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Brown trout (*Salmo trutta*) redd locations in Iron Creek, Lawrence County, South Dakota, USA

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ABSTRACT: This study documented brown trout (*Salmo trutta*) redds and their locations in the eastern most 1.8 km stretch of Iron Creek, Lawrence County, South Dakota, USA, during the fall of 2023. The first redds were observed on September 19, 2023. Weekly observations continued until no new redds were observed on October 27. Throughout the six-week period, a total of 67 redds were documented, with a peak of 19 redds on September 23. Stream temperatures varied from 2 to 10°C throughout the study, with the highest number of redds observed at 9°C. This is the first and only study to document brown trout redd locations and the timing of redd construction in Iron Creek.

Keywords: *Salmo trutta*, spawning, non-native, self-sustaining.

INTRODUCTION

Brown trout (*Salmo trutta*) were introduced in 1890 into the Black Hills of South Dakota, USA (Barnes, 2007). There are now self-sustaining brown trout populations in nearly all 1,287 km of streams (Erickson and Koth, 2000; James, 2011; Kientz, 2016). Although a popular sport fish in South Dakota, there is little information on brown trout spawning and reproduction specific to several streams in the Black Hills (Scarnecchia *et al*., 2023).

Brown trout are fall spawners in the northern hemisphere (Witzel and MacCrimmon, 1983; Wydowski and Whitney, 2003). In the few streams within the Black Hills where brown trout spawning has been documented, it typically occurs from mid-October through mid-November (Ketelsen *et al*., 2017; Blaine *et al*., 2018; Martling *et al*., 2020; Robidoux *et al*., 2022). Both Martling *et al*. (2020) and Robidoux *et al*. (2022) observed peak brown trout spawning activity during the first week of November in one stream in the Black Hills.

During spawning, most salmonids create gravel pit nests, called redds, to deposit eggs (Helfman *et al*., 2003). Redd location is dependent upon stream morphology, depth, substrates, water velocity, and temperature (Knapp and Preisler, 1999). Brown trout, in particular, favour high water velocity, shallow depths, and coarse substrates (Witzel and MacCrimmon, 1983; Grost *et al*., 1990; Martling *et al*., 2020). Water temperature and velocity can cause variations in spawning times (Warren *et al*., 2012).

Redd counts are commonly used to evaluate trout populations and monitor fish dynamics (Meffe, 1986; Konkel and McIntyre, 1987; Pratt, 1992; Weaver, 1992; Rieman and McIntyre, 1996). Redd counts are non-invasive and relatively easy to do (Dunham *et al*., 2001). Although they can be used to effectively monitor populations, there is the potential for observational error (Dunham *et al*., 2001; Muhlfeld *et al.,* 2006; Murdoch *et al*., 2018; Baldock *et al*., 2023). In some stream reaches, redds have been counted for over 60 consecutive years (Thurow *et al*., 2019) and are frequently used to estimate fish abundance (Dauphin *et al*., 2010).

Martling *et al*. (2020) and Robidoux *et al*. (2022) enumerated and mapped redds in Spearfish Creek, within the City of Spearfish, South Dakota, USA. Iron Creek is a

