Stream temperatures and the elevational distribution of redband trout in southwestern Idaho

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STREAM TEMPERATURES AND THE ELEVATIONAL DISTRIBUTION OF REDBAND TROUT IN SOUTHWESTERN IDAHO

Bruce W. Zoellick

ABSTRACT.—During July to September 1994–1996, I examined water temperatures at the lower end of the elevational distribution of redband trout (Oncorhynchus mykiss gairdneri) in 4 streams in the Owyhee Mountains in southwestern Idaho. Maximum water temperatures in Castle, Shoofly, Little Jacks, and Big Jacks creeks during low flows during a drought in 1994 ranged from 26.7°C to 29.0°C. Water temperatures fluctuated 9.5–11°C during the 24-h period maximum temperatures were observed. Stream flows at the lower end of Big Jacks and Little Jacks creeks in 1994 were <0.003 m$^3$ s$^{-1}$ and subsided underground 50–130 m downstream of pools inhabited by trout. Trout were distributed to lower elevations where drainage basin area was larger in 2 of 3 yr ($P < 0.03$). Lower elevational limits of redband trout distribution in Big Jacks, Little Jacks, Castle, and Shoofly creeks were 920, 934, 972, and 1090 m above sea level, respectively, in 1994. With higher stream flows in 1995–96, trout were found 3–6 km farther downstream in Castle, Big Jacks, and Shoofly creeks at elevations of 860, 991, and 998 m, respectively, and tolerated maximum temperatures of 25.5–29.0°C. Trout were not distributed farther down Little Jacks Creek because of poor channel conditions. Maximum daily water temperatures of 29.0°C may have limited trout distribution in Big Jacks Creek, as flows and suitable channel conditions (but higher temperatures) continued >5 km downstream of the lowest pool inhabited by trout in 1995–96.

Key words: redband trout, Oncorhynchus mykiss gairdneri, desert streams, water temperature, elevation, southwest Idaho, distribution.

Redband trout (Oncorhynchus mykiss gairdneri) in desert basins of western North America are thought to have evolved adaptations to live in harsh environments characterized by extremes in water temperature and flow (Behnke 1992). However, little is known about the environmental extremes redband trout tolerate in desert streams. Redband trout were observed feeding at water temperatures of 28.3°C in Chino Creek, a tributary to the Owyhee River in northern Nevada (Behnke 1992). In contrast, rainbow trout (Oncorhynchus mykiss icerius) are typically stressed by water temperatures >22°C (Behnke 1992). Redband trout inhabit desert streams in the Snake River basin in southwestern Idaho. Many of these streams become intermittent at lower elevations, and flows fluctuate greatly year to year depending on winter snowpacks.

Knowledge of the maximum temperatures redband trout tolerate would assist fisheries managers in determining potential distribution of redband trout in streams in the Snake River basin in southwestern Idaho. With watershed restoration, redband trout may be able to inhabit more streams or extend their downstream distribution in occupied streams. Studies of the elevational distribution of redband trout in relation to water temperatures and stream flows are needed to determine if or how these parameters limit distribution. Stream flows and consequently trout distribution may also be influenced by watershed characteristics such as drainage basin area and elevation of source springs.

The objectives of this study were (1) to determine the lower elevational distribution of redband trout in 4 drainages typical of streams on the northeastern slopes of the Owyhee Mountains that are tributaries to the Snake River, (2) to determine the maximum water temperatures trout were tolerating at the lower end of their distribution in these streams, and (3) to examine whether the size of the drainage basin affected the lower elevation to which trout were distributed in a stream. Additionally, I compared the distribution of redband trout and maximum water temperatures at the lower limit of their distribution between years of low stream flows in 1994 and average flow conditions in 1995 and 1996.
STUDY AREA

I conducted the study on Big Jacks, Little Jacks, Shoofly, and Castle creeks, which flow northward from the Owyhee Mountains to the Snake River, near the town of Bruneau in southwestern Idaho (Fig. 1). Redband trout occupy the upper reaches of these streams, all of which are usually intermittent at the lower end of the drainages and are moderately confined by side valley slopes with gradients of 1.5–4% (B channel types, Rosgen 1994; Table 1). Big Jacks and Little Jacks creeks and the upper portion of Shoofly Creek flow through 30- to 210-m-deep canyons with narrow floodplains and stream substrates dominated by cobble-sized rocks. Stream substrates in Castle Creek are primarily gravels and finer-sized particles as are the lower portions of Shoofly Creek. Streamside vegetation is dominated by willows (Salix lasiolepis, S. lasiandra, S. exigua, and S. lutea). In areas of historical heavy livestock grazing and where flows become intermittent, streamside vegetation is composed of mesic forbs such as goldenrod (Solidago sp.) and grasses.

Little Jacks Creek is a tributary to Big Jacks Creek, but it rarely flows aboveground past a highly degraded, braided stream channel (D channel type; Rosgen 1994) starting 6.9 km upstream of its confluence with Big Jacks Creek. Big Jacks Creek flows to stream km 20.3 (site of a U.S. Geological Survey gaging station) 60% of the time (primarily during the...
TABLE 1. Characteristics of 4 drainages in which redband trout were studied in southwestern Idaho, 1994–1996.

