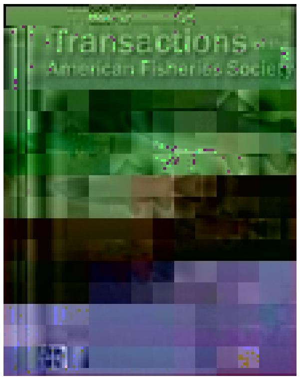

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Smoltification in an Impounded, Adfluvial Redband Trout Population Upstream from an Impassable Dam: Does It Persist?

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ARTICLE

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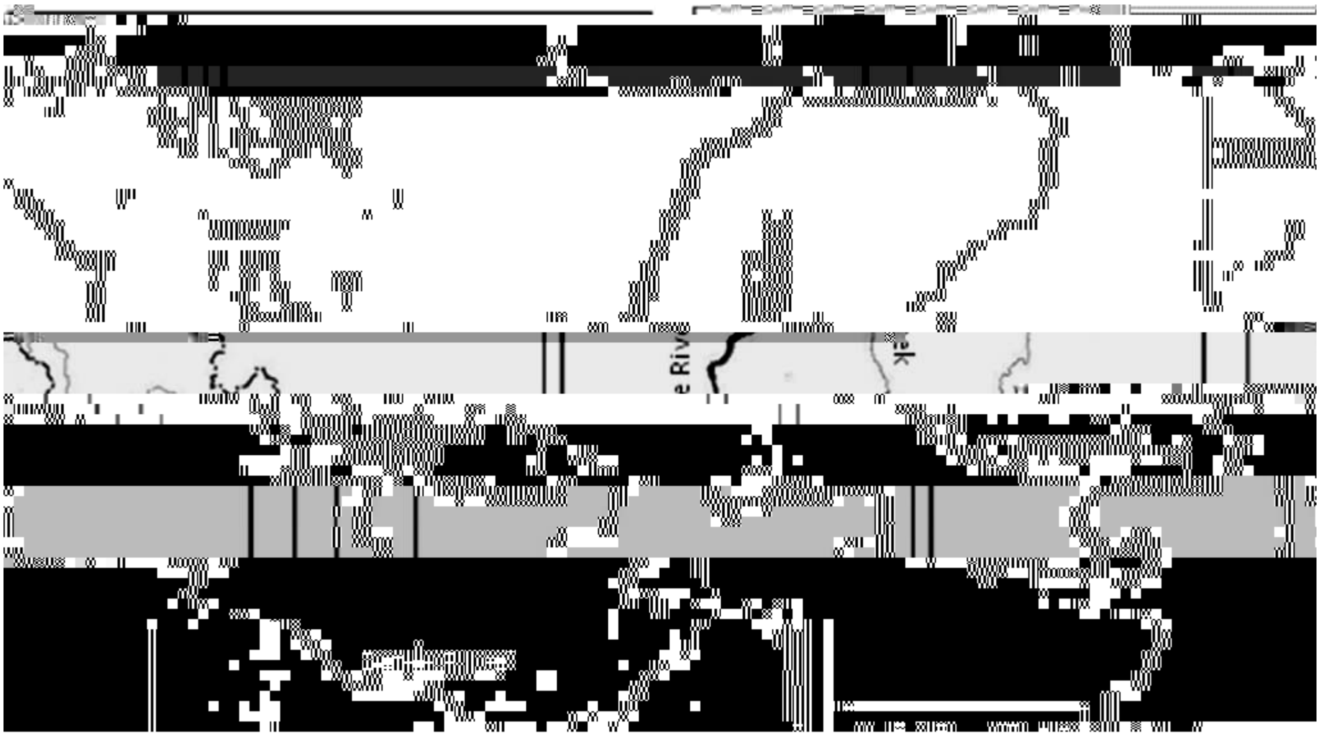

FIGURE 1. Study area indicating location of Mann Creek, Weiser River drainage, southwestern Idaho, relative to Brownlee Dam (left panel), and Hells Canyon, Oxbow, and Brownlee dams on the Snake River (right panel).

Thrower and Joyce 2004; Thrower et al. 2008). Examples exist of residual *O. mykiss* populations that produce anadromous offspring. Thrower and Joyce (2004) documented an Alaskan rainbow trout population that produced anadromous offspring after 70 years of isolation in freshwater. Pascual et al. (2001) documented anadromy in a stock of rainbow trout that was thought to originate from a resident freshwater population. Genetic analyses also suggest that gene ow between sympatric resident and anadromous forms of rainbow trout is more common than previously suspected (Olsen et al. 2006; McPhee et al. 2007; Pearsons et al. 2007).