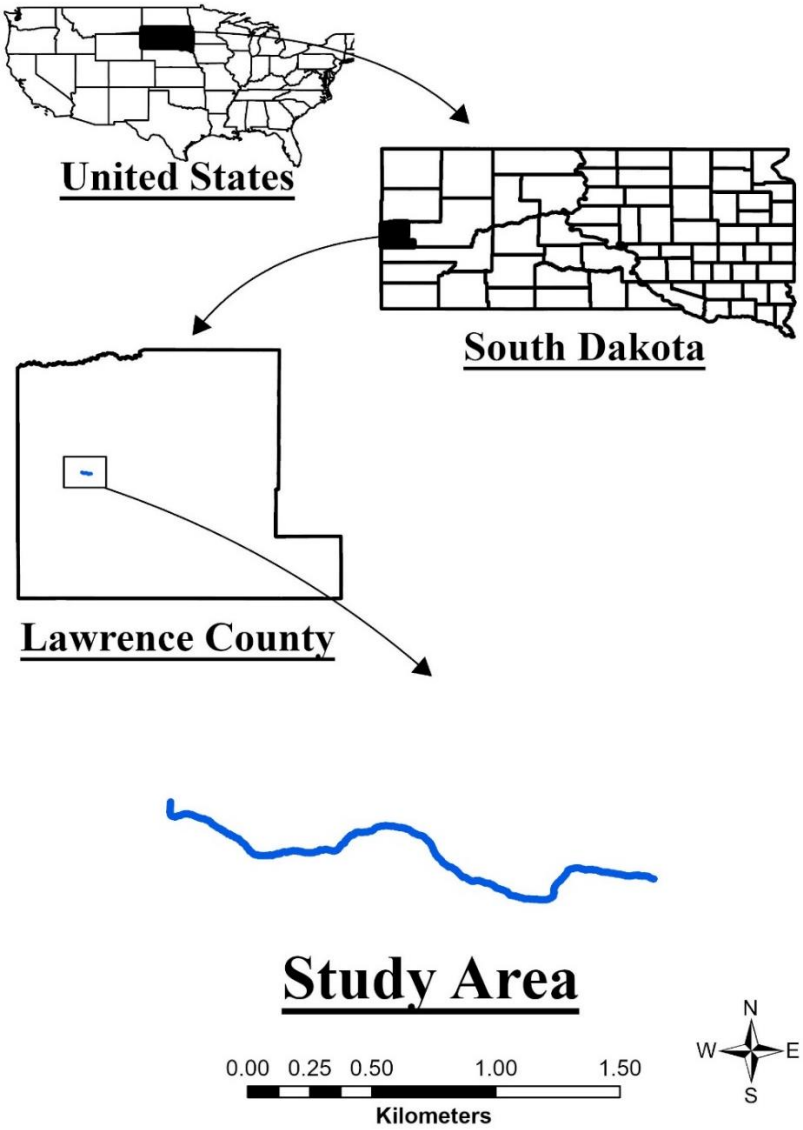

Figure 1. The study location where brown trout redds were observed within Iron Creek within Lawrence County within South Dakota within the USA.

tributary of Spearfish Creek, approximately 18 km upstream from Spearfish city limits (Hoogestraat, 2011). Fish populations in Iron Creek are infrequently sampled during the summer, and spawning has never been documented (SDGFP, 2020). Since 2014, approximately 97% of all of the fish sampled in Iron Creek have been brown trout (SDGFP, 2020).

The objective of this study was to document the presence and locations of brown trout redds in Iron Creek.

METHODS AND MATERIALS

Study area

Iron Creek is a tributary of Spearfish Creek in the northern Black Hills, Lawrence County, South Dakota, USA (Figure 1). Iron Creek flows from west to east perpendicular to Spearfish Creek (James, 2011). The study area started 1.8 km upstream from the confluence of Iron Creek with Spearfish Creek (44.3761492° N 103.9361559° W) and ended at the confluence (44.3733638° N 103.9186522° W). This section of Iron Creek cuts through a steep narrow canyon of Paleozoic and Cenozoic-aged rocks and igneous quartz latitic intrusive rocks underlies the creek (Hoogestraat, 2011). While sections of Iron Creek have no flow, downstream spring infiltration produces flows in this stretch of 0.028 m^3/s to 0.057 m^3/s (Hortness and Driscoll, 1998). Iron Creek is classified as an intermittent stream characterized by seasonal flows originating from ground-water and precipitation (Hortness and Driscoll, 1998).

Figure 2. Image of a brown trout on a typical redd in Iron Creek, Lawrence County, South Dakota, USA observed fall of 2023.

Redd identification and location

Redd sampling began on September 19, 2023. Data was collected approximately weekly by walking the stream and recording redd locations with a Global Position System unit (Geo 7X Trimble, Westminster, California, USA). Redds were documented each week even if they had been documented in prior observations. Redd identification followed the techniques described previously (Gallagher *et al*., 2007) and was loosely defined as the presence of a clear pit and overturned substrate that formed a mound and/or a clear tail (Figure 2). Final sampling occurred on October 27, 2023, when no new redds were observed and spawning ceased.

Environmental data collection

Water temperatures were collected each week. Ambient air temperatures and hours of daylight were acquired for each sampling date (Wunderground, 2023).

Table 1. The number and timing of brown trout redds observed during the fall of 2023 in a 1.8-km section of Iron Creek, Lawrence County, South Dakota, USA.

Date	Redds	
	New	Cumulative
September 19	9	9
September 23	19	28
October 03	16	44
October 10	16	60
October 17	7	67
October 27	0	67

RESULTS

A total of 67 redds were observed over the six-week spawning period (Table 1). Redds were first observed on September 19, with no new redds observed on October 27. Peak spawning activity was on September 23 with 19 redds being observed. Brown trout were the only fish

