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# Interactions Among Aquatic Vegetation, Waterfowl, Flows, and the Fishery Below Island Park Dam

## Abstract

*Management of Island Park Reservoir has significantly affected abundances of rainbow trout* (Oncorhynchus mykiss) *and wintering trumpeter swans* (Cygnus buccinator) *on the Henry's Fork of the Snake River. Trout and swan numbers both increased following dam operation changes that resulted in increased winter flows during the 1970s. Throughout the 1980s and early 1990s, declines occurred in overall macrophyte abundance and in the relative abundance of tall, erect species capable of providing fish habitat and waterfowl forage throughout the winter. This was most likely caused by introduction of fine sediment into the river resulting from drawdowns of Island Park Reservoir in 1979 and 1992, a series of scouring spring flows in the early 1980s, low winter flows during drought years in the late 1980s, and increased waterfowl herbivory throughout the period. Although fluctuations in the rainbow trout population cannot be tied directly to changes in the macrophytes, our review of the literature suggests that robust and abundant macrophytes benefit the fishery and associated angling opportunities through increased invertebrate abundance, water depth, and trout habitat. We recommend managing Island Park Reservoir to minimize the probability of extensive sediment transport into the river, maximize winter flows, and minimize abrupt flow increases during the spring. Furthermore, we recommend continuing the waterfowl hazing program at Harriman State Park and exploring new techniques for reducing waterfowl abundance on the Henry's Fork between Island Park Dam and Riverside during autumn and winter. The effects of these and other management actions on the Rocky Mountain trumpeter swan populations should be carefully monitored to maintain viability of the Greater Yellowstone population.*

**Key words:** macrophytes, trumpeter swans, water management, rainbow trout

## Introduction

The Henry's Fork downstream of Island Park Dam and Reservoir supports one of the most popular rainbow trout (*Oncorhynchus mykiss*) fisheries in the United States (Van Kirk and Griffin 1997). The 24 km (15 miles) of river downstream of the dam include the Box Canyon, Last Chance, and Harriman State Park reaches of the river (see Van Kirk and Benjamin this issue), all of which have supported large amounts of angling pressure since the early 1970s (Jeppson 1973, Coon 1977, Rohrer 1983, Rohrer 1984, Angradi and Contor 1989, Van Kirk *et al.* 1999). The 15 km (9 miles) of river from Last Chance to Pinehaven, including Harriman State Park, also provide important winter habitat for trumpeter swans (*Cygnus buccinator*) (Snyder 1991, Vinson 1991, Shea *et al.* 1996). The rainbow trout population declined 80 percent in Box Canyon between 1978 and 1991 (Van Kirk and Gamblin this

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issue). The Idaho Department of Fish and Game (IDFG) uses Box Canyon as an indicator reach for the longer stretch from Island Park Dam to Riverside. The number of trumpeter swans wintering between Island Park Dam and Pinehaven increased four-fold between 1972 and 1990 (Fig. 1). During the winter of 1988-89, over 100 trumpeter swans died on the Henry's Fork as a result of cold temperatures and low flow releases from Island Park Dam (Vinson 1992, Shea and Drewien 1999). The following winter saw about 900 trumpeter swans wintering on the Henry's Fork, which resulted in a severe decline in the abundance of macrophytes (rooted aquatic plants) in the river between Last Chance and Pinehaven (Vinson 1992, Shea *et al.* 1996). Low flows and loss of macrophyte cover have been associated with poor over-winter survival of age-0 juvenile rainbow trout in the Henry's Fork below Island Park Dam (Griffith and Smith 1995), illustrating that management of swans, flows, and fisheries are inter-related in this reach of river. These management issues are tied together by macrophytes.

