Rainbow Trout Growth and Survival on the Beaver Tailwater in Arkansas

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Abstract: Beaver Dam on the White River in northwest Arkansas, built in the 1960s for hydropower and flood control, releases cold water downstream suitable for trout survival. The trout fishery in Beaver Tailwater relies heavily on stockings, as natural reproduction is limited or nonexistent. In 2006, a 330–406 mm protected slot limit was implemented along with reduced stocking rates to increase the number of large rainbow trout (*Oncorhynchus mykiss*) in Beaver Tailwater. Further, a catch-and-release area was changed to a special regulation area (SRA) that allowed harvest but restricted angling to the use of artificial lures or flies with barbless single-point hooks. Outside the SRA bait was allowed, but anglers there were also restricted to barbless single point hooks. From July 2009 to April 2010, four cohorts of rainbow trout were tagged with coded wire tags, stocked into the tailwater, and sampled monthly using electrofishing to estimate growth and survival. Annual survival (0.5%–5.7%) and growth rates (3–4 mm mo^{-1}) were low for all stocked cohorts. However, creel and electrofishing surveys conducted in 2010 and 2017 detected an improvement in rainbow trout size structure, suggesting that the 2006 regulations and/or reduced stocking rates have benefited the population.

Key words: stocking, return-to-creel, tagging, slot, regulated river

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On the White River in northwestern Arkansas and southwestern Missouri, several dams were constructed in the 20th century for various purposes (e.g., flood control, hydropower), with one result being that hypolimnetic releases have created suitable habitats for coldwater fishes (e.g., rainbow trout [*Oncorhynchus mykiss*]) below these dams. Beaver Lake in northwest Arkansas is the first impoundment on the White River system, and its tailwater (Beaver Tailwater) provides angling opportunities for rainbow and other trout species. Similar to other tailwater salmonid fisheries across North America, this tailwater is stocked intensively by the Arkansas Game and Fish Commission (AGFC) and receives over 80,000 h of fishing pressure annually (C. Graham, AGFC, unpublished data). Rainbow trout were first stocked there in 1966. Because natural reproduction is limited to nonexistent, the population is exclusively maintained by stocking efforts (Pender and Kwak 2002, Williams et al. 2004).

The AGFC has attempted to optimize stocking practices in the Beaver Tailwater to increase the quality of the put-and-take rainbow trout fishery. In a public workshop held by AGCF regarding management of trout in the Beaver Tailwater, one of the key issues raised by anglers was a desire for more large trout, especially rainbow trout. To address this, AGFC implemented several regulatory changes including the 2006 implementation of a 330–406 mm protected slot limit with a daily creel of five trout of which only one could be larger than 406 mm. The regulation was an attempt to improve rainbow trout size structure and was designed to balance the interests of anglers desiring to target larger trout with those wishing to harvest trout but not focused on large fish (Hutt and Bettoli 2007). Also in 2006, the AGFC converted a catch-and-release area to a special regulation area (SRA) that allowed harvest of trout but restricted angling to artificial lures or flies with a single barbless hook. Bait fishing on the rest of Beaver Tailwater was allowed but was likewise restricted to single barbless hooks. Because Pender and Kwak (2002) indicated that Beaver Tailwater had low productivity and possibly insufficient forage to support high stocking densities, AGFC reduced stocking rates in 2006 from 190,000 to 96,000 fish a year to limit any potential density-dependent processes that may have affected growth and survival rates of trout within the tailwater.

Although several studies have investigated survival rates of brown trout (*Salmo trutta*) in Beaver Tailwater (e.g., Pender and Kwak 2002, Quinn and Kwak 2011), little information exists about survival and growth rates of rainbow trout. Therefore, the objectives of this study were to estimate growth and survival rates of

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stocked rainbow trout in the fishery. Knowing these rates will help inform management strategies used on the Beaver Tailwater to make measurable changes in this fishery.

Study Area

Beaver Dam was constructed in 1966 by the U.S. Army Corps of Engineers for flood control and hydropower; it is the most recent impoundment constructed in the upper White River system. Beaver Tailwater flows approximately 10.8 km through northwestern Arkansas (Figure 1) before entering Table Rock Lake. The dam's total maximum operational discharge is 257 m^3 sec^{-1}, while the capacity of a single turbine is 112 m^3 sec^{-1}. Base flows are approximately 1.8 m^3 sec^{-1}. Maintenance of dissolved oxygen concentrations follow guidelines set by the White River Dissolved Oxygen Committee's Operational Action Plan. When dissolved oxygen falls below 6 ppm at base flow or 4 ppm during generation, vacuum breaker vents can be opened to improve dissolved oxygen concentrations. U.S. Geological Survey gages monitor discharge, water temperature, and dissolved oxygen from May/June through January annually. The average monthly water temperatures in 2009 and 2010 ranged from 7.89 to 10.94 °C (USGS unpublished data).