Numerous factors can determine whether a salmonid can complete an anadromous life cycle. One important life history factor is the ability of juveniles to undergo smolti cation, the physiological and morphological adaptation to seawater in preparation for ocean life. Smolti cation and migration in individual sh can be in uenced by growth, size, water temperature, and photoperiod (Zaugg and Wagner 1973; Pereira and Adelman 1985; Hirata et al. 1988). Additionally, genetics (Nichols et al. 2008) and landscape features (Narum et al. 2008) may in uence life history expression and whether sh undergo smolti cation. Numerous physical and biological indicators of the complex process of smolti cation have been reported, including decreased condition factor (Zaugg and McLain 1972; Beeman et al. 1995), a silver body coloring or high skin re ectance (Haner et al. 1995), and increased Na^+, K^+ -ATPase activity levels in the gill laments (Zaugg and McLain 1972). The enzyme assay that detects Na^+, K^+ -ATPase activity in gill laments is one of the more quantitative measures of smolti cation progress (Schrock et al. 1994).

In this study we evaluated whether the redband trout population inhabiting Mann Creek and the reservoir that once had an anadromous component (before 1958) continues to undergo smolti cation. Presence or absence of smolti cation was assessed by (1) comparing the proportion of migrants displaying a silver, smolt-like body coloration (putative smolts) with those migrants not displaying such coloration (putative nonsmolts), (2) comparing mean Na^+, K^+ -ATPase activity in the gill laments of putative smolts and putative nonsmolts, and (3) comparing the migration timing of the study population with the migration of neighboring anadromous steelhead populations in the Snake River basin.

METHODS

Sampling—Juvenile redband trout migrants were captured with a rotary screw trap (Thedinga et al. 1994; Roper and Scarnecchia 2000) positioned 2 km above the reservoir from 18 March to 3 June 2009. Water temperature was recorded hourly at the screw trap location with a Hobo Pro version 2 water temperature data logger. Stream discharge was measured periodically throughout the trapping season with a owmeter to establish a relationship between discharge and staff-gauge readings from a gauge located near the trap.

Fork length (FL) for each sh captured was recorded to the nearest millimeter and weight (W) to the nearest 0.1 g. Condition factor (K) was calculated for each sh by means of the formula $K = W/FL^3$ (Westers 2001). Scale samples were collected from each sh and independently aged by two readers. An age was assigned to each sh by using a double-blind protocol described by Scarnecchia et al. (2006). Fish age was determined from each scale sample independently by two readers and when discrepancies occurred, samples were re-aged independently by the same two readers. If there were any remaining discrepancies, the two readers consulted with each other and identi ed a single age for the sample.

Juveniles were assigned one of three body coloration patterns described by Negus (2003): banded, intermediate, or silver (Figure 2). Banded sh retained all parr marks, and the body was dark, colorful, or both. Intermediate sh had no parr marks near when dischen218.rsanearthe t

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hereafter referred to as DART. The theoretical 50% passage date for Mann Creek redband trout at LGR was calculated by adding the number of days estimated to travel from the Mann Creek trap to LGR to the 50% passage date at the trap in Mann Creek. Redband trout would have to travel approximately 424 km downstream to reach LGR. We used published travel rates for steelhead smolts (Giorgi et al. 1997; Moore et al. 2010) and mean travel times reported by DART from populations in the Snake River basin that travel approximately 400 km to estimate travel time from Mann Creek to LGR.

Analyses—Analysis of variance (ANOVA) (signi cant at *P* 0.05) was used to compare mean ATPase activities between banded and nonbanded sh for three migration periods: early (19 March–10 April), middle (28 April–5 May), and late (21 May–4 June).

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studies. Furthermore, Thrower and Hard (2009) found that migrant progeny of resident *O. mykiss* had much lower marine survival rates than migrant progeny of anadromous parents, and Pearse et al. (2009) found that relatively few resident *O. mykiss* successfully completed an anadromous life cycle. Although smoltification is a necessary process for salmonids to complete an anadromous life cycle, it is only one of many factors that determine whether a fish can successfully migrate to and from a marine environment.

In our study area, coastal-origin hatchery rainbow trout *O. mykiss irideus* have been stocked extensively since 1967 (Kozfkay et al. 2009). These stockings may have led to introgression of native and hatchery fish. Genetic analyses indicated that fish sampled from Mann Creek Reservoir were introgressed (Matt Campbell, Idaho Department of Fish and Game, unpublished data), while fish sampled in the headwaters of Mann Creek did not show signs of introgression (Kozfkay et al. 2011). There is evidently a barrier that prevented hatchery fish from introgressing with the headwater populations. However, it is unknown whether the putative smolts in our study are derived from the introgressed population, the pure population, or both populations. Future studies should examine genetic differences between the banded and nonbanded fish in this study as they could provide important information regarding smoltification traits and capabilities in *O. mykiss*.

Our results suggest the possibility that in portions of the Snake River drainage where steelhead have been extirpated as a result of artificial barriers, remnant populations may retain the potential for anadromy if migratory paths were reconnected. To fully interpret the evidence presented here that an isolated redband trout population continues to undergo morphological, physiological, and behavioral changes associated with smoltification, future research should examine other *O. mykiss* populations, especially those in more interior regions, that have been blocked from migration for much longer periods of time. Examining populations with a longer history of isolation from marine environments could be useful for understanding the persistence of smoltification capabilities as well as other co-occurring aspects of redband trout life history.

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