The purpose of this paper is to discuss the relationships among

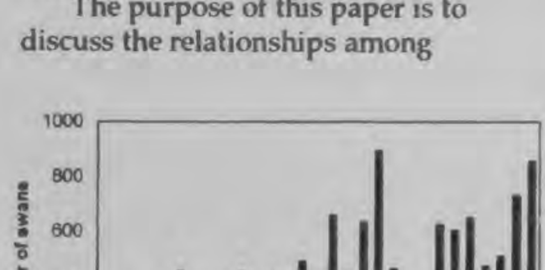


**Figure 1.** *Number of trumpeter swans counted on the Henry's Fork above Pinehaven during February surveys. Data from Shea and Drewien (1999) and R. Shea (Department of Biological Sciences, Idaho State University, personal communication).*

macrophyte ecology, waterfowl management, flow releases and the rainbow trout fishery below Island Park Dam. The paper is organized into four sections as follows: 1) a review of the ecological role of macrophytes and their importance to trout in the Henry's Fork; 2) a brief summary of management of the Rocky Mountain populations of trumpeter swans as related to the Henry's Fork; 3) a discussion of flow management at Island Park Dam and its effects on macrophytes, swans and trout; and 4) conclusions and management recommendations.

## Ecological Role of Macrophytes

Macrophytes play an important ecological role in low-gradient streams such as the Henry's Fork between Last Chance and Pinehaven. In mid- to high-latitude streams, seasonal variations in sunlight availability and discharge determine the growth potential of macrophytes, which in turn affects trophic mechanisms, physical habitat characteristics, and flow hydraulics in the stream environment. Herbivory by a variety of vertebrates and invertebrates can have a significant effect on the characteristics of the macrophyte assemblage.

The greatest growth of macrophytes occurs during the late spring and early summer, when sunlight availability is greatest (Sand-Jensen *et al.* 1989). Maximum macrophyte biomass generally occurs during the summer or early autumn and then decreases throughout autumn and winter as the above-substrate portions of the plants senesce. On the Henry's Fork, maximum macrophyte biomass occurs in October (Angradi 1991, Vinson *et al.* 1992), and minimum biomass occurs in February or March (Angradi 1991, Vinson 1991, Griffith and Smith 1995). As sunlight becomes available again in the spring, new growth begins from tubers or rhizomes buried in the stream bottom. However, as flows increase during the spring, growth may be inhibited by decreased light availability because of water turbidity (Sand-Jensen *et al.* 1989) or by bed scour (Shea *et al.* 1996). French and Chambers (1997) found that reducing summer flow velocity in the low-gradient reaches of a British Columbia stream increased macrophyte growth. The greatest effects of flow velocity on macrophyte growth occurred between velocities of 0.4 and 0.8 m/s. Vinson *et al.* (1992) measured velocities ranging from 0.3 to 0.4 m/s in the Harriman State Park section of the Henry's Fork during March 1990, during which time flows ranged from 12.2 $m^3/s$ (431 cfs) to 15.7 $m^3/s$ (554 cfs). Flows usually increase from March through May or June (Benjamin and Van Kirk 1999). Therefore, springtime velocities in the Henry's Fork are likely to be in the critical range of 0.4 to 0.8 m/s identified by French and Chambers (1997).

Macrophyte beds slow water velocity (Gregg and Rose 1982, Sand-Jensen and Mebus 1996), trap fine sediment (Gregg and Rose 1982, Barko *et al.* 1991), and increase habitat for macroinvertebrates and fish (Dionne and Folt 1991, Wright 1992). Although conventional wisdom for many decades held that macrophytes are rarely consumed and therefore have little importance in food webs, recent work has demonstrated that substantial herbivory occurs by crayfish, snails, fish, waterfowl, and invertebrates (Lodge 1991, Jacobsen and Sand-Jensen 1992). Because macrophytes obtain most of their nutrients from sediments deposited on the stream bottom, they provide a mechanism for the introduction of sediment-derived nutrients into the aquatic food web (Barko *et al.* 1991). In addition to food provided by growing plants, macrophyte-derived detritus is an important food source for invertebrates after the plants begin to senesce (Gregg and Rose 1982, Wright 1992). In the Henry's Fork, most particulate organic matter is derived from macrophytes and algae, and seasonal increases in the availability of macrophyte-derived organic matter occur after the growing season (Angradi 1991, Angradi 1993a, Angradi 1993b).