The river was first stocked with rainbow trout in 1966, with brown trout in 1985, cutthroat trout (*Oncorhynchus clarkii*) in 1989, and brook trout (*Salvelinus fontinalis*) in 1994 (Williams et al. 2004). As of the time of this study, Beaver Tailwater was receiving monthly stockings of rainbow trout (96,000 annually), and 5000 brown trout were stocked annually. Angler catch rates of brown trout were much lower (≤0.01 trout h^{-1}) than rainbow trout (0.91 trout h^{-1}) (C. Graham, AGFC, unpublished data). Paddlefish (*Polyodon spathula*) were also present in the river and a snagging season existed from 15 April–15 June. Trout are sometimes incidentally snagged by paddlefish equipment; AGFC regulations state that trout snagged incidentally may not be released and that snagging must be discontinued after two trout have been taken. Walleye (*Sander vitreus*) and striped bass (*Morone saxatilis*) were also present in the fishery but occur in low numbers.

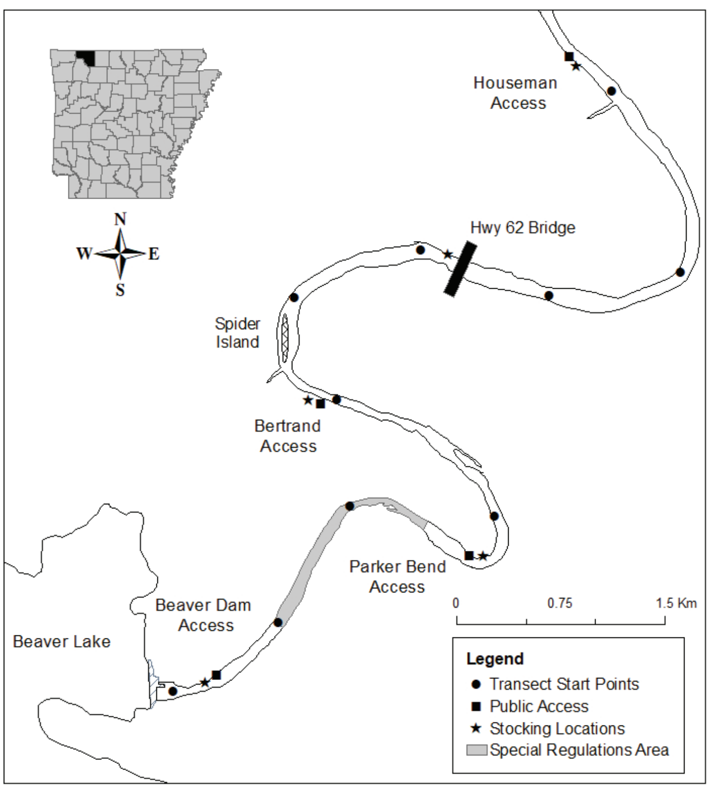

Figure 1. Sampling transects, stocking locations, public access sites, and the special regulation area on Beaver Tailwater, Arkansas.

Methods

Rainbow Trout Marking

Between July 2009 and April 2010, four cohorts of rainbow trout raised at the Norfork National Fish Hatchery were tagged with double length (i.e., 2.2 mm), blank coded wire microtags using a Mark IV CWT microtagging unit (Northwest Marine Technology [NMT] Inc., Olympia, Washington). Each cohort was tagged in different anatomical locations, including the snout (July 2009 cohort), below the dorsal fin (i.e., dorsal; November 2009 cohort), posterior to the dorsal side of the head (i.e., nape; February 2010 cohort), and in the caudal peduncle (i.e., caudal; April 2010 cohort). Fish were anesthetized with tricaine methanesulfonate prior to tagging. The adipose fins or left pelvic fins of rainbow trout in each cohort were removed to facilitate later identification of tagged fish in the field. Trout were held in the hatchery for a withdrawal period of 21 days prior to stocking. Within one week prior to stocking, approximately 100 fish from each cohort except for the November 2009 cohort were measured for TL (mm), weighed (g), and checked for retention of microtags. Retention of tags in dorsal musculature during a concurrent tag retention study was high (98%) 209 days post-tagging (AGFC, unpublished data).

