. that have a high potential for invasion and/or a high potential for affecting the river or fishery? Is there an aquatic nuisance species management/protection plan in place for the Henrys Fork?

Several aquatic nuisance species are present in Idaho and are therefore likely to invade the Henrys Fork (Table 5). *Myxobolus cerebralis* (the causative agent of whirling disease) and *Potamopyrgus antipodarum* (the New Zealand mud snail) are already present in the Henrys Fork drainage. Whirling disease is present in the Henrys Fork at Mack's Inn (Gregory 2003) and Howard Creek (http://www.esg.montana.edu/cgi-bin/fhhucd?01240700009295). New Zealand mud snails were discovered in the Buffalo River during 2000 and in the Henrys Fork at Box Canyon and Last Chance during 2001 (Harju 2007, http://www.esg.montana.edu/cgi-bin/aimtab?001119009999111000012407). Both nuisance species are thought to be transported by fishermen (Bergersen and Anderson 1997; Kerans et al. 2005; Vinson et al. 2007) and other vectors including trout.

New Zealand mud snails also have the potential to negatively affect fish populations. This is primarily because they dominate available resources (Hall et al. 2006), rapidly colonize available substrate and achieve high population densities (Kerans et al. 2005), and have negligible food value to trout (Vinson and Baker in press). However, a recent study (James 2007) has shown that "Laboratory tests confirmed that exposure of mud snails to temperatures of zero [Celsius, 32 °F] for more than 72 hours resulted in 100% mortality." Therefore, impacts from mud snails in the Henrys Fork may be minimal, particularly as distance downstream from the mouth of the Buffalo River increases.

Idaho has an aquatic nuisance species plan which outlines steps for preventing and containing spread of aquatic nuisance species (Idaho Invasive Species Council Technical Committee 2007). These steps are as follows: 1) early intervention – prevention, 2) early detection and rapid response, 3) containment control and restoration, 4) reaching important audiences through education and training, 5) broadening knowledge through research and technology transfer, 6) assuring adequate funding, 7) creating an adequate and effective legal structure, and 8) coordination of efforts. These efforts are coordinated locally through the Henrys Fork Cooperative Weed Management

Unit. Unfortunately, there are currently few options available for controlling or eliminating aquatic nuisance species once they become established.

Table 5. High-priority aquatic nuisance species known to be in Idaho. These species are present in Idaho, but still in a potentially containable state in known waters or with local eradication possible (Idaho Invasive Species Council Technical Committee 2007).

	Common Name	Scientific Name
Animals		
	New Zealand mudsnail	*Potamopyrgus antipodarum*
	Asian clam	*Corbicula fluminea*
	Whirling disease	*Myxobolus cerebralis*
Plants		
	Eurasian watermilfoil	*Myriophyllum spicatum*
	Parrot feather milfoil	*Myriophyllum aquaticum*
	Yellow flag iris	*Iris pseudacorus*
	Curly leaf pondweed	*Potamogeton crispus*
	Purple loosestrife	*Lythrum salicaria*
	Saltcedar	*Tamaricaceae spp.*

e. Effect of homes and business along the Henrys Fork

Does residential and/or commercial development affect the Henrys Fork, the Buffalo River, or the fishery in the Caldera?

The main impacts of homes and business along the river are input of nutrients from leaking septic systems or lawn fertilizer and the creation of the need to restrict river movement to protect property or structures. As discussed in section X.o, sewage is now routed to a centralized treatment facility and the minimal lawn area likely makes fertilizer inputs insignificant. Because the Henrys Fork is primarily spring fed, channel movements are rare. Therefore, impacts from homes and businesses are likely minimal.

XIII. Recommendations

a. Research

- Monitor macrophyte density and species composition from Last Chance through Harriman East. Initiate comprehensive studies to determine how to re-establish macrophyte biomass and species composition present in the late 1970s and early 1980s.

- Initiate studies to assess impacts of waterfowl grazing and nutrient changes on macrophyte species composition and density, and on the role that algae may play in this relationship. This may include experimenting with grazing exclosures and altering nutrient levels. Assess whether un-grazed macrophytes can provide habitat for juvenile rainbow trout through the winter.
- Initiate comprehensive invertebrate evaluation to assess changes in invertebrate density and species composition through the period of record. Include studies from each side of Box Canyon to assess affects of sediment input in that area.
- Continue annual Box Canyon population estimates, with special reference to continuing to quantify the relationship between late winter flows during the previous water year (December – February) and age-2 rainbow trout abundance in the year the sampling is conducted (Figure 12).
- As evidenced by the three outlying points on Figure 12, there is occasionally some additional factor, besides late winter flows, that affects year-class strength, and therefore the number of trout in Box Canyon. Continue to evaluate the data to assess what this factor may be.
- Assess out-migration of juvenile trout from the Buffalo River throughout the year.
- Assess winter abundance of age-0 trout in near-bank habitat at Last Chance.
- Evaluate juvenile trout use and potential to improve use of winter habitat in tributaries to the Henrys Fork including Blue Springs Creek, Antelope Park Creek, Big Bend Creek, Thurmon Creek (Silver Lake), and Fish Pond Creek.
- Evaluate winter habitat availability for juvenile trout at Riverside Campground and Cardiac Canyon. Evaluate movement of juvenile and adult trout between these areas and the Caldera Section of the Henrys Fork.
- Conduct angler survey (as planned) that can be compared to past surveys.