Macrophytes provide habitat for invertebrates in the form of shelter, colonization substrate, and oviposition sites (Gregg and Rose 1982). Macroinvertebrate abundance, biomass, and taxon richness were all significantly higher in macrophyte beds than in unvegetated substrate in an English chalk stream (Wright 1992). In the Harriman State Park reach of the Henry's Fork, invertebrates of the orders Trichoptera (caddisflies), Ephemeroptera (mayflies), and Diptera (midges and gnats) were the most important foods of rainbow trout during the summer months (Angradi and Griffith 1990). These organisms benefit from abundant macrophytes, which were found at all study sites. Vertebrates and terrestrial invertebrates, whose abundances do not depend on the macrophytes, were rare in the diet of Henry's Fork rainbow trout.

Whereas the importance of macrophytes in providing habitat for invertebrates is well recognized, the role of macrophytes in providing direct cover for trout in streams is less clear. Macrophytes provide cover and foraging habitat for various sunfish species in warm-water ponds and streams (Dionne and Folt 1991, Trebitz and Nibbelink 1996). Higher macrophyte densities lead to higher invertebrate prey densities but also to reduced foraging success in the interior of macrophyte beds. Bed edges provide increased foraging opportunities because of better visibility and maneuvering ability, while still providing cover for foraging fish (Trebitz and Nibbelink 1996). The direct effects of macrophytes in providing summer cover and foraging habitat for trout in the Henry's Fork have not been studied. However, trout elsewhere use channels along bed edges as optimal locations to forage in relative security (Sand-Jensen and Mebus 1996, Trebitz and Nibbelink 1996). Anecdotal observations by anglers suggest that this is true in the Henry's Fork during late summer and autumn. When combined with the role of macrophyte beds in providing cover and food for macroinvertebrates, the primary food for rainbow trout in the Henry's Fork, the presence of dense macrophyte beds in the Henry's Fork likely provides increased foraging opportunities for rainbow trout and associated angling opportunities during the summer and early autumn.

The role of macrophytes in providing cover for juvenile trout in the Henry's Fork during the winter has been studied extensively (see Gregory this issue). When water temperatures fall below about 9 °C (48 °F), age-0 trout seek daytime cover that will completely conceal them from predators (Smith and Griffith 1994), emerging from the cover only at night to feed (Contor and Griffith 1995). Preferred concealment cover is provided by interstitial spaces within complex arrangements of cobbles and boulders on the stream bottom (Meyer and Griffith 1997a). When this cover type is limited, as it is in the Last Chance, Harriman, and Pinehaven reaches of the Henry's Fork, competition among individual age-0 trout occurs for existing concealment spaces, and thus larger individuals are more likely to survive the winter than smaller ones (Meyer and Griffith 1997b). The limited availability of winter concealment habitat for age-0 fish in the Henry's Fork below Island Park Dam results in a trout population that is limited by survival of individuals through their first winter (Mitro 1999).

Although macrophyte beds sufficient in density to provide concealment cover for age-0 fish are present in the Last Chance and Harriman reaches during the early part of the winter, persistence of macrophytes is not sufficient to provide concealment cover for significant numbers of fish throughout the entire winter (Griffith and Smith 1995, Mitro 1999). Between October 1994 and February 1995, IDFG personnel captured age-0 trout in the Last Chance reach using electrofishing. Sampling yielded 302 fish during the 5-month period. Although 89 percent of the trout were caught further than 2 m from the shoreline where macrophytes provided the only cover, 78 percent of the total number of trout captured were caught during October and November. Equal sampling effort later in the winter failed to yield the numbers of fish that were captured during autumn. During subsequent winters, Mitro (1999) found that few age-0 fish survived the winter at Last Chance, and essentially none survived between Last Chance and Pinehaven. For example, an estimated 170,462 juvenile rainbow trout were present between the mouth of Box Canyon and Pinehaven in the autumn of 1996, but no juvenile trout were captured in this reach during the spring of 1997 (Mitro 1999). Most juvenile trout present in these areas during autumn emigrate during mid- to late winter as macrophyte biomass approaches its minimum. Whereas some of these fish migrate to better winter habitat in the Box Canyon and Riverside reaches, many die or leave the Island Park-to-Riverside reach altogether (Mitro 1999).

