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Comparison of Two Life History Strategies after Impoundment of a Historically Anadromous Stock of Columbia River Redband Trout

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Abstract

In this study we collected information on abundance, age structure, migration, and exploitation to characterize the population demographics and reproductive characteristics of a historically anadromous Columbia River Redband Trout Oncorhynchus mykiss gairdneri population now isolated in a southwestern Idaho reservoir and limited to resident and adßuvial life histories. We estimated there were 3,905 adßuvial individuals in Mann Creek Reservoir in October 2008 based on a markÐrecapture population estimate. The adßuvial population sex ratio of 2.78 females per male captured at a weir, peak spawn timing near the peak of the hydrograph (late April), age at spawning (4Ð6 years), and growth patterns (slow growth in the stream followed by rapid growth in the reservoir) were all characteristic of an anadromous population. Resident Þsh abundance was not estimated, but the Þsh were characterized by relatively slow growth, earlier sexual maturity, and a reverse sex ratio (0.23 females per male) compared with the adßuvial Þsh. The two life histories (resident and adßuvial) and their differential use by the sexes are consistent with life

In contrast to the numerous studies of sympatric resident and anadromous Rainbow Trout, there has been relatively little research regarding interior populations of Columbia River Redband Trout *O. mykiss gairdneri* derived from an anadromous component, such as those that occur above barrier dams (Holecek et al. 2012). In the Snake River basin above Hells Canyon Dam exist many isolated Columbia River Redband Trout populations that were formerly anadromous, but because of barriers are now restricted to freshwater and are no longer able to complete an anadromous life history. These formerly anadromous fish may remain sympatric with resident forms and express an adfluvial life history (i.e., spawning in streams and rearing in reservoirs or lakes). Understanding the life history characteristics of one such adfluvial population of Columbia River Redband Trout in Idaho existing above barrier dams may provide valuable ecological and management information about how impoundments influence key life history characteristics. Rainbow Trout exhibit substantial plasticity in expressing an array of life history strategies, which precludes generalizations about important life history characteristics such as growth, abundance, or reproduction. Each population must be managed with regard to its distinct life history (or histories) and whether or not these life histories are altered by impoundment.

The objective of this study was to characterize population size, growth, exploitation, and reproductive characteristics of the Columbia River Redband Trout inhabiting Mann Creek Reservoir and Mann Creek upstream of the reservoir to understand key life history attributes now that the population can no longer express an anadromous life history. The stock shows evidence of the retention of potential anadromy (Holecek et al. 2012), so understanding the past role and future potential of anadromy is necessary in interpreting the observed life history of this stock. We evaluated several specific life history aspects of the adfluvial form, including abundance, exploitation rates, growth, reproductive characteristics, and recruitment. For the resident form we evaluated age, growth, and reproductive characteristics to compare the two current life history strategies.

METHODS

Study area.— The study area includes Mann Creek Reservoir and Mann Creek upstream of the reservoir in southwestern Idaho in the Snake River drainage above the Hells Canyon Complex Dams (Figure 1). Mann Creek Reservoir was completed in 1967 following the construction of Mann Creek Dam, a U. S. Bureau of Reclamation project. The reservoir has an active capacity of 13,563,000 m^3, a drainage area of approximately 138.6 km^2, a full pool surface area of 114.5 ha, a mean depth of 10.0 m, and a normal pool elevation of 880.1 m (Young et al. 1977; Dillon 1991; Kozfkay et al. 2009). Mann Creek, the only direct tributary to the reservoir, flows approximately 25 km south into the reservoir from the headwaters, which originate at an elevation of approximately 2,100 m. The land surrounding Mann Creek Reservoir is high-desert sagebrush-steppe habitat.

Mann Creek Reservoir was built as an irrigation reservoir and as a result there are large annual fluctuations in water

FIGURE 1. Study area map of Snake River Hells Canyon Dams and the Mann Creek, Weiser River drainage, southwestern Idaho.

volume and limnological conditions. During our 2008 2009 study the reservoir was reduced an average of approximately 85% in volume from 13,563,000 m^3 to 2,220,303 m^3. Water level drawdowns for the past 16 years have ranged from 12.8 to 19.5 m in elevation, the lowest water levels occurring in late summer and early fall (Kozfkay et al. 2009). However, the reservoir does have a minimum conservation pool (861 m) that prevents complete drawdowns from occurring (Kozfkay et al. 2009).

The Columbia River Redband Trout we investigated inhabit both Mann Creek Reservoir and Mann Creek upstream of the reservoir. Steelhead had access to Mann Creek prior to construction of the Hells Canyon C-250.432.5(o).2(f)-43).

fish captured were examined for a caudal fin punch, identified as hatchery or wild origin, measured (TL; mm), and released.

Population size was calculated using Chapman's (1951) modification of the Peterson estimate

$$N = \frac{(M+1)(C+1)}{(R+1)} - 1,$$

where N = the population estimate, M = the number of marked fish, C = total number of fish in the recapture event, and R = the number of marked fish caught during the recapture event. The assumptions of this estimate were that (1) the population was closed, (2) all fish had equal capture probability, (3) capture and marking did not affect catchability, (4) fish did not lose their marks between sampling, and (5) all marks were reported. The 95% confidence intervals (CIs) for the population estimate were calculated using a Poisson distribution of R (Seber 1982).