b. Preventative measures

- Implement measures to increase flows from Island Park Dam when extremely cold weather may produce severe ice conditions.
- Implement measures to prevent drawdown of Island Park Dam to the point where sediment is mobilized and transported into the Henrys Fork.

c. Active restoration

- Encourage activities that reduce grazing pressure on macrophytes by waterfowl.
- If above studies suggest that improved passage at Silver Lake Dam will increase winter survival for a substantial number of juvenile trout, install a bottom-release spillway system on Silver Lake Dam, provide for upstream passage of juvenile trout from Thurmon Creek through the spillway system, and evaluate resulting migration to and from Silver Lake.

- Continue drought management planning and experiment with lower early winter flows in exchange for higher late winter flows. Prepare contingency plans to increase flows if severe cold during early winter begins to cause frazil or anchor ice formation. Evaluate tests by assessing age-2 rainbow trout abundance as above.
- If the Last Chance canal is ever abandoned as a water delivery facility, maintain it as side-channel habitat for juvenile trout. This channel will provide much more habitat if beaver build and maintain dams in it, but will be essentially worthless without those structures, which are incompatible with water delivery.
- Replace and maintain riparian exclosure fencing as needed.
- Any future restoration should focus on activities that maximize survival of juvenile trout through the later part of their first winter. To be cost effective and provide meaningful amounts of habitat, and therefore have population level effects, these activities must make large blocks of habitat available for juvenile trout, not just individual habitat units. For example, large blocks of habitat are made available by increased late winter flows (more habitat wetted and available for habitation), the fish ladder on the Buffalo River (allowing the establishment of a migratory population whose offspring will potentially remain in the Buffalo River through their first winter), and creating passage on Silver Lake (connectivity to overwintering habitat, similar to that provided by the Buffalo River). Conversely, we have seen that placing habitat structures such as Christmas trees, rock structures, and artificial habitat fail to provide any population level increases in fish survival through the winter (Gregory 2000a).

XIV. Acknowledgements

This study is based on years of scientific endeavor. The author and the Henry's Fork Foundation wish to thank all of the researchers, fisheries managers, and authors whose work has collectively given us such a profound understanding of how the Caldera Section of the Henry's Fork functions, and shown us the way to future scientific enquiry. External reviews of a draft of this document were provided by Dr. Jack Griffith, Dr. Rob Van Kirk, and Lee Mabey; their input greatly improved this assessment. We also thank the Ishiyama Foundation for their generous funding of this study.

XV. References

Andree, K. B., R. P. Hedrick, and E. MacConnell. 2002. A review of the approaches to detect *Myxobolus cerebralis*, the cause of salmonid whirling disease. Pages 197 – 211 in J. L. Bartholomew and J. C. Wilson, editors. Whirling disease: reviews and current topics. American Fisheries Society, Symposium 29, Bethesda, MD.

Angradi, T., and C. Contor. 1989. Henry's Fork fisheries investigations. Project F-71-R-12, Subproject III, Jobs 7a and 7b. Idaho Department of Fish and Game, Idaho Falls, ID.

Ball, K., and P. Jeppson. 1980. Regional fisheries management investigations. Project F-71-R-5. Idaho Department of Fish and Game, Idaho Falls, ID.

Behnke, R.J. 1992. Native Trout of Western North America. American Fisheries Society Monograph 6.

Benjamin, L., and R. W. Van Kirk. 1999. Assessing instream flows and reservoir operations on an eastern Idaho river. Journal of American Water Resources Association. 35:899-910.

Bergersen, E. P. and D. E. Anderson. 1997. The distribution and spread of Myxobolus *cerebralis* in the United States. Fisheries 22(8): 6-7.

Bezzerides, N. C. 1999. Riparian management and restoration in the upper Henry's Fork basin, Idaho. Master's thesis, University of Montana, Missoula, MT.

Bjornn, T. C. and D. W. Reiser. 1991. Habitat requirements. American Fisheries Society Special Publication 19: 83-138.

