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Research Article

# Short-Term Movement and Survival of Resident Brown Trout in Response to Instream Habitat Manipulation

**Austin G Galinat[1], Jacob L Davis[2]*, Greg Simpson[2]**

[1]South Dakota State University, Northern Plains Bio Stress Laboratory (SNP) Box: 2140B, Brookings, South Dakota 57007, USA

[2]South Dakota Department of Game, Fish and Parks, 4130 Adventure Trail, Rapid City, South Dakota 57702, USA

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**Abstract:** While long-term impacts to local fish populations in response to habitat work has been researched extensively, impacts to populations during the actual implementation of projects is poorly understood. During this study, fish movement and survival was quantified pre-, during- and post-construction period of an instream habitat manipulation project involving placement of boulders and large-woody debris. Twenty Brown Trout *Salmo trutta* were implanted with radio transmitters during November of 2015 and located for a period of 13 weeks. Our results indicated that fish moved significantly less post-construction than pre-construction. Additionally, survival was 100% for known-fate fish. This work illustrates that actual installation of instream habitat had little to no impact on the resident fish population.

***Correspondence to:** **Davis JL,** South Dakota Department of Game, Fish and Parks, 4130 Adventure Trail, Rapid City, South Dakota 57702, USA, Tel: (+1) 6053941759; E-mail: jake.davis@state.sd.us

## Introduction

Understanding the movement of stream fishes is often of importance for fisheries managers. In particular, interpreting movements of salmonids can provide inference into life history characteristics (Solomon and Templeton 1976), spawning (Rustadbakken et al. 2004) and habitat use (Young 1995). Many studies have focused on movements of Brown Trout *Salmo trutta* in lotic systems (Bunnell et al. 1998; Burrell et al. 2000; James et al. 2007). As a result, movement of Brown Trout can be related to abiotic factors such as discharge (Bunt et al. 1999), water temperature (Garrett and Bennett 1995), or photoperiod (Clapp et al. 1990). Additionally, movement may be influenced by size of the fish (Meyers et al. 1992) and feeding strategies (Bachman 1984).

Instream habitat manipulation is often utilized to improve populations of stream-dwelling salmonids (Whiteway et al. 2010). Improvements of trout biomass, abundance, and survival have been associated with habitat enhancement (Binns 2004, Baldigo et al. 2008b). (Riley and Fausch 1985) documented an increase in abundance and biomass of age-2 and older trout in six northern Colorado streams following habitat enhancement. Similarly, (Solazzi et al. 2000) documented an increase in salmonid abundance following the increase of winter habitat in two coastal Oregon streams.

Beginning in the early 2000s, declines in Brown Trout abundance in Rapid Creek, South Dakota concerned fisheries managers. Annual population surveys indicated that abundance of adult Brown Trout (>200 mm total length) had declined by approximately 70% (Carreiro and Wilhite 2007). During this period, the region was experiencing a protracted drought (2002-2005) resulting in below average annual discharge in Rapid Creek (James et al. 2010), potentially reducing carrying capacity for Brown Trout. Coincident with drought conditions, nuisance blooms of *Didymosphenia geminate* were reported in Rapid Creek, leading fisheries managers to suspect this may have contributed to the decline of Brown Trout). However, subsequent research indicated that *D. geminata* did not appear to be limiting Brown Trout recruitment (James 2011; James and Chipps 2010) and while the drought period was associated with low trout biomass, it did not fully explain the population decline of adult Brown Trout in Rapid Creek (James et al. 2010). Lack of stream complexity was also considered to be a potential limiting factor (Davis et al. 2016). Over time, high discharge resulted in altered stream hydrology and degraded instream habitat (Schultz et al. 2011). In response, an approximately 760 meter section of Rapid Creek below Pactola Dam (located 20 km west of Rapid City, SD) underwent habitat enhancement, which increased stream complexity through the addition of large wood debris and boulder complexes. This work included placement of 100 boulders and 300 trees and root wads, which required the use of heavy machinery within the wetted width and the riparian area.