Exploitation rates of adfluvial fish.—Annual exploitation rate was estimated using a tag-derived estimate that was initiated in October 2008 by anchor-tagging 245 adfluvial trout during the mark–recapture estimate. For a second tag based estimate, 675 anchor-tagged wild trout were released downstream of a weir between 2 March and 14 June 2009. For both tag return estimates, the number of tags reported by anglers to an Idaho Fish and Game hotline as being caught in the subsequent year after marking was used to calculate exploitation (μ'):

$$\mu' = \mu / \lambda(1 - \text{Tag}_l)(1 - \text{Tag}_m),$$

where μ is the unadjusted exploitation (number of tags recovered/number of tags released), λ is the tag reporting rate, Tag_l is the estimated tag loss and Tag_m is the estimated tagging mortality (Meyer et al. 2008). We estimated tag loss (5.7%) from results of this study and used the mean angler reporting rate (53%) reported by Meyer et al. (2009) as part of a statewide angler exploitation investigation in Idaho. Meyer et al. (2009) reported short-term (7 d) tagging mortality of trout as 0% to 1.8%. Meyer et al. (2008) assumed long-term tagging mortality for trout was 15%; their estimate was based primarily on literature values reported for centrarchids (Hayes et al. 1997; Miranda et al. 2002). We have no tagging mortality estimates to compare so we used two values, 2% and 15%, for long-term tagging associated mortality and assumed that the true value is within those bounds.

Run timing, sex ratios, and abundance of adfluvial fish.—To assess the run timing, sex ratios, and spawner abundance for the migratory portion of the spawning population ascending from the reservoir, we operated a picket weir located 1 km upstream from the confluence of Mann Creek and the reservoir from February through June, to bracket the suspected spawning season (February–June; Busby et al. 1996). Migratory adults were sampled over the period 25 February to 15 June 2009. There were 8 d during this interval, however, when the trap was breached as a result of high water and fish were not sampled.

Upstream migrants were captured, enumerated, measured (TL; mm), weighed (g), marked with a T-bar anchor tag, and released upstream of the weir. Anchor tags were placed approximately 10 mm below the anterior half of the dorsal fin at a 45° angle to the long axis of the fish and then gently tugged to ensure they were locked behind the pterygiophores of the dorsal fin (Mourning et al. 1994). We assigned sex to each fish captured at the weir based on secondary sexual characteristics (presence of kype or milt for males and presence of ovipositor or eggs for females). Mortalities observed at the weir and from 90 harvested fish observed during creel surveys confirmed that secondary sexual characteristics were an accurate predictor of sex for mature fish (100% accuracy). Sex was assigned to each fish prior to a necropsy where gonads were removed to confirm true sex of each fish. Observed sex ratios were compared to an expected 1:1 ratio using a chi-square goodness of fit test (α = 0.05; Zar 1984). To estimate anchor tag loss a subsample of fish were marked with both an anchor tag and an opercle punch; a standard hole punch was used to remove a 1-cm diameter hole of tissue from the left operculum of the fish. Fifty upstream migrants were opercle-punched and anchor-tagged, and all downstream migrants were examined for both marks.

The run timing was characterized in three ways: the distribution of time of ascent, the distribution of time of descent, and the amount of time an individual fish remained in the creek above the trap (i.e., number of days between upstream capture and downstream recapture). A t-test was used to determine if the number of days spent in the creek above the trap differed between males and females. Spawner abundance into Mann Creek was estimated using the same Chapman-modified Peterson equation previously described. The mark group was fish migrating upstream, and the recaptures were the downstream migrants (postspawn) that were captured and examined for marks before being released below the weir. The 95% CIs were estimated using normal approximation methods because R was greater than 50 (Seber 1982).

Age and growth.—To obtain age-specific information on growth for resident and adfluvial fish we collected scales from above the lateral line and between the posterior edge of the dorsal fin and the anterior edge of the adipose fin (Scarnecchia 1979). Scale samples were sealed in an envelope until they were pressed between glass slides for imaging. Digital images (25× and 40× magnification) of each prepared structure were captured using a Leica DC 500 camera attached to a Leica DM4000B compound microscope. Ages were assigned to fish using a double-blind protocol described by Scarnecchia et al. (2006). Each sample was aged independently by two readers and any discrepancies were re-aged independently by the same two readers. If there were any remaining discrepancies the two readers consulted and identified a single age for the sample. Scale annuli were identified by tightly banded and discontinuous or broken circuli (Lux 1971).

Growth rates were characterized with the von Bertalanffy growth model expressed as

$$(TL)_t = L_{\infty}\left[1 - e^{-K(t - t_0)}\right],$$

where $(TL)_t$ is total length at time t, L_{∞} is the maximum theoretical length, K is the growth coefficient, and t_0 is an initial condition time coefficient where length is theoretically 0 (von Bertalanffy 1957).