Bouck, G. R., and R. C. Ball. 1966. Influence of capture methods on blood characteristics and mortality in the rainbow trout (*Salmo gairdneri*). Transactions of the American Fisheries Society 95:170-176

Busack, C. A. and G. A. E. Gall. 1980. Ancestry of artificially propagated California rainbow trout strains. California Fish and Game 66:17-24.

Chapman, D. W. 1966. Food and space as regulators of salmonid populations in streams. The American Naturalist 100:345-357.

Contor, C. R. 1989. Diurnal and nocturnal winter habitat utilization by juvenile rainbow trout in the Henry's Fork of the Snake River, Idaho. Master's thesis, Idaho State University, Pocatello, ID.

Contor, C. R., and J. S. Griffith. 1994. Nocturnal emergence of juvenile rainbow trout from winter concealment relative to light intensity. Hydrobiologia 299:179-183.

Coon, J. 1977. Henry's Fork fisheries investigations. Project F-66-R-2, Job VII. Idaho Department of Fish and Game, Idaho Falls, ID.

Coon, J. 1978. Henry's Fork fisheries investigations. Idaho Department of Fish and Game, Idaho Falls, ID.

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(supplement 1):267-282.

Cunjak, R. A., R. A. Allen, and G. Power. 1987. Seasonal energy budget of brook trout in streams: implications of a possible deficit in early winter. Transactions of the American Fisheries Society 116:817–828.

Cushman, R. M. 1985. Review of ecological effects of rapidly varying flows. North American Journal of Fisheries Management 5:330-339, 1985

Dillon, J., M. Gamblin, and W. C. Schrader. 2004. Federal aid in fish restoration. 2000 Annual performance report, program F-71-R-25. Regional Fisheries Management Investigations, Upper Snake Region (Subprojects I-G, II-G, III-G, IV-G). Idaho Department of Fish and Game, Idaho Falls, ID.

Ecosystem Research Institute. 1996. A water quality summary of Island Park Reservoir. Logan, UT.

Ecosystems Research Institute. 2007. Island Park Hydroelectric Project FERC No. 2973 2006 Water Quality Data Summary, Prepared for: Fall River Rural Electric, Ecosystems Research Institute. Logan, UT.

Forsgren, Perkins, and Associates, P.A. Consulting Engineers. 1975. North Fremont County sewer facilities planning study. Report to Fremont County, ID.

Fredericks, J., W. C. Schrader, D. Garren, and D. Keen. 2003. Federal Aid in Fish Restoration 2001 Job Performance Report. Program F-71-R-26 Regional Fisheries Management Investigations. Upper Snake Region (Subprojects I-G, II-G, III-G, IV-G). Idaho Department of Fish and Game. Idaho Falls, ID

Gamblin, M. 1995. Regional fisheries management investigations Upper Snake Region, F-71-R-17, Jobs 6-a, 6-b, 6-c, and 6-d. Idaho Department of Fish and Game, Idaho Falls, ID.

Gamblin, M., T. J. Herron, B. A. Rich, and W. C. Schrader 2001. Federal aid in fish restoration 1993. Job performance report, program F-71-R-18. Regional Fisheries Management Investigations, Upper Snake Region (Subprojects I-A, II-A, III-A, IV-A). Idaho Department of Fish and Game, Idaho Falls, ID.

Gamblin, M., T. J. Herron, B. A. Rich, and W. C. Schrader. 2002. Regional fisheries management investigations Upper Snake Region, (Subprojects I-G, II-G, III-G, IV-G) Idaho Department of Fish and Game, Idaho Falls, ID.

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). Idaho Department of Fish and Game, Idaho Falls, ID.

Garren, D., W. C. Schrader, D. Keen, and J. Fredericks. 2006a. Idaho Department of Fish and Game fishery management report. 2005 Upper Snake Region. Idaho Department of Fish and Game, Idaho Falls, ID.

Garren, D., W. C. Schrader, D. Keen, and J. Fredericks. 2006b. Regional fisheries management investigations Upper Snake Region, (Subprojects I-G, II-G, III-G, IV-G). Program F-71-R-28. 2002 Annual performance report. Idaho Department of Fish and Game, Idaho Falls, ID.

Garren, D., W. C. Schrader, D. Keen, and J. Fredericks. 2006c. Regional fisheries management investigations 2003 Annual Performance Report, (Subprojects I-G, II-G, III-G, IV-G). Program F-71-R-28. 2002 Annual performance report. Idaho Department of Fish and Game, Idaho Falls, ID.