The four tagged cohorts were stocked by hatchery personnel on 29 July 2009, 13 November 2009, 12 February 2010, and 16 April 2010, respectively, at standard AGFC stocking locations (Figure 1). All four cohorts were stocked at the Dam, Parker Bend, and Bertrand accesses. The July and November cohorts were also stocked at the Highway 62 Bridge, and the February and April cohorts were also stocked at the Houseman access for a total of five stocking locations for each cohort. No cohorts were stocked inside the SRA. The tagged cohorts contained all rainbow trout stocked into Beaver Tailwater during three of the four respective stocking months; the July 2009 cohort accounted for 79% of all rainbow trout stocked into Beaver Tailwater that month.

Field Sampling

The tailwater was divided into 22 sampling transects approximately 500 m long using Geographic Information System (GIS) software. Ten transects (Figure 1) were selected and sampled by electrofishing. Sampling occurred each month during the study, with the first sampling event after each cohort was stocked conducted within one week of stocking in order to obtain an initial measure of relative abundance and size. Transects were sampled by using a fiberglass electrofishing boat equipped with a 5.0 GPP electrofishing unit (Smith-Root Inc., Vancouver, Washington) for approximately 600 sec. The GPP unit was operated for direct current at 50–1000 V and 30 pulses per sec to achieve a current of approximately 2.0 amps. All sampling used one netter and was conducted at night during periods of no dam generation. From Beaver Dam to Spider Island, transects were conducted along the bank and in the channel while meandering in a downstream direction from bank to bank. Downstream of Spider Island, Beaver Tailwater transitions rapidly to a lentic environment (i.e., Table Rock Lake) and electrofishing efficiency is reduced due to deep water. Therefore, electrofishing was conducted on the right or left descending bank when sampling those transects.

Upon capture, all rainbow trout were checked for fin clips; if the fish had a fin clip, it was measured and weighed, checked for a microtag, and returned to the river. An annual population survey conducted in September 2009 and 2010, as well as a partial growth and mortality sample conducted in October 2010 at our first three sample transect locations below Beaver Dam, overlapped some of the dates for our study. Methods for these samples differed from our study, primarily in terms of areas shocked; thus, those fish were not included in the catch-curve analyses but were used for growth estimates.

Data Analysis

All analyses were conducted only using tagged fish in each cohort. One-way ANOVAs were used to test if mean TL differed between cohorts, both prior to stocking and during the initial electrofishing surveys. Growth of each cohort was calculated by examining the relation between mean TL and days post-stocking using a weighted regression with numbers of individuals collected as weights in the regression models (Kutner et al. 2005, Miranda and Bettoli 2007). Growth was considered significant if the slopes of the regression lines differed from zero. Differences in slopes of weighted regression lines (i.e., growth rates) were examined among cohorts and areas using ANCOVA. Time to reach and exceed the slot limit (i.e., 330 mm and 406 mm, respectively) were estimated by subtracting mean TL prior to stocking from the slot lengths and then dividing by the estimated growth rate determined from the regression analysis described above (mm day^{-1}).

Weighted catch-curve analysis was used to estimate survival of each cohort using transformed (loge [catch+1]) catch data (Miranda and Bettoli 2007). Persistence was estimated by using the x-intercept of the weighted regression. Daily survival rates were estimated using $e^{-Z_{daily}}$. Annual mortality (Z) was calculated by multiplying Z_{daily} by 365 and annual survival was estimated using e^{-Z} (Ricker 1975). Annual survival rates of fish in each cohort collected inside and outside the SRA were also estimated. Differences in slopes of weighted regression lines were examined among cohorts and areas using ANCOVA. Minitab 16 software was used to perform all statistical tests and significance was declared at $P < 0.05$.

Results

A total of 23,388 trout were tagged and stocked during the study (Table 1). Prior to stocking, mean TL of rainbow trout in the July 2009 cohort (265 mm) was smaller than the February 2010 (287 mm) and April 2010 cohorts (293 mm; $F = 26.10$; df = 2; $P < 0.001$). Retention of wire tags prior to stocking was 81% for the July 2009 cohort and 99%–100% for the February 2010 and April 2010 cohorts.