Fecundity and age at maturity Fecundity data were collected from trout of different ages to provide information regarding migratory decisions and any potential differences

FIGURE 3. Number of Columbia River Redband Trout captured during 2009 spawning season at the weir site on Mann Creek, Idaho, and mean daily water temperature and discharge.

related to stream discharge and sh capture at the weir. Peak sh captures for upstream migrants occurred during an ascending limb of the hydrograph. Capture of upstream migrants usually dropped signi cantly, however, at periods of peak discharge (Figure 4). Capture of downstream migrants was highest during peak discharge, including the second highest single daily capture of downstream migrants (36), which occurred on the same day as the highest daily discharge (6.12 m^3/s). No clear patterns of capture could be identi ed in relation to stream temperature.

Age and Growth

Ad uvial sh ranged from ages 1 to 9, while resident sh were ages 1 to 4. Estimated growth of migratory adults captured in the reservoir was higher than estimated rates for resident sh captured in Mann Creek, based on scale length-at-age data tted to von Bertalanffy growth curves (Figure 5).

Fecundity and Age at Maturity

Mean fecundity for 24 ad uvial females (TL range, 309 476 mm) was 2,345 eggs (range, 1,204 4,063 eggs). The GSI averaged 16.4 (range, 12.6 22.6), but there were no signi cant correlations between GSI and age, length, or fecundity. The earliest maturity observed for ad uvial sh was age 2 for males and age 3 for females. The largest proportion of the spawning run consisted of age-4 and age-5 sh, and younger sh (ages

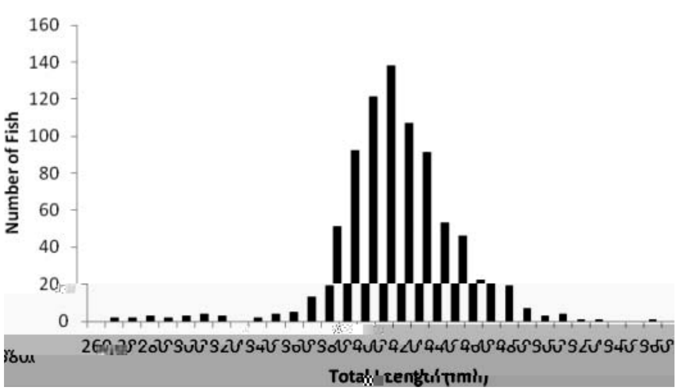

FIGURE 4. Length-frequency distribution of Columbia River Redband Trout captured at the weir on Mann Creek, Idaho.

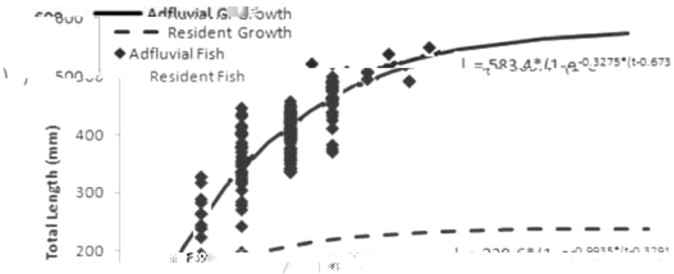

FIGURE 5. Growth comparison between resident and ad uvial Columbia River Redband Trout from Mann Creek drainage, Idaho. Data points represent individual sh used to develop growth curves.

iteroparous salmonids, where females leave shortly after spawning and males remain to seek additional spawning opportunities (Quinn and Myers 2004). Migratory males spending more time in the stream during spawning season may also contribute to skewed sex ratios observed from fish examined during creel surveys in Mann Creek Reservoir by Holecek (2010), who reported a sex ratio of 2.88 females per male for 66 harvested wild fish. Holecek (2010) reported that the months of May and June accounted for 52% of wild trout harvest and 30% of annual angler effort in the reservoir, suggesting females that return to the reservoir quickly are more likely to be harvested than males that remain in the stream where there is less fishing pressure (Holecek 2010). Schill et al. (2007) reported very low exploitation rates and angler effort for resident Columbia River Redband Trout in southwest Idaho streams. This observed pattern again illustrates the different life history strategies between males and females: females return to the reservoir where growth opportunity is higher but harvest is also higher, while males maximize spawning opportunity at the expense of growth opportunity.

We conclude that the migratory fish in the Mann Creek drainage that historically exercised an anadromous life history appear to be exercising the next best option, an adfluvial life history, which is probably similar in relative costs and benefits to the anadromous form. This pattern of life history modification to adfluvial may be occurring in other locations in the region where anadromy has been eliminated. The creation of reservoirs in the western USA has resulted in great habitat alteration and fragmentation for Rainbow Trout populations (Thurow et al. 2007). Results of our study area suggest that this wild Columbia River Redband Trout population has adapted relatively well to this altered habitat and now provides a recreational fishery. The ability of the species to adapt readily to altered habitats is well supported by their wide geographic distribution (MacCrimmon 1971) and diverse life histories (Behnke 1992). Future studies should evaluate other similar native populations isolated in reservoir systems because there is evidence that such populations could potentially serve a role in recovery of extinct or critically endangered steelhead populations (Thrower et al. 2008).

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