Garren, D., W. C. Schrader, D. Keen, and J. Fredericks. 2008. Idaho Department of Fish and Game Fishery Management Annual Report, Upper Snake Region 2006. Idaho Department of Fish and Game, Idaho Falls, ID.

Goodman, K. 1994. 1994 assessment of water quality on the Henry’s Fork of the Snake River. Henry's Fork Foundation, Ashton, ID.

Goodman, K. T. 1995. 1995 assessment of water quality on the Henry’s Fork of the Snake River. Henry's Fork Foundation, Ashton, ID.

Granath, Jr. W. O. and M. A. Gilbert. 2002. The role of *Tubifex tubifex* (Annelida: Oligochaeta: Tubificidae) in the transmission of Myxobolus cerebralis (*Myxozoa, Myxosporea*, Myxobolidae). Pages 79 – 85 in J. L. Bartholomew and J. C. Wilson, editors. Whirling disease: reviews and current topics. American Fisheries Society, Symposium 29, Bethesda, MD.

Gregg, W. W. 1981. Aquatic macrophytes as a factor affecting the microdistribution of benthic stream invertebrates. Master’s thesis, Idaho State University, Pocatello, ID.

Gregory, J. S. 1997. Spring spawning on the Henrys Fork and tributaries upstream from Riverside Campground. Project completion report for the Henry's Fork Foundation, Ashton, ID. Gregory Aquatics, Mackay, ID.

Gregory, J. S. 1998. Winter use of artificial structures and an off channel canal by juvenile rainbow trout in the Henrys Fork of the Snake River. Project completion report for the Henry’s Fork Foundation, Ashton, ID. Gregory Aquatics, Mackay, ID.

Gregory, J. S. 1999a. Box Canyon insect abundance and emergence and rainbow trout spawning assessment supplement. Report to Henry's Fork Foundation, Ashton, ID. Gregory Aquatics, Mackay, ID.

Gregory, J. S. 1999b. Henrys Fork basin habitat assessment Henrys Fork (Island Park to mouth) and Big Bend Ridge summer 1999. Report to Henry’s Fork Foundation, Ashton, ID. Gregory Aquatics, Mackay, ID.

Gregory, J. S. 2000a. Winter fisheries research and habitat improvements on the Henry’s Fork of the Snake River. Intermountain Journal of Science 6(3):232-248.

Gregory, J. S. 2000b. Winter use of an off channel canal by juvenile rainbow trout in the Henrys Fork of the Snake River, Idaho. Report to Henry’s Fork Foundation, Ashton, ID. Gregory Aquatics, Mackay, ID.

Gregory, J. S. 2000c. Henrys Fork basin habitat assessment Henrys Fork (Island Park to mouth) and Bend Ridge, Summer 1999. Report to Henry's Fork Foundation, Ashton, ID. Gregory Aquatics, Mackay, ID.

Gregory, J. S. 2000d. Migration of adult rainbow trout between the Henrys Fork and the Buffalo River during spring 2000. Report to Henry's Fork Foundation, Ashton, ID. Gregory Aquatics, Mackay, ID.

Gregory, J. S. 2000e. Downstream migration of rainbow and brook trout in the Buffalo River during 1999. Report to Henry's Fork Foundation, Ashton, ID. Gregory Aquatics, Mackay, ID.

Gregory, J. S. 2000f. Box Canyon insect abundance and emergence and rainbow trout spawning assessment: supplement. Project Completion Report Supplement. Report to Henry's Fork Foundation, Ashton, ID. Gregory Aquatics, Mackay, ID.

Gregory, J. S. 2001. Winter migration and survival of telemeterized juvenile rainbow trout in the Henrys Fork of the Snake River, Idaho. Report to Henry's Fork Foundation, Ashton, ID. Gregory Aquatics, Mackay, ID.

Gregory, J. S. 2003. Henrys Fork Long Term Monitoring: Summer 2002, Annual project report, Report to Henry's Fork Foundation, Ashton, ID. Gregory Aquatics, Mackay, ID.

Gregory, J. S. 2003. Use of the Buffalo fish ladder by upstream migrating rainbow trout. Report to Henry's Fork Foundation, Ashton, ID. Gregory Aquatics, Mackay, ID.

Gregory, J. S. and A. M. Emery-Miller. 2006. Henrys Fork long term monitoring: summer 2005, Annual project report, Report to Henry's Fork Foundation, Ashton, ID. Gregory Aquatics, Mackay, ID.

Gregory, J. S. and A. M. Emery-Miller. 2008. Rainbow trout migration, movement and survival in the Henrys Fork of the Snake River, Idaho. Final Report, Report to Henry's Fork Foundation, Ashton, ID. Gregory Aquatics, Mackay, ID.

Gregory, J. S. and J. S. Griffith. 1996a. 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.