Shea (1997) sampled macrophyte biomass along transects at Last Chance and Harriman State Park that had been sampled previously in 1979 and 1986. Shea (1997) reported that: 1) total macrophyte biomass in 1986 and 1997 was about half of what it had been in 1979 (Fig. 2); and 2) there had been a

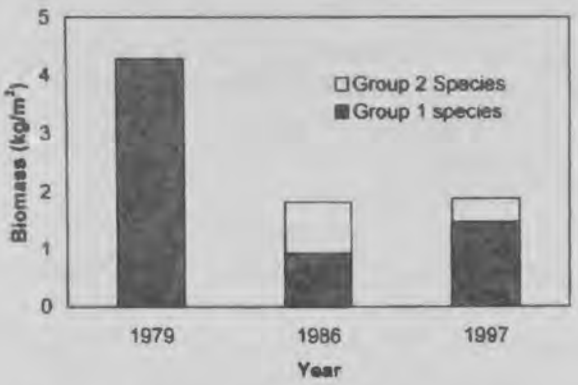


**Figure 2.** *Mean macrophyte biomasses segregated by group type in the Last Chance and Harriman State Park reaches of the Henry's Fork. Data from Hampton (1981), Angradi and Contor (1989), and Shea (1997).*

previously unrecognized shift in macrophyte species composition from dominance by the so-called "Group-1" species—tall, robust erect species that thrive in low velocity, silt-rich environments (*Potamogeton pectinatus, P. richardsonii, Elodea canadensis,* and *Myriophyllum exalbescens*)—to greater representation by "Group-2" species—shorter, bottom-dwelling species more tolerant of higher water velocities and capable of colonizing disturbed sites (*Callitriche hermaphroditica, Ranunculus aquatilis, Eleocharis acicularis,* and *Zannichellia palustris*) (Table 1). The Group-1 species are generally capable of persisting in greater densities throughout the winter, and because of their growth forms, have a greater ability to slow current velocities and provide concealment cover for juvenile trout.

The decline in total macrophyte biomass and in relative Group-1 species biomass that occurred during the early 1980s was likely initiated by release of sediment from Island Park Dam in 1979 and exacerbated by high spring flows in the early 1980s (Shea *et al.* 1996, Shea 1997). Thus, inability of macrophytes in the Henry's Fork to provide juvenile trout cover through the entire winter likely dates back at least to the early 1980s. Additionally, during the winter of 1989-90, the winter swan carrying capacity of the Henry's Fork was likely exceeded, and significant damage occurred to macrophytes because of waterfowl herbivory and associated disturbance to plants and their tubers. Much of the Harriman State Park reach was left with a sandy stream bottom with little or no macrophytes (Vinson 1992, Shea *et al.* 1996).

**Table 1.** *Total wet-weight biomass (kg/m²) and percentage of total biomass of macrophyte species in the Henry's Fork below Island Park Dam along nine transects sampled in the Last Chance and Harriman State Park reaches in 1979 (Hampton 1981), 1986 (Angradi and Contor 1989), and 1997 (Shea 1997).*

| | Year | | |
|---|---|---|---|
| Species | 1979 | 1986 | 1997 |
| Group 1 | | | |
| *Elodea canadensis* | 1.01 (23.5%) | 0.01 (0.6%) | 0.29 (15.4%) |
| *Myriophyllum* spp. | 1.12 (26.1%) | 0.80 (44.0%) | 1.02 (54.3%) |
| *Potamogeton pectinatus* | 1.37 (31.9%) | 0.11 (6.0%) | 0.13 (6.9%) |
| *Potamogeton richardsonii* | 0.76 (17.7%) | 0 (0%) | 0.02 (1.1%) |
| Group 2 | | | |
| *Callitriche hermaphroditica* | 0.03 (0.7%) | 0 (0%) | 0.01 (0.5%) |
| *Eleocharis acicularis* | 0 (0%) | 0 (0%) | 0.02 (1.1%) |
| *Ranunculus aquatilis* | 0 (0%) | 0.70 (38.5%) | 0.30 (16.0%) |
| *Zannichellia palustris* | 0 (0%) | 0.20 (11.0%) | 0.09 (4.8%) |
| Total | 4.29 | 1.82 | 1.88 |

## Waterfowl Management

During much of the 20th century, the Harriman State Park reach of the Henry's Fork was an important wintering site for the remnant populations of trumpeter swans that survived in the Rocky Mountains. Although often referred to by managers as the Rocky Mountain population (Pacific Flyway Subcommittee on Rocky Mountain Trumpeter Swans 1998), in reality two distinct breeding populations winter together in this area: the resident Greater Yellowstone population and the migratory western Canada population (Shea and Drewien 1999). About 3,500 swans wintered in the Greater Yellowstone region in February 2000. This included about 400 from the resident Greater Yellowstone population and about 3,100 from western Canada (USDI Fish and Wildlife Service 2000).