While long-term impacts of instream habitat manipulation have been well documented (Gowan and Faush 1996; White et al. 2011) few movement studies have been conducted to examine any short-term effects on resident fish in response to anthropogenic activity, specifically during the construction period. Specific to the Rapid Creek, resident Brown Trout have exhibited high site fidelity outside of spawning periods (James et al. 2007), and short-term effects on aspects such as displacement and survival in response to the construction of in-stream habitat work were unknown. As a result, our objectives were to evaluate the response of the resident Brown Trout population to instream habitat work. Specifically, we aimed to 1) assess short-term movement of resident Brown Trout before, during, and after the construction period and 2) evaluate any impacts to fish survival as a result of instream construction.

## Methods

We studied a 4 km section of Rapid Creek below Pactola Dam, approximately 15 km west of Rapid City, South Dakota. Annual discharge below Pactola Dam averages about 1.47 $m^3/s$ (USGS 2008), and the mean stream width within this reach averages 11 m (James et al. 2010). The fish assemblage consists of naturalized Brown Trout, Brook Trout *Salvelinus fontinalis*, and Rainbow Trout *Oncorhynchus mykissin* this section of Rapid Creek (Bucholz and Wilhite 2010). While the tailwater area of Rapid Creek represents less than 0.5% of the perennial cold-water stream habitat in the Black Hills, it is the largest tailwater trout fishery in the Black Hills and a popular destination for anglers; as such, the tailrace section is managed as a "catch-and-release" trout fishery and restricted to fishing with artificial lures only.

In November 2015, we captured 20 resident Brown Trout (mean TL=297 mm; range=218 mm-555 mm; mean weight=304 g; range=92 g-1454 g) using a backpack electrofishing unit (Smith Root LR-24, Vancouver, WA, USA)one month prior to the initiation of instream habitat enhancement. Five individuals were captured within 4 separate sections of Rapid Creek, for a total of 20 fish **(Figure 1)**. Three of these sections were included in the habitat enhancement work, while one was located approximately 2.5 km downstream to monitor movement of individuals not impacted by instream habitat construction. To monitor fish directly impacted by the construction, fish in the enhancement area were tagged within proximity (<5 m) of construction sites. Fish were anesthetized using a carbon dioxide and surgically implanted with radio transmitters (Model F1500, Advanced Telemetry Systems, Isanti, MN; mean weight=1.3 g; range) using the shielded-

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needle technique (Ross and Kleiner 1982). Following tag implantation, fish were held in recovery cages within the creek for 4 hours post-surgery to assess any short-term mortality (Marking and Meyer 1985; Gilderhus and Marking 1987) and deleterious effects (Taylor and Roberts 1999; Pirohen and Schreck 2003) associated with the surgical procedure. Following the monitoring period, we released fish near their original capture location (<5 m).