Gregory, J. S. and J. S. Griffith. 1996b. Aggressive behaviour of underyearling rainbow trout in simulated winter concealment habitat. Journal of Fish Biology 49:237-245.

Gregory, J. S. and J. S. Griffith. 2000. First winter survival of caged wild and hatchery cutthroat trout in allopatry and sympatry with brook trout. Intermountain Journal of Science 6(3):217-222.

Gregory, J. S., S. S. Beesley, and R. W. Van Kirk. 2000. Effect of springtime water temperature on the time of emergence and size of *Pteronarcys californica* in the Henry's Fork catchment, Idaho, U.S.A. Freshwater Biology 45:75-83.

Gregory, J., and R. Van Kirk. 1997. Box Canyon insect abundance and emergence and rainbow trout spawning assessment. Henry's Fork Foundation, Ashton, ID.

Gregory, J., and R. Van Kirk. 1998. Henrys Fork habitat assessment Island Park Dam to Warm River summer 1997. Report to Henry's Fork Foundation, Ashton, ID. Gregory Aquatics, Mackay, ID.

Gregory, J., K. Meyer, and R. Van Kirk. 1995. Box Canyon insect abundance and emergence and rainbow trout spawning assessment. Henry's Fork Foundation, Ashton, ID.

Griffith, J. S. 1988a. 1987 fisheries research, Henry’s Fork Foundation newsletter 1988:6.

Griffith, J. S. 1988b. Review of competition between cutthroat trout and other salmonids. Pages 134–140 *in* R. E. Gresswell, editor. Status and management of interior stocks of cutthroat trout. American Fisheries Society, Symposium 4, Bethesda, MD.

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.

Griffith, J. S., R. Smith, and C. C. Brand. 1990. Evaluation of instream habitat structures in the Henry’s Fork of the Snake River. Report to the Henry’s Fork Foundation, Island Park, ID, and the Targhee National Forest, St. Anthony, ID. Department of Biological Sciences, Idaho Sate University, Pocatello, ID.

Griffith, J., M. Stute, and J. Gregory. 1996. Distribution and first-winter ecology of trout in small streams of the Targhee National Forest. Project completion report for the Henry's Fork Foundation, Ashton, ID, and the Targhee National Forest, St. Anthony, ID. Department of Biological Sciences, Idaho State University, Pocatello, ID.

HabiTech, Inc. 1994. Flushing flow investigations; Henry's Fork of the Snake River 1993-1994. Project completion report for Idaho Division of Environmental Quality, Idaho Falls, ID. HabiTech, Inc., Laramie, WY.

HabiTech, Inc. 1998. Henry’s Fork watershed sediment studies 1997. Project completion report for Henry's Fork Foundation, Ashton, ID. HabiTech, Inc., Laramie, WY.

Hackett, B. and B. Bonnichsen. 1994. Volcanic Crescent. Pp. 24-61 *in* T. Shallat, ed., Snake: the plain and its people. Boise State University, Boise, ID.

Hall, R. O. Jr., M. F. Dybdahl, and M. C. Vanderloop. 2006. Extremely high secondary production of introduced snails in rivers. Ecological Applications, 16:1121–1131.

Hampton, P. D. 1981. The wintering and nesting behavior of the Trumpeter Swan. Master’s Thesis, University of Montana, Missoula, MT.

Harju, T. K. 2007. Modeling regional distribution and local food web dynamics of the New Zealand mud snail (*Potamopyrgus antipodarum*). Master’s thesis, Montana State University, Bozeman, MT.

High, B. and K. A. Meyer in press Survival and dispersal of triploid hatchery rainbow trout in an Idaho river. North American Journal of Fisheries Management.

Horak, D. L. and W. D. Klein. 1967. Influence of capture methods on fishing success, stamina, and mortality of rainbow trout (*Salmo gairdneri*) in Colorado. Transactions of the American Fisheries Society 96:220 – 222.

Idaho Department of Fish and Game. 2007. Fisheries Management Plan 2007-2012. Boise, ID.

Idaho Invasive Species Council Technical Committee. 2007. Idaho aquatic nuisance species plan: A supplement to Idaho's strategic action plan. Prepared for Governor C. L. "Butch" Otter and the Idaho Invasive Species Council. Boise, ID.

Idaho Water Resources Board. 1992. Comprehensive state water plan; Henrys Fork Basin. Idaho Water Resources Board, F. D. Rydalch, C. Parr, G. M. Gray, B. J. Bell, K. E. Hungerford, D. R. Kramer, W. Platts, M. Satterwhite.

Irving, D. B. 1987. Cutthroat trout abundance, potential yield, and interaction with brook trout in Priest Lake tributaries. Master's thesis, University of Idaho, Moscow, 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.