Fourteen electrofishing samples were conducted between 30 July 2009 and 20 December 2010. During this time only 806 tagged fish from the four cohorts were recaptured during the electrofishing surveys (Table 2), 89 of which were collected during the annual population survey. Most (93%) tagged fish were collected above the

Table 1. Number of rainbow trout stocked into Beaver Tailwater, Arkansas, from July 2009 to April 2010. Subsamples of approximately 100 fish were examined 30 days post-tagging to determine mean TL (mm) and tag retention rates. The November 2009 cohort did not have its length or tag retention recorded before it was stocked. Mean TL with the same superscript not different (ANOVA, $P > 0.05$).

Cohort	Date stocked	Tag location	Number tagged	Tag retention (%)	Length (mm)
July 2009	29 Jul 2009	Snout	8136	81	265[a]
November 2009	13 Nov 2009	Dorsal	5200	n/a	n/a
February 2010	12 Feb 2010	Nape	2802	99	287[b]
April 2010	16 Apr 2010	Caudal	7250	100	293[b]

Table 2. Growth of microtagged cohorts of rainbow trout stocked into Beaver Tailwater, Arkansas, between July 2009 and April 2010. Weighted linear regressions were used to estimate whether growth was significant for the overall number of fish collected. Growth rate was used to estimate days to reach and exceed the 330- to 406-mm slot-length limit.

Cohort	n	Intercept	Slope	r^2	P	Days to reach 330 mm	Days to reach 406 mm
July 2009	314	285.4	0.119	0.725	<0.0001	374	1011
November 2009	228	280.5	0.100	0.667	0.002	493	1250
February 2010	102	279.4	0.133	0.601	0.008	381	954
April 2010	162	296.4	0.240	0.849	<0.0001	140	457

Hwy. 62 Bridge; 43% of tagged fish were collected inside the SRA even though no tagged fish were stocked into that area. Lengths of rainbow trout during the four initial field samples were greater in the April 2010 cohort (295 mm) than the other three cohorts (range 277 to 283 mm; $F=5.58$; df = 3; $P=0.001$). Mean TL of fish in the July 2009 cohort was smaller at the hatchery (265 mm) than in the initial sample (283 mm; $F=11.20$; df = 1; $P=0.001$); mean TL was similar between these periods for the other three cohorts.

Survival

Annual rainbow trout survival rates were uniformly low and similar among cohorts ($F=2.15$ df = 3 $P=0.115$, Figure 2), but annual survival of the July 2009 cohort (5.7%) was more than double that of other cohorts (0.5%–3.0%). Persistence of cohorts in the tailwater was short. The July 2009 cohort persisted for approximately 17 months (Figure 2). However, the July cohort could only be detected for 12 months, after which the fish could no longer be distinguished from a snout-tagged cohort stocked in July 2010 and not part of this study. Fish from the November 2009 cohort persisted for 15 months. Persistence of the February 2010 and April 2010 cohorts approached zero at 8 months and 10 months post-stocking, respectively. Daily mortality values ranged from 0.8% to 1.5%. Annual survival did not differ between areas (outside SRA vs. inside SRA) for any of the four cohorts (Figure 3).

Growth

Due to the observed movement of stocked fish into the SRA from stocking locations, growth differences were not examined between areas as fish were likely not confined to each area. All four cohorts exhibited slow but significant growth during the study (Table 2). The April 2010 cohort (7.3 mm mo^{-1}) grew faster than the other cohorts (3.0–4.0 mm mo^{-1}) ($F=2.99$; df = 3; $P=0.042$). Time to reach 330 mm (i.e., the slot limit) varied between 140–493 days, while time to reach 406 mm (i.e., out of slot) was between 457 and 1250 days.

Discussion

Poor survival and growth of stocked, catchable rainbow trout observed during our study are consistent with other studies (Weiland and Hayward 1997, Bettinger and Bettoli 2002, Baker and Sammons 2021). Many factors, such as predation and harvest, can influence the growth and survival of rainbow trout in tailwaters. Striped bass and walleye were encountered during our study, often in the lower section of the SRA, but in small numbers (C. Graham, AGFC, unpublished data). A 2009–2010 creel survey indicated that anglers harvested 82% of walleye caught, and few ($n=189$) were caught. Thus, predation by these species likely has a limit-