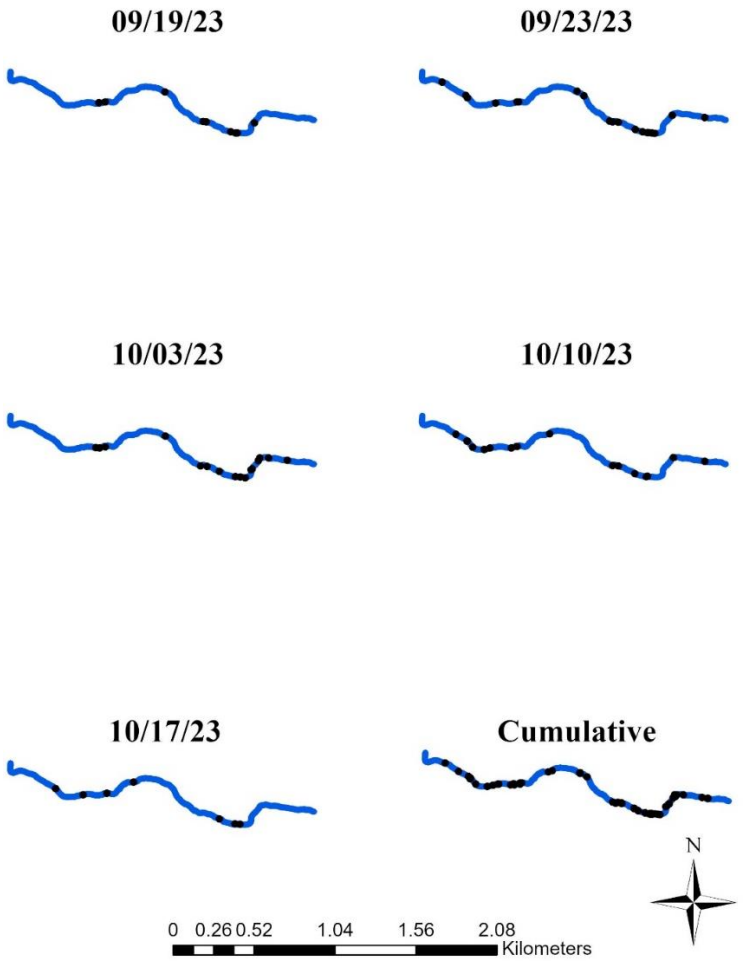

Figure 3. The location of brown trout redds, as indicated by black dots, during the fall of 2023 in a 1.8 km section of Iron Creek, Lawrence County, South Dakota, USA.

Table 2. Water temperature (°C), air temperature (°C), and hours of daylight during the period when brown trout redds were observed in Iron Creek, Lawrence County, South Dakota, USA.

Date	Water (°C)	Air (°C)	Daylight (hours)
September 19	9.0	19.6	12.4
September 23	9.3	12.1	12.2
October 3	6.0	14.3	11.6
October 10	6.3	11.4	11.3
October 17	7.0	14.8	11.0
October 27	3.0	-7.0	10.5

species visually observed during the study. During the fifth week of the study, redds started to deteriorate rapidly making it more difficult to observe redds previously recorded. Redd locations by week are shown in Figure 3. Maximum redd formation was observed at water temperatures of approximately 9.0°C in September (Table 2). Water temperatures dropped to 3.0°C on the last sampling date.

DISCUSSION

Redd construction in Iron Creek began three to four weeks earlier than reported for brown trout in other, albeit lower elevation, creeks in the northern Black Hills (Blaine *et al*., 2018; Martling et al., 2020; Robidoux *et al*., 2022). Robidoux *et al*. (2022) and Martling *et al*. (2020) reported brown trout initial redd construction downstream in

Spearfish Creek on October 13 and 15, respectively. Similarly, Blaine *et al*. (2018) first observed redds on October 17 in Crow Creek in the northern Black Hills. It is also possible that redd construction in Iron Creek could have occurred earlier than the first sampling date of September 19 because redds were already present on this date.

Just as was observed with the start of redd construction, the peak of redd construction in Iron Creek on September 23 was approximately six weeks earlier than the October 31 and November 3 dates reported for Spearfish Creek by Martling *et al*. (2020) and Robidoux *et al*. (2022), respectively. Maximum redd construction in Iron Creek was also approximately eight weeks earlier than that reported for brown trout in Crow Creek (Blaine *et al*., 2018). Spawning in Iron Creek ceased three-to-four weeks earlier than that reported for nearby streams as well (Blaine *et al*., 2018; Martling *et al*., 2020; Robidoux *et al*., 2022).

Although located less the 30 km from the current study, the Blaine *et al*. (2018), Martling *et al*. (2020), and Robidoux *et al*. (2022) redd surveys were all conducted in creeks at elevations approximately 500 meters lower than Iron Creek. The higher elevation of Iron Creek likely explains the difference in redd timing. In addition to altitude, the timing of spawning and redd construction timing can be influenced by latitude, substrate composition, photoperiod, and water temperatures (Webb and McLay, 1996; Makrov *et al*., 2011; Warren *et al*., 2012; Riedl and Peter, 2013).