James, C. A. 2007. Investigations of the invasive New Zealand mudsnailPotamopyrgus antipodarum in Idaho: implications for temperature limitations. Master's Thesis, University of Idaho. Moscow, ID.

Jeppson, P. 1973. Snake River fisheries investigations. Project F-66-R-3, Job III-a. Idaho Department of Fish and Game, Idaho Falls, ID.

Jeppson, P. 1975. Mackay Reservoir fishery investigation. Idaho Department of Fish and Game. Boise, ID.

Joint Planning Committee 2005. Henrys Fork drought management plan. Fremont-Madison Irrigation District, Henry's Fork Foundation, North Fork Reservoir Company, Trout Unlimited, The Nature Conservancy, Bureau of Reclamation.

Keil. W. M. 1928. The fishes of Idaho. Idaho Department of Fish and Game, Boise.

Kerans, B. L. and A. V. Zale. 2002. The Ecology of Myxobolus cerebralis. Pages 145 – 166 in J. L. Bartholomew and J. C. Wilson, editors. Whirling disease: reviews and current topics. American Fisheries Society, Symposium 29, Bethesda, MD.

Kerans, B. L., M. F. Dybdahl, M. M. Gangloff, and J. E. Jannot. 2005. *Potamopyrgus antipodarum*: distribution, density, and effects on native macroinvertebrate assemblages in the Greater Yellowstone Ecosystem. Journal of the North American Benthological Society 24:123-138.

Kiffney, P. M., and P. Roni. 2007 Relationship between productivity, physical habitat and aquatic invertebrate and vertebrate populations of forest streams: and information-theoretic approach. Transactions of the American Fisheries Society 136:1088-1103.

Larson, G. L. and S. Moore, 1985. Encroachment of exotic rainbow trout into stream populations of native brook trout in the southern Appalachian mountains. Transactions of the American Fisheries Society 114:195-203.

Lindstrom, J. W., 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.

Lohr, S. C. and J. L. West. 1992. Microhabitat selection by brook and rainbow trout in a southern Appalachian stream. Transactions of the American Fisheries Society 121:729-736.

Loomis, J., D. Reading, and L. Koontz. 2005. The economic value of recreational fishing and boating to visitors and communities along the upper Snake River. Report to Henry's Fork Foundation, Ashton, ID and Trout Unlimited, Idaho Falls, ID.

MacConnell, E. and E. R. Vincent. 2002. The effects of Myxobolus cerebralis ion the salmonid host. Pages 95 – 107 in J. L. Bartholomew and J. C. Wilson, editors. Whirling disease: reviews and current topics. American Fisheries Society, Symposium 29, Bethesda, MD.

Mason, B., and R. L. Hunt. 1967. Mortality rates of deeply hooked rainbow trout. Progressive Fish-Culturist 29:87-91.

McDaniel, J. 1994. An angler's view: report from the Ranch. Henry's Fork Foundation newsletter 1994:Summer.

McFadden, J. T. 1977. An argument supporting the reality of compensation in fish populations and a plea to let them exercise it. In Assessing the effects of power-plant-induced mortality on fish populations. Van Winkle, ed. Environmental Science Division. Oak Ridge National Lab. Proceedings of May 3 – 6 Conference, Gatlinburg, TN.

Meyer, K. A. 1995. Experimental evaluation of habitat use and survival of rainbow trout during their first winter in the Henrys Fork of the Snake River, Idaho. Master's thesis, Idaho State University, Pocatello, ID.

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. 1994. Habitat selection and factors influencing the distribution of benthic aquatic invertebrates in the Henrys Fork of the Snake River, Idaho. Project completion report for the Henry's Fork Foundation, Ashton, ID. Department of Biological Sciences, Idaho State University, Pocatello, ID.

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

Mickelson, M. 1994 A not-so-brief, somewhat adulterated, unabridged and biased history of the Henry's Fork Foundation 1984-1993. Henry's Fork Foundation.

Minshall, G. W., C. T. Robinson, and T. V. Royer. 1993. Henry's Fork of the Snake River, Idaho, sediment impact study. Department of Biological Sciences, Idaho State University, Pocatello, ID.

Mitro, M. G. 1999. Sampling and analysis techniques and their application for estimating recruitment of juvenile rainbow trout in the Henrys Fork of the Snake River, Idaho. Ph.D. dissertation, Montana State University, Bozeman, MT.

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, Idaho. 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.

Nowell, C. and J. Kerkvliet. 2000. The economic value of the Henry's Fork Fishery. Intermountain Journal of Sciences 6:285-292.