The primary threat to both groups of swans is the loss of more suitable winter habitat further south and the resulting dependence of swans upon marginal winter habitat in the Greater Yellowstone region. During the 1990s, waterfowl managers attempted to reduce vulnerability of these swans to high winter mortality primarily by dispersing swans away from Harriman State Park and Red Rock Lakes National Wildlife Refuge and encouraging use of other wintering sites. As part of this effort, over 50 years of supplemental winter feeding at Red Rock Lakes National Wildlife Refuge was terminated in 1992, and more than 1,400 trumpeter swans were translocated out of the Harriman-Red Rock area between 1988 and 1997 (Pacific Flyway Subcommittee on Rocky Mountain Trumpeter Swans 1998, Shea and Drewien 1999). Reducing the vulnerability of swans to high winter mortality in the Harriman-Red Rock area is especially important to maintaining the viability of the Greater Yellowstone population because of its small size. Loss of 100 individuals, as occurred at Harriman State Park during the winter of 1988-89, would have a substantial negative effect on this population.

Swans and other waterfowl are attracted to Harriman State Park in autumn because it is a sanctuary closed to waterfowl hunting and because of macrophytes available in the river and Silver and Golden lakes prior to freeze-up. However, the volume of macrophytes available in Harriman State Park and adjacent river reaches is inadequate to sustain the more than 1,500 trumpeter swans estimated to arrive on the Henry's Fork each autumn and is likely inadequate even to sustain the 800 or more that remained in the vicinity during the winter of 1999-2000 (Fig. 1). Hazing at Harriman State Park has occurred at varying intensities since 1988 in an attempt to encourage trumpeter swans and other waterfowl to use other areas in November and December and reduce herbivory on macrophytes in the Last Chance to Pinehaven reach. Although trumpeter swans have increased their use of more southerly portions of southeastern Idaho, most of the Rocky Mountain birds continue to winter in sites, including Harriman State Park, which will freeze in a severe winter. Only a recent series of milder-than-average winters has allowed increasing numbers of wintering swans to survive in eastern Idaho without substantial mortality. Winter translocations were halted in 1997, and managers presently lack an effective strategy to encourage trumpeter swans to use alternate wintering areas (Shea and Drewien 1999).

Waterfowl hazing at Harriman State Park has both positive and negative effects on swans. A benefit for swans is that hazing encourages some birds to move further south early, while they still are strong, and leaves more vegetation for use later in the winter as food becomes less available elsewhere. The drawback for swans is that hazing causes birds to expend energy during the important autumn hyperphagia period, when they normally would be foraging as much as possible while avoiding unnecessary energy expenditures. It is unclear if either of these effects is significant at the population level. Additional effects of hazing include substantial reductions in annual use of Harriman State Park by geese and ducks. Although useful quantitative data are lacking for goose and duck use of the Henry's Fork, this hazing effect is readily apparent to observers.

Because large numbers of swans and other waterfowl foraging during autumn and winter cause significant macrophyte reductions, the fishery is benefited by reductions in waterfowl abundances, regardless of the techniques used, and regardless of whether or not the hazing program is meeting desired waterfowl management objectives. Waterfowl hazing and translocation, along with higher winter flows during the late 1990s, resulted in a modest recovery of macrophytes (Shea 1997). The Box Canyon rainbow trout population also has increased since 1996 (Van Kirk and Gamblin this issue), at least in part because of increased winter flows (Mitro 1999). How much of the trout population increase is attributable to improvements in macrophytes is unclear. However, it is certain that reduction in winter waterfowl numbers benefits the rainbow trout fishery by increasing abundances of macrophytes.