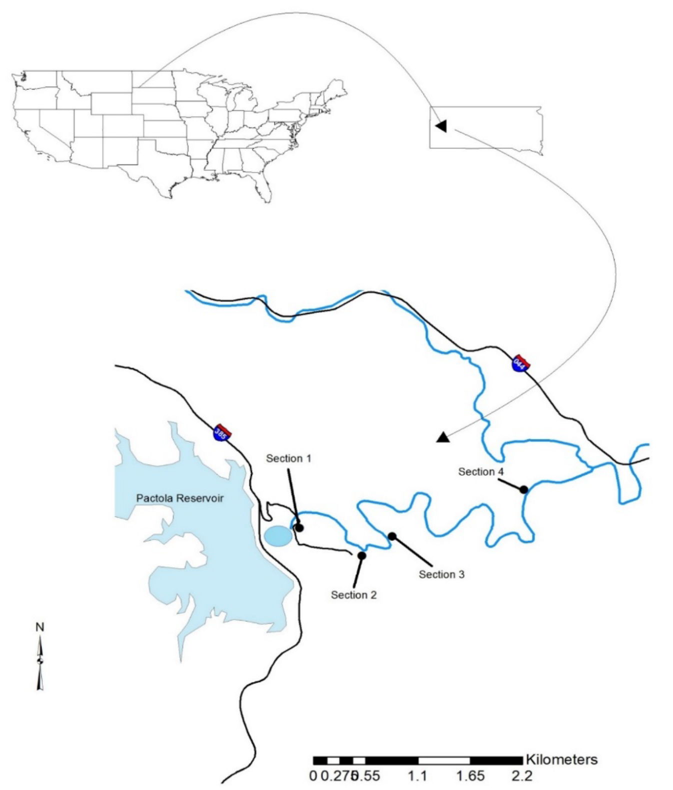


**Figure 1:** Locations of sections for radio-tagged Brown Trout in Rapid Creek, South Dakota.

Fish were located three times a week using a three-element folding Yagi antenna (Advance Telemetry Systems, Isanti, Minnesota) and scanning receiver (Challenger R2000, Advanced Telemetry Systems, Isanti, Minnesota). For fish locating, a Trimble Geo Explorer 3 was used to collect GPS points and angle bearings along the stream bank at three separate areas for each fish. When fish were unable to be tracked for the duration of the study, we used criteria reported by (Lindstrom and Hubert 2004) to assign fish losses to one of three outcomes: transmitter failure, apparent mink predation, or unknown fate. Transmitters were considered to have failed if weakened signals or slowed pulse frequencies were observed prior to not being able to locate the fish/transmitter during subsequent surveys. Predation by mink, hereafter referred to as ‘apparent predation’, was inferred when transmitters were located outside of the stream channel in riparian areas where mink sign (e.g., tracks, scat, latrines, or potential den sites) was noted, and when movement had not been detected by the fish for multiple tracking events. We assigned an ‘unknown’ fate to fish that, after being released in the stream, we were unable to track for the entire study period because they either left the study area or their transmitters were located within the stream. Fish were tracked during three “periods” which were defined as “pre-construction”, “construction” and “post-construction”.

**Table 1:** Tagging reach, frequencies, total length (mm), weight (g), number of times located, and fate (U=unknown, S=survived) of 20 Brown Trout in Rapid Creek, Black Hills, South Dakota, 2015-2016.

| Tagging reach | Frequency | Length | Weight | Number of locations | Fate |
|---|---|---|---|---|---|
| 1 | 148.411 | 555 | 1454 | 3 | U |
| 1 | 148.312 | 320 | 285 | 32 | S |
| 1 | 148.242 | 249 | 161 | 31 | S |
| 1 | 148.103 | 264 | 196 | 30 | S |
| 1 | 148.023 | 245 | 132 | 31 | S |
| 2 | 148.371 | 335 | 338 | 30 | S |
| 2 | 148.292 | 290 | 252 | 30 | S |
| 2 | 148.261 | 300 | 240 | 28 | S |
| 2 | 148.161 | 268 | 182 | 29 | S |
| 2 | 148.041 | 262 | 164 | 31 | S |
| 3 | 148.081 | 255 | 418 | 31 | S |
| 3 | 148.181 | 340 | 347 | 33 | S |
| 3 | 148.222 | 241 | 138 | 31 | S |
| 3 | 148.121 | 250 | 136 | 34 | S |
| 3 | 148.352 | 220 | 92 | 29 | S |
| 4 | 148.14 | 381 | 573 | 31 | S |
| 4 | 148.061 | 381 | 418 | 30 | S |
| 4 | 148 | 255 | 161 | 19 | S |
| 4 | 148.202 | 320 | 276 | 32 | S |
| 4 | 148.331 | 218 | 107 | 29 | S |

For statistical analysis, we summarized mean number of movements, gross movement, and net movement for each period. We used methods described by (Brown et al. 2001) to define gross and net movements. When possible, data was compiled, and log transformed prior to analysis of variance to stabilize the variances (Warton and Hui 2011). Following transformation, data was assessed for normality with Shapiro-Wilks test and homogeneity of variance using a Folded F test. A one-way ANOVA was used to evaluate differences in in total gross movements between sections. We used a two-way analysis of variance to test for difference in gross movement between periods and between sections ($\alpha$=0.05). If differences existed, pairwise comparisons were performed using Tukey honestly significantly different means comparison procedure (Kuehl 2000). Sigma Plot 11.0 was used for analysis (Systat Software Inc., San Jose, USA).

## Results

Fish were tracked for three weeks during the pre-construction and construction periods, followed by seven weeks post-construction. At the conclusion of the tracking period, 19 of the 20 radio tagged Brown Trout were still being actively located **(Table 1)**. One fish in section one was only located 3 times. It was assigned an "unknown fate" and removed from the analysis. All other fish were located an average of 30 times (range=19-34). During the study, 574 fish locations were recorded.