Paini, R. A., Jr., and J. F. Stiehl. 1993a. An oral history of angling experience and environmental conditions of the caldera stretch of the Henry's Fork of the Snake River. Washington and Lee University, Lexington, VA, and the Henry's Fork Foundation, Island Park, ID.

Paini, R. A., Jr., and J. F. Stiehl. 1993b. The effect of angling quality on the economic contribution of anglers to the Island Park area from 1990 through 1993. Washington and Lee University, Lexington, VA, and the Henry's Fork Foundation, Island Park, ID.

Piper, R. G., I. B. McElwain, L. E. Orme, J. P. McCraren, L. G. Fowler, and J. R. Leonard. 1982. Fish Hatchery Management. U S Fish and Wildlife Service, Washington, D. C.

Platts, W. S. 1991. Livestock grazing, pp. 389–424. *In*: W. R. Meehan, ed. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication 19:389–423.

Platts, W. S., F. J. Wagstaff, and E. Chaney. 1989. Cattle and fish on the Henry's Fork. Rangelands 11(2):58-62.

Rohrer, R. L. 1983. Henry's Fork fisheries investigations. Project F-73-R-4, Subproject IV, Study XI. Idaho Department of Fish and Game, Idaho Falls, ID

Rohrer, R. L. 1984. Henry's Fork fisheries investigations. Project F-73-R-5, Subproject IV, Study XI. Idaho Department of Fish and Game, Idaho Falls, ID.

Schill, D. J. 1991. Job performance report Project F-73-R-13, Subproject II, Study IV, Job 1, statewide data summary. Idaho Department of Fish and Game, Boise, ID.

Schill, D. J. and R. L. Scarpella. 1997. Barbed hook restrictions in catch-and-release trout fisheries: a social issue. North American Journal of Fisheries Management 17:873-881.

Schill, D. J., J. S. Griffith, and R. E. Gresswell. 1986. Hooking mortality of cutthroat trout in a catch-and-release segment of the Yellowstone River, Yellowstone National Park. North American Journal of Fisheries Management 6:226-232.

Schisler, G. J., and E. P. Bergersen. 1996. Postrelease hooking mortality of rainbow trout caught on scented artificial baits. North American Journal of Fisheries Management 16:570-578.

Schrader, W. C. and R. W. Griswold. 1992. Winter habitat availability and utilization by juvenile cutthroat trout, brown trout, and mountain whitefish in the South Fork Snake River, Idaho. Final Progress Report, Project No. 0-AG-10-10920. Idaho Department of Fish and Game. Boise, ID.

Schrader, W. C., M. Gamblin, T. J. Herron, and B. A. Rich. 2002. Federal aid in fish restoration. 1995 Job performance report, Program F-71-R-20. Regional Fisheries Management Investigations, Upper Snake Region (Subprojects I-G, II-G, III-G, IV-G). Idaho Department of Fish and Game, Idaho Falls, ID.

Shea, R. E. 1999. Assessment of aquatic macrophytes at Harriman State Park, Idaho. October 1999. Department of Biological Sciences. Idaho State University, Pocatello, ID.

Shea, R. E., J. A. Kadlec, R. C. Drewien, and J. W. Snyder. 1996. Assessment of aquatic macrophytes at Harriman State Park and at other key swan wintering sites withing the Henry's Fork watershed, Idaho. Project completion report for the Henry's Fork Foundation, Ashton, ID. Department of Biological Sciences, Idaho State University, Pocatello, ID.

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. 129:101-118.

Smith, R. W. 1992. Effects of concealment cover availability and water temperature on overwinter survival and body condition of juvenile rainbow trout in the Henry's Fork of the Snake River, Idaho. Master's thesis, Idaho State University, Pocatello, ID.

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.

U.S. Fish and Wildlife Service. 2007. Trumpeter swan survey of the Rocky Mountain Population, Winter 2007. Division of Migratory Birds and State Programs, Denver, CO. 27pp.

USCFF. 1897. Report of the Commissioner, Washington, D.C.

Valdimarsson, S. K. and N. B. Metcalfe. 1998. Shelter selection in juvenile Atlantic salmon, or why do salmon seek shelter in winter? Journal of Fish Biology 52:42-49.

Van Kirk, R. 1996. The Henry's Fork fishery above Mesa Falls: An overview of management history and implications for rehabilitation and restoration. Henry's Fork Foundation, Ashton, ID.

Van Kirk, R. W. 2000. Henry's Fork aquatic resources bibliography. Intermountain Journal of Science 6(3):312-332.

Van Kirk, R. W. and A. V. Zale. 2000. Editors. Intermountain Journal of Science.