## Flow Management at Island Park Dam

Flows in the Henry's Fork have been regulated at Island Park Dam since 1938. The hydrologic impacts of regulation and suggestions for improved dam management are discussed in Benjamin and Van Kirk (1999) and summarized here. Island Park Reservoir provides 167 million $m^3$ (135,000 acre-feet) of storage for the Fremont-Madison Irrigation District. Prior to 1972, the reservoir was usually filled by reducing flows to near zero on 15 November and increasing them when the reservoir was nearly full in February or March. Under near zero-flow conditions at Island Park Dam, the only discharge into the Henry's Fork in Box Canyon was provided by the Buffalo River, a spring-fed tributary with a winter flow of about 5.7 $m^3/s$ (200 cfs). Although near-zero flows were released at Island Park Dam for at least a portion of most winters, high flow years resulted in an average winter release of 5.7 $m^3/s$ (200 cfs) in addition to the flow provided by the Buffalo River. In contrast, reservoir inflow (unregulated flow) is about 12.7 $m^3/s$ (450 cfs). Furthermore, the pre-1972 management regime allowed significant increases in winter discharge over short periods of time to satisfy peak-power demands downstream. Coefficients of variation in winter flows at Island Park were nearly an order of magnitude greater under the pre-1972 management regime than those observed in the relatively constant, spring-fed natural flow regime of the upper Henry's Fork.

Beginning in 1972, dam operations changed in response to hydroelectric needs downstream, resulting in winter flow releases from Island Park Dam that averaged about 8.5 $m^3/s$ (300 cfs). Higher winter flows under the post-1972 regime are obtained in large part by commencing storage on 1 October rather than 15 November, thereby increasing the length of time over which the reservoir is filled. Reservoir storage that occurs prior to 15 November is termed "adverse storage," and is allowed by a formal agreement signed in 1984 by the Fremont-Madison Irrigation District, the U. S. Bureau of Reclamation, Utah Power and Light, and the City of Idaho Falls. It is likely that improved winter flows at Island Park Dam allowed wintering trumpeter swan numbers to increase throughout the 1970s and 1980s (Fig. 1) by preventing ice formation and dewatering of macrophyte beds. However, even under the improved management scenario, winter flows out of Island Park Dam can approach zero, as they did during the winter of 1988-89.

The largest discrepancy between the managed and natural flow regimes at Island Park Dam is the decrease in winter flows under the managed regime. Low winter flows have two major effects on wintering swans. If air temperatures are relatively mild and the river does not freeze, low winter flows reduce the amount of foraging habitat available to swans by dewatering (Vinson 1991) but allow greater access to macrophytes in areas where water is present (Shea *et al.* 1996). When air temperatures are very cold, as occurred during the winter of 1988-89, the river can freeze, and wintering swans and other waterfowl lose access to the macrophyte food source. Furthermore, the amount of wetted habitat available to both fish and swans under a given discharge is greatly increased by the presence of abundant macrophytes because of the ability of dense macrophyte beds to increase channel roughness and occupy volume in the stream channel (Vinson 1991, Vinson *et al.* 1992).

Vinson (1991) recommended a minimum flow of 14.2 $m^3/s$ (500 cfs) below the Buffalo River (i.e., about 8.5 $m^3/s$ [300 cfs] from Island Park Dam and 5.7 $m^3/s$ [200 cfs] from the Buffalo River) and an optimum flow of 19.8 $m^3/s$ (700 cfs) (i.e., about 14.2 $m^3/s$ [500 cfs] from Island Park Dam) for maintenance of trumpeter swan winter habitat. However, constraints of fulfilling water rights preclude winter discharges exceeding 8.5 $m^3/s$ (300 cfs) at Island Park Dam except in years when the reservoir is nearly full at the beginning of the storage season (Benjamin and Van Kirk 1999). A flow release of 14.2 $m^3/s$ (500 cfs) at the dam exceeds inflow during most years and is therefore essentially unattainable regardless of initial reservoir content.

A flow regime at Island Park that results in higher winter flows and more consistent springtime flows will, in general, benefit macrophytes. Higher flows during autumn and early winter deter swans and other waterfowl from overwintering on the Henry's Fork, because high flow velocities make foraging difficult. Over the long term, fewer waterfowl wintering on the Henry's Fork will result in a more robust macrophyte assemblage and in a lower probability of high winter mortality among wintering waterfowl in the event of an extremely cold winter. Higher winter flows also reduce the formation of anchor ice, which can cause considerable damage to macrophytes. Lower and more stable flows during the spring benefit macrophytes, particularly the Group-1 species, by reducing scouring and allowing new growth to become established.