Total gross movements between sections were not significantly different (P=0.579). Total net movements between sections were also not significantly different (P=0.077). However, gross movements between periods was significantly different with less movement occurring during and-post-construction compared to pre-construction (P=0.012) **(Figure 2)**. Movement between sections within periods was not significantly different (P=0.820).

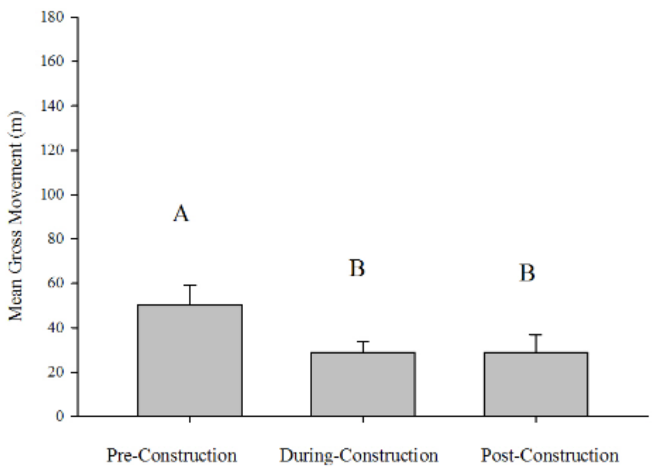


**Figure 2:** Mean gross movement of radio-tagged Brown Trout Pre-, During-, and Post-construction of instream habitat manipulation in Rapid Creek, South Dakota. Bars with different letters denote statistical significance (P<0.05).

## Discussion

Our results indicate that disturbance to resident Brown Trout during construction of instream habitat work is minimal. Movement by resident fish in specific locations where heavy equipment installed large woody debris and boulders was similar to fish in undisturbed areas. Resident fish also returned to original tagging locations soon after construction ended if displacement occurred. Additionally, survival was not impacted as no mortalities were observed.

Our results were similar to other studies that documented minimal movement and high site fidelity by stream-dwelling Brown Trout (Burrell et al. 2000; Knouft and Spotila 2002). Additionally, we observed movement patterns that were comparable to other Brown Trout populations within the Black Hills of South Dakota that exhibited small home ranges outside of spawning periods (James et al. 2007; Rehm 2019). While some studies have documented increased movements by resident Brown Trout during nocturnal periods (Clapp et al. 1990; Diana et al. 2004), we only located fish during daylight hours.

While one fish was classified with an unknown fate, survival of the remaining transmitter fish was 100%. To our knowledge, few studies, if any, have evaluated survival of adult resident fish during the construction phase of in-stream habitat work; thus, making comparisons difficult. However, we observed higher survival than other radio telemetry studies on resident trout in the same study area where 30% of assigned transmitter fish fates were mink predations (Davis et al. 2016). While it is hard to make inferences into the observed differences, it is possible that increased anthropogenic disturbances along the steam bank during and post-construction may have reduced the level of mink activity in the area.

The presence of the radio transmitter could have influenced our results. However, minimal impacts by the surgical procedure on aspects such as survival, swimming performance, and general behavior have been documented (Robertson et al. 2003; Aarestrup et al. 2005). With a maximum tag weight being 1% of total body weight, all fish included in this study were under the 2% rule (Winter 1983). Additionally, the high survival rate observed in this study is likely indicative of negligible impacts by the surgery or the transmitters themselves. While tagger experience has been documented to impact the well-being of a fish (Thiem et al. 2011), only one experienced tagger (>100 surgical implantations) was used.

While in-stream habitat manipulation has been a useful tool for fisheries managers, direct, short-term effects on the resident population of fish had gone largely untested. Our results indicated that while short-term displacement may occur, the duration was limited, and fish returned to home territories (i.e. original tagging locations) soon after construction finished. Additionally, movement was significantly less post-construction, which may indicate that adult habitat had been improved. Interestingly, post-construction hydrologic models did estimate that fry, juvenile, and adult habitat had been increased by the instream work (Kenney 2018). While future work should focus on survival and movement of resident fish in relation to various forms of habitat manipulation (e.g. bank reconstruction, channel shaping, etc.), this study provides inference into short-term responses by resident stream-dwelling trout.

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