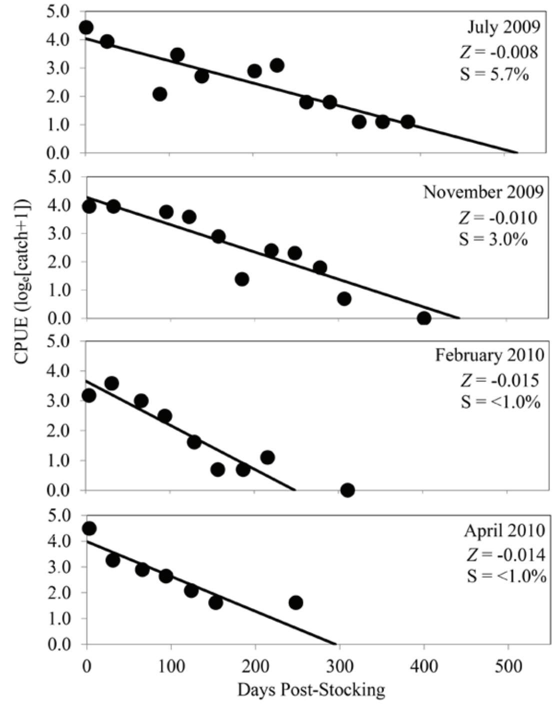

Figure 2. Catch-curve analysis for four cohorts of microtagged rainbow trout stocked into Beaver Tailwater, Arkansas, between July 2009 and April 2010. Symbols denote observed catches and the line is the daily instantaneous mortality rate (*Z*) for each cohort, which was used to derive annual survival (S).

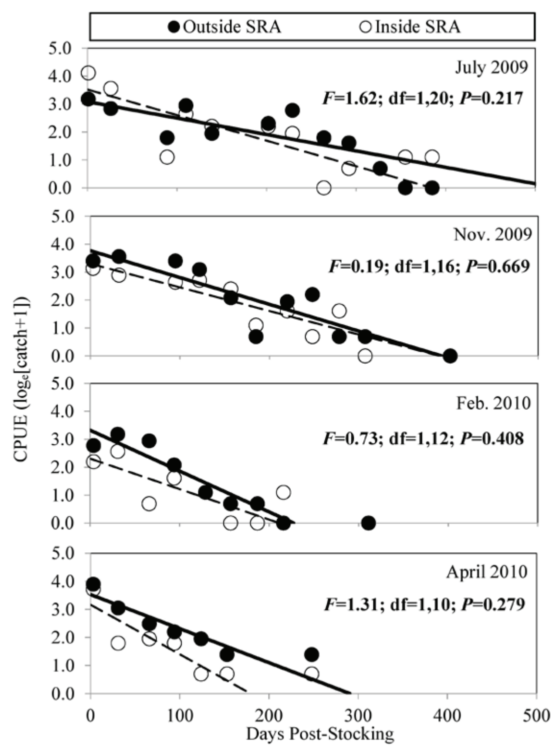

Figure 3. Catch-curve analysis for cohorts of microtagged rainbow trout stocked into Beaver Tailwater, Arkansas, between July 2009 and April 2010. Closed circles represent CPUE of fish from the cohort collected outside the special regulations area (SRA) and open circles represent CPUE of fish from the cohort collected inside the SRA. Weighted regression lines of fish collected outside (solid line) and inside (dashed line) the SRA are included.

ed contribution to the poor survival of rainbow trout observed in this study. Similarly, low harvest of rainbow trout reported during 1998–2001 and 2008–2010 creel surveys in the Beaver Tailwater suggested that exploitation was not a major source of trout mortality in Beaver Tailwater: despite catching 55%–75% of all rainbow trout stocked, anglers released the majority (61%–67%) of fish caught (Williams et al. 2004; C. Graham, Arkansas Game and Fish Commission, unpublished data).

Several studies have suggested that growth rates of trout in Beaver Tailwater are slow due to an inadequate food base (Brown et al. 1967, Blanz et al. 1969, Weiland and Hawyard 1997, Pender and Kwak 2002). Food limitation can be common in tailwaters and may result in poor condition and slowed growth rates (Odenkirk and Estes 1991, Biro et al. 2004, Dodrill et al. 2016, Dunnigan and Terrazas 2021). These factors are compounded further because hatchery origin trout often exhibit reduced predator avoidance and ability to consume natural prey, reducing their return-to-creel rates (Bachman 1984, Álvarez and Nicieza 2003, Araki et al. 2008). Trout in poor condition may become vulnerable to mortality from factors such as predators, flow variation, and spawning costs (Werner and Gilliam 1984, Walters and Juanes 1993, Post et al. 1999, Annear et al. 2002). Thus, an already limited food base in Beaver Tailwater may not have been able to sustain growth for an artificially high-density trout population, resulting in few large rainbow trout.