Van Kirk, R. W. and B. Burnett. 2004. Hydrologic alteration and its ecological effects in the Henry's Fork watershed upstream of St. Anthony. Project Completion report for: Greater Yellowstone Coalition, Henry's Fork Foundation, Henry's Fork Watershed Council, Snake River Cutthroats, The Nature Conservancy, Trout Unlimited.

Van Kirk, R. W. and C. B. Griffin. 1997. Building a collaborative process for restoration: Henrys Fork of Idaho and Wyoming. In J.E. Williams, M.P. Dombeck, W. Elmore and C.A. Wood, eds. Watershed Restoration: Principles and Practices. American Fisheries Society, Bethesda, MD, pp. 253-276.

Van Kirk, R. W. and L. Benjamin. 2000. Physical and human geography of the Henry's Fork watershed. Intermountain Journal of Science. 6(3):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(3):263-284.

Van Kirk, R. W. and R. Martin. 2000. Interaction among aquatic vegetation, waterfowl, flows, and the fishery below Island Park Dam. Intermountain Journal of Science. 6(3):249-262.

Van Kirk, R., and K. Giese. 1999. Angler effort and catch on the Buffalo River during 1998 and effects of the Buffalo River fish ladder on the Box Canyon rainbow trout population. Report to Idaho Fish and Wildlife Foundation. Department of Biological Sciences, Idaho State University, Pocatello, ID.

Van Kirk, R., L. Albano, J. Didier, and D. Hayes. 1997. Angler effort and catch on the Buffalo River, 1996 and 1997. Henry's Fork Foundation, Ashton, ID.

Van Kirk, R., S. Beesley, J. Didier, D. Hanson, and D. Hayes. 1999. Angler effort and catch and floater use in Box Canyon. Report to Idaho Fish and Wildlife Foundation, Boise, ID. Department of Biological Sciences, Idaho State University, Pocatello, ID.

Vincent, E. R. 2002. Relative susceptibility of various salmonids to whirling disease with emphasis on rainbow and cutthroat trout. Pages 109 – 115 in J. L. Bartholomew and J. C. Wilson, editors. Whirling disease: reviews and current topics. American Fisheries Society, Symposium 29, Bethesda, MD.

Vinson, D. 1990. DRAFT Baseflow determination for wintering trumpeter swans on the Henry's Fork of the Snake River. USDI Fish and Wildlife Service, Boise, ID.

Vinson, M. R. and M. A. Baker. 2008. Poor growth of rainbow trout (Oncorhynchus *mykiss*) fed New Zealand mud snail (*Potamopyrgus antipodarum*). North American Journal of Fisheries Management. 28:701 – 709.

Vinson, M. R., D. K. Vinson, and T. R. Angradi. 1992. Aquatic macrophytes and instream flow characteristics of a Rocky Mountain river. Rivers 3:260-265.

Vinson, M., H, Tarita, and E. Dinger. 2007. Status of New Zealand mud snails (*Potamopyrgus antipodarum*) in the Green River downstream from Flaming Gorge Dam: current distribution; habitat preference and invertebrate changes; food web and fish effects; and predicted distributions. USDI Bureau of Land Management & Utah State University, National Aquatic Monitoring Center, Department of Aquatic, Watershed and Earth Resources, Utah State University, Logan, UT.

Wagner, E. J. 2002. Whirling disease prevention, control, and management: a review. Pages 217 – 225 in J. L. Bartholomew and J. C. Wilson, editors. Whirling disease: reviews and current topics. American Fisheries Society, Symposium 29, Bethesda, MD.

Wales, J. H. 1939. General report of investigations of the McCloud River drainage in 1938. California Fish and Game 25:272-309.

Waters, T.F., 1995, Sediment in Streams: Sources, Biological Effects and Control. American Fisheries Society Monograph 7. Bethesda, MD.

Whitehead, R. L. 1978. Water resources of the Henrys Fork basin in eastern Idaho. Water Information Bulletin 46. Idaho Department of Water Resources, Boise, ID.

Wiley, R. W., R. A. Whaley, J. B. Satake, and M. Fowden. 1993. Assessment of stocking hatchery trout: a Wyoming perspective. North American Journal of Fisheries Management 13:160-170.

Wydoski, R. S. 1977. Relation of hooking mortality and sublethal hooking stress to quality fishery management. Pages 43-87 in R. A. Barnhart and T. D. Roelofs, editors. Catch-and-release fishing as a management tool. California Cooperative Fishery research Unit, Humbolt State University, Arcata.

Young, M. K. 1995. Synthesis of management and research considerations. Pp. 55-61 in M. K. Young, ed., Conservation assessment for inland cutthroat trout. Rocky Mountain Forest and Range Experiment Station, U.S. Forest Service, General Technical Report RM-GTR-256.