From a fisheries perspective, the observation that age-0 trout begin requiring concealment cover when water temperatures drop below 9 °C (48 °F) early in autumn suggests that higher flows during autumn and early winter would benefit their survival by buffering the effects of rapidly decreasing atmospheric temperatures and by providing more available habitat (Gregory this issue). However, even under the current status of macrophytes in the Henry's Fork, sufficient macrophyte biomass is available to provide cover for trout during autumn and early winter (Griffith and Smith 1995, Mitro 1999, Gregory this issue). Furthermore, in autumn when macrophytes are present at or near their maximum biomass, they act to increase water depth at a given discharge (Vinson 1991, Vinson *et al.* 1992), thereby providing adequate water depths at relatively low flows. Later in the winter when macrophyte biomass decreases, virtually all age-0 trout in the Last Chance and Harriman reaches, where macrophytes provide the majority of the available cover, migrate to the narrower, deeper sections of the river in Box Canyon and Pinehaven to Riverside reaches, where cover is provided by cobble-boulder substrate and woody debris. Because these reaches are relatively narrow compared to the Last Chance and Harriman reaches, small increases in discharge result in relatively larger increases in amount of trout habitat. This suggests that higher flows during mid- to late winter would benefit age-0 trout survival more than high flows during autumn.

Mitro (1999) found a strong positive correlation ($r^2 = 0.98$) between springtime abundance of age-0 rainbow trout in Box Canyon and late-winter (15 January to 31 March) discharge from Island Park Reservoir (see also Gregory this issue). In 1997, when late-winter discharge averaged 22.8 $m^3/s$ (805 cfs), an estimated 14,788 age-0 rainbow trout were present in Box Canyon in May. By contrast, in 1996, when late-winter discharge averaged 17.1 $m^3/s$ (604 cfs), only 7,903 age-0 rainbow trout were estimated to be present in Box Canyon in May. However, relative to the total number of juvenile rainbow trout present between Island Park Dam and Pinehaven at the beginning of the winter, the 1995-96 overwinter survival/retention rate was 5.1 percent, only slightly lower than the 5.8 percent survival/retention rate of 1996-1997. Further study is needed to quantify the relationship between winter flow regime and winter survival of age-0 trout between Island Park Dam and Riverside.

Each year, there is a limit to the water available to release for fish and wildlife during winter. Managers must decide how to best shape the volume and timing of available flows. Benjamin and Van Kirk (1999) showed that winter flows below Island Park Dam are more sensitive to reservoir content at the beginning of the storage season than to precipitation, and therefore recommended that management of all reservoir-related resources be conducted to maximize reservoir volume at the beginning of autumn. Furthermore, Benjamin and Van Kirk (1999) recommended the designation of 1 May as the reservoir-fill target date, rather than the historical 1 April target. This shift allows a greater percent of the reservoir to be filled by springtime flows than by winter baseflow.

Higher releases in autumn and early winter buffer temperature changes, provide increased habitat for trout, and cause many waterfowl to migrate south out of the Harriman State Park area. However, higher flows during mid-to-late winter appear more beneficial to the fishery and also reduce the occurrence of ice formation, which can provide access to macrophyte forage for waterfowl committed to remaining on the Henry's Fork for the entire winter. A combination of waterfowl hazing in autumn and early winter and using available water to provide higher flows during mid-to-late winter (rather than autumn and early winter) may therefore maximize benefits to macrophytes, wintering swans, and the fishery.

In addition to management of flows per se, a second but no less important aspect of Island Park Dam management is inadvertent mobilization of sediment from the reservoir bottom when the reservoir is drawn down to low levels (Van Kirk and Gamblin this issue). Large amounts of fine sediment were released to the Henry's Fork below Island Park Dam by reservoir drawdowns during 1979 and 1992. At least in the short-term, some negative effects occurred. In addition to the macrophyte decline following both drawdowns (Shea 1997), survival of wintering juvenile rainbow trout at Last Chance was reduced as a result of sediment deposition (Griffith and Smith 1995) and invertebrate abundances and species composition declined after the 1992 drawdown (Ecosystems Research Institute 1995). Attempts at removing sediment deposited in the river below Island Park Dam following the 1992 event were unsuccessful as cleaned areas refilled rapidly (Gregory this issue).