We acknowledge that batch marking of cohorts may limit the accuracy of growth estimates due to size variation within a stocked cohort. For example, the July 2009 cohort varied from 124 to 327 mm. Individualized tags (e.g., PIT, Floy tags) could be used to estimate growth rates more accurately (Shoup and Michaletz 2017). However, we examined mean TL prior to stocking and during the initial electrofishing sample for three of four cohorts and found no differences between time periods (unpublished data), suggesting that electrofishing captured a representative sample of mean cohort TL.

In 2006 stocking rates were reduced for rainbow trout (50%) and brown trout (19%), which may have alleviated density dependent processes in Beaver Tailwater (Weiland and Hayward 1997, Dibble et al. 2015, Korman and Kennedy 2017). Density dependence in salmonid populations has been extensively reviewed and is often associated with reduced growth and increased mortality (Grossman and Simon 2019). Density dependence may cause a reduction in fitness impairing the ability to endure high flow, evade predators, and successfully forage, and ultimately may result in failure to meet management goals of a put-grow-take fishery (Weiland and Hayward 1997, Dibble et al. 2015, Grossman and Simon 2019). Tailwater trout fisheries are managed primarily for angler satisfaction, and any reduction in catch rates associated with reduced stockings may result in angler dissatisfaction. Therefore, stockings should be done at a rate that balances angler satisfaction and agency funding. Having clearly defined objectives and standards for angler satisfaction can help guide management actions. Despite reduced stockings of trout on Beaver Tailwater, angler catch rates have remained within the range sought by managers (i.e., 0.8–1.0 fish h^{-1}). Electrofishing surveys in 2010 and 2017 found that the rainbow and brown trout size structures had also improved with 30% of rainbow trout being in or above the protected slot (C. Graham, AGFC, unpublished data).

Catch-and-release and/or special regulation areas have been established on five of Arkansas' tailwater trout fisheries to reduce angling mortality, increase survival rates, grow larger trout, and increase angler satisfaction. Rainbow trout survival and growth estimates for the SRA and the rest of the tailwater were not significantly different in our study despite only 2% of fish in the SRA being harvested (C. Graham, Arkansas Game and Fish Commission, unpublished data). This suggests that fish most likely moved between regulatory zones, further supporting that movement may be a factor affecting survival. No fish were stocked directly into the SRA; however, 43% of recaptures occurred inside SRA. Most (72%) fish from the July 2009 cohort were collected inside the SRA one day post-stocking. Our results indicate rainbow trout either moved downstream from the dam or upstream from Parker Bend. No barriers exist to prevent movement inside and outside the SRA, thus limiting the effectiveness of the special regulations (Hayes et al. 1997). Rapid post-stocking movements are likely a result of disorientation and searching for adequate habitats. Movement studies have demonstrated that rapid dispersal of rainbow trout stocked in tailwaters is common and results in low return-to-creel rates (Bettinger and Bettoli 2002, Quinn and Kwak 2011, Baker and Sammons 2021). The SRA regulations did not appear to affect trout population dynamics; however, they altered constituent behavior and may separate constituents with differing viewpoints (e.g., harvest-oriented, catch-and-release-oriented; Hyman and McMullin 2018).

Despite poor growth rates and survival of trout in Beaver Tailwater, this system exemplifies the effectiveness of adaptive management at dealing with complex social and biological challenges. Alteration of abiotic features (e.g., flow regimes and nutrients) are often beyond managers' capabilities. However, implementing regulations and adjusting stocking rates are feasible actions. By interacting with anglers via public forum AGFC was able to identify concerns within the fishery, then take feasible actions to successfully address these concerns and increase the size structure of rainbow trout. It is unclear whether the reduced stocking or slot limit are responsible for this improved size structure; however, it is likely a combination of both and demonstrates their effectiveness to benefit tailwater trout populations. Slot limits can effectively alter size structures while benefiting both harvest and catch-and-release oriented anglers. Finally, the reduced stocking rates increased return-to-creel which has major financial benefits to the agency, ultimately benefiting the constituents and the fishery as a whole.

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