Brown trout spawning in Iron Creek follows the previously-observed pattern of brown trout spawning earlier in the Black Hills of South Dakota than in their native range (Witzel and MacCrimmon, 1983; Wydowksi and Whitney, 2003; Alp *et al*., 2003). In Europe and Asia, brown trout spawning typically occurs during the end of November and early December (Rubin *et al*., 2005; Syrjänen *et al*., 2020).

The redd densities observed in Iron Creek were much lower than those reported previously for several other streams in the Black Hills. The density of approximately 6 redds/km observed in Iron Creek between September 19 and October 7 was considerably lower than 84 redds/km (Martling et al., 2020) or 91 redds/km (Robidoux *et al*., 2022) observed in Spearfish Creek. Redd densities of 106 redds/km and 43 redds/km were observed in Rapid and Box Elder Creek in the Black Hills, respectively (Ketelsen *et al*., 2017). In contrast, the redd density observed in Iron Creek was similar to the 5 redds/km reported by Blaine *et al.* (2018) for Crow Creek. Stream morphology, water velocities, and substrate size can affect redd densities (Riedl and Peter, 2013; Webb *et al*., 1996; Makrov *et al*., 2011). All of the other creeks in the Black Hills where redd surveys have been conducted are much larger and typically have higher in-stream flows than Iron Creek.

Redd superimposition occurs when a fish deposits eggs in an existing redd (Reiser and Wesche, 1977; Gallagher and Gallagher, 2005; Essington *et al*., 1998) and can occur between the same or different fish species (Togaki *et al*., 2023). Redd superimposition was not observed in Iron Creek. However, because of the duration of some of the redds and the limited observation period of one day per week, superimposition could have occurred. Both Martling *et al*. (2020) and Robidoux *et al*. (2022) observed superimposition in Spearfish Creek downstream from Iron Creek. Although redd density and superimposition may be positively related (McNeil, 1964; Dudley, 2019), Gortázar *et al*. (2012) observed superimposition even when densities were low. This suggests spawners may prefer pre-existing redds. Togaki *et al*. (2023) hypothesized that the headstreams and upper reaches of streams have a greater potential for superimposition due to the increased density of spawners per suitable habitat. However, observations in this study appear to indicate that this did not occur in Iron Creek.

Because this study was only for one spawning season, it may not be indicative of spawning activities during years with different precipitation patterns or different brown trout population dynamics. Also, because redds were present on the first day of this study, spawning may have started prior to the start of this study. However, using weekly ground based redd counts, as performed in this study, decreases bias compared to aerial and single pass peak redd counts (Murdoch *et al*., 2018). The results from 1.8 km section surveyed may also not be applicable to other sections of the Iron Creek. Lastly, the limited experience of the individual observing redds may have also influenced the results (Gallagher *et al*., 2007; Muhlfeld *et al*., 2006; Baldock *et al*., 2023). Dunham *et al*. (2001) found counting errors of omissions and false identification caused redd counts being between 28% and 254% compared to actual redd numbers. Muhlfeld *et al.* (2006) suggested observer errors can be reduced if annual redd counts are conducted by experienced observers. It is essential that observers receive sufficient training in redd location and marking to ensure all redds are recorded.

This study provides a baseline for redd numbers and locations in Iron Creek, thereby allowing potential subsequent counts to provide information on brown trout population dynamics (Meffe, 1986; Konkel and McIntyre, 1987; Pratt, 1992; Weaver, 1992; Rieman and McIntyre, 1996). Redd density data, when combined with fish marking or tagging, can be used to determine the relative size of spawning populations (Beard *et al*., 1991; Gosset *et al*., 2006; Gauthey *et al*., 2015). Future changes in redd numbers and locations may also indicate anthropogenic changes or provide for early detection of instream habitat degradation (Warren *et al*., 2012). In addition, the baseline information provided in this study also allows for the use of future redd counts to evaluate any subsequent stream restoration (Barlaup *et al*., 2008) or habitat improvement projects (Mundahl and Schnaser, 2023). Redd counts could be a simple and cost-effective way to examine stream changes by humans or animals. For example,

current Black Hills National Forest, which includes Iron Creek, management has a goal of increased beaver (*Castor* spp) populations (Bates *et al*., 2021). Beaver dam analogs have also been, and are currently being, constructed on streams in the Black Hills National Forest (Keene, 2024). Periodic redd counts could be used to evaluate potential changes in stream fish populations resulting from increased beaver activity or the presence of a new beaver dam analog (Kemp *et al*., 2012; Lokteff *et al*., 2013).

Conclusion

In conclusion, this is the first study documenting brown trout spawning and redd locations in Iron Creek, Lawrence County, South Dakota, USA. This study lays the foundation for future monitoring of brown trout spawning and reproduction in Iron Creek Lake, as well as assessing the potential influence of such spawning on mainstem Spearfish Creek brown trout populations. Lastly, the results of this survey will influence future stream habitat improvements or restoration efforts.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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