The long-term impacts of sediment releases from Island Park Dam are less clear. Sediment-deficient conditions can exist below large dams where sediment is rarely or never released (Collier *et al.* 1996). Macrophytes require substrate and nutrients to grow, and sediment provides both. Bezzerides (1999) hypothesized that recruitment of willows has been reduced as a result of sediment deprivation below Island Park Dam. A careful long-term sediment release plan may eventually be developed for Island Park Dam. For now, however, we recommend avoiding a severe drawdown of the reservoir, both to reduce the chance of mobilizing a large amount of reservoir sediment at one time and to increase allowable winter discharge under the constraints of satisfying irrigation rights.

## Summary And Recommendations

Management of Island Park Reservoir has substantially affected both the Henry's Fork rainbow trout fishery and the Rocky Mountain trumpeter swan populations. Increased winter flows beginning in the early 1970s allowed both the fishery and the swan population to flourish. Although the trout population was limited by winter concealment habitat for juveniles, stocking of hatchery fish circumvented this limitation. Following cessation of stocking in 1978, drawdowns of Island Park Reservoir in 1977, 1979, 1981, and 1984 introduced large numbers of reservoir fish into the river, which compensated for low natural recruitment (Van Kirk and Gamblin this issue). The 1979 drawdown also introduced a large amount of sediment into the river, which likely initiated the shift in macrophyte assemblage dominance from Group-1 to Group-2 species. High spring flows during the early 1980s, low winter flows during the drought of the late 1980s, and increased waterfowl numbers combined to cause additional negative effects on macrophytes. This exacerbated what was probably already poor winter survival of age-0 rainbow trout between Last Chance and Pinehaven.

The reservoir drawdown of 1992 revived the ailing fishery by introducing 10,000 adult reservoir trout into the river (Van Kirk and Gamblin this issue). However, release and deposition of reservoir sediment negatively affected macrophytes and what little cobble-boulder juvenile trout concealment habitat existed along the banks in the Last Chance reach. From the end of the drought in 1994 through 1999, the combination of increased winter flows and reduced wintering swan numbers (relative to the record number of 1989-90) has resulted in modest improvements in macrophyte abundance and species composition. Improvements in the rainbow trout population occurred most likely because of the increased winter flows rather than macrophyte recovery. However, anecdotal observations by anglers suggest that angling opportunities and the overall quality of the angling experience from Last Chance to Pinehaven have increased since 1995, particularly during late summer and early autumn when macrophyte biomass is at its peak.

### Recommendations

1. Manage Island Park Reservoir to maximize winter discharge and minimize abrupt flow increases during the spring when macrophytes are beginning to grow. Winter flows can be maximized by maintaining the highest reservoir level possible at the beginning of the storage season and by extending the target fill-date to 1 May rather than the traditional 1 April.
2. Avoid severe drawdowns of Island Park Reservoir. This increases allowable winter discharge and also protects the river from a single large sediment deposition event, which negatively affects both macrophytes and trout overwinter habitat, at least in the short-term.
3. Continue the waterfowl hazing program at Harriman State Park. Explore additional management techniques to minimize numbers of waterfowl on the Henry's Fork between Island Park Dam and Riverside during autumn and winter. Any decrease in waterfowl numbers will benefit macrophytes, which in turn benefit the fishery and associated angling experiences. If waterfowl hazing proves to be more beneficial to the fishery than to the Rocky Mountain trumpeter swan population itself, it may be more equitable in the long term to fund the hazing program from angling-oriented sources rather than from waterfowl management sources.
4. Continue monitoring macrophytes and juvenile trout survival. In particular, continue research into the relationship between winter flow regime and overwinter survival of age-0 trout, so that water available for winter flows can be released in a manner that optimizes benefits to macrophytes, wintering waterfowl and juvenile trout survival.
5. Continue monitoring the Rocky Mountain trumpeter swan populations and especially the resident Greater Yellowstone population. Any waterfowl, flow, or fisheries management actions should be conducted in a way that enhances long term viability of the Greater Yellowstone population.

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