<table>
<thead>
<tr>
<th>Stream</th>
<th>Stream order</th>
<th>Drainage basin area (km²)</th>
<th>Geologic parent material</th>
<th>Elevation (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Big Jacks</td>
<td>3</td>
<td>633</td>
<td>rhyolite lava</td>
<td>1670</td>
</tr>
<tr>
<td>Little Jacks</td>
<td>2</td>
<td>290</td>
<td>rhyolite lava</td>
<td>1673</td>
</tr>
<tr>
<td>Shoofly</td>
<td>2</td>
<td>55</td>
<td>rhyolite lava</td>
<td>1639</td>
</tr>
<tr>
<td>Castle</td>
<td>3</td>
<td>790</td>
<td>granite/lava</td>
<td>1774</td>
</tr>
</tbody>
</table>

*Confluence of drainage with Snake River; Big Jacks and Little Jacks join to form Jacks Creek

months of January through June; Kjelstrom et al. 1995) and occasionally flows aboveground to the Snake River in early spring and during storm events. In 1992, Big Jacks Creek did not flow down to the gage site. Shoofly Creek also rarely flows to the Snake River. Flows in Castle, Big Jacks, and Shoofly creeks are diverted for irrigation at the lower end of the drainages where the streams enter broader valleys with associated low-gradient, unconfined channels (C channel type; Rosgen 1994).

METHODS

I visually observed redband trout at the lower end of each drainage in late June 1994–1996 to determine their approximate elevational distribution. I then used a Smith-Root Model 12-A backpack electrofisher to collect fish to determine the lower limit of distribution of redband trout in each stream. Pools that provided relatively high quality habitat (depths of 0.2–0.3 m with some cover) for redband trout were electrofished to determine if trout were present. I sampled downstream where flows subsided underground or to 200 m downstream of the last pool where trout were encountered by electrofishing. Exceptions were Shoofly Creek, which was sampled only as far downstream as a private land boundary in 1994, and similarly Castle Creek in 1996. Trout may have been distributed farther down Castle Creek in 1996 and probably were distributed farther down Shoofly Creek in 1994.

I visually checked the presence of trout at the lower end of their distribution in Little Jacks Creek every 2 wk during the summer in 1994–95 and also on this schedule in Big Jacks Creek in 1994. Little Jacks Creek was observed monthly in 1996. All sites were rechecked for trout in September by electrofishing.

Trout density was estimated in July by electrofishing representative sites within 3 km of the lower limit of trout distribution. Two or 3 electrofishing passes were made and population sizes estimated for 60- to 80-km-long segments using the Zippin capture-removal model (Zippin 1958).

I placed a thermograph in or near the farthest downstream pool where redband trout were encountered. Pools were shallow enough that flows thoroughly mixed, resulting in no thermal stratification as determined from measurements with a hand-held thermometer. Thermographs were placed in the streams in late June 1994–1996 and monitored water temperatures through September. Water temperatures were recorded every 2 h, or the daily maximum, minimum, and average temperatures were recorded. Temperature readings of thermographs were checked against hand-held thermometers when they were set in the stream and again when they were retrieved.

In 1995 maximum-registering thermometers were placed at the lower end of the distribution of trout in Little and Big Jacks creeks. Thermographs were placed in these creeks in 1995 prior to electrofishing, and the thermographs were 50–2700 m upstream of the lower end of the trout distributions. Therefore, thermometers were used in addition to thermographs to measure maximum temperatures.

I measured stream flows with a pygmy flow meter using standard discharge measurement methods (U.S. Geological Survey 1977). Discharges were measured in late summer (August–September) to determine base flows. I also used U.S. Geological Survey (USGS) gage data from a station at stream km 20.3 of Big Jacks Creek to determine stream flows.

Elevations at the lower end of the trout distribution on each drainage were calculated from USGS 7.5-minute topographic maps.
Using least-squares linear regression, I examined the relationship between the lower elevation of trout distribution and drainage basin size. The relationship between lower elevation of occurrence and drainage basin area was examined for each year.

RESULTS

I electrofished 2.3, 2.9, and 1.4 km of stream near the lower limit of trout distribution in the 4 streams in 1994, 1995, and 1996, respectively. Trout were continuously distributed; pools providing some security or resting cover were almost always occupied by 1 or more trout. Densities were low, averaging 2.2 trout/100 m² of stream (range = 0.2 to 7 trout/100 m², n = 4) within 3 km of the lower limit of trout distribution in 3 streams in which I examined density (Big Jacks, Castle, and Shoofly creeks). Adult trout ranged from 146 mm to 231 mm in length; young-of-year trout were 50-75 mm long. All fish appeared healthy.

Trout were always present in September at the sites of their lower limit of distribution determined from electrofishing in late June and early July. Trout were also always observed at the lower limit of their distribution when monitored biweekly or monthly during July to September.

ELEVATIONAL DISTRIBUTION.—Elevations at the lower limit of redband trout distribution in 1994 were 920-1090 m (Table 2). Flows in Big Jacks Creek continued at <0.003 m³ s⁻¹ just 50 m farther downstream of the last pool inhabited by trout in 1994. Similarly, stream flows in Little Jacks Creek of <0.003 m³ s⁻¹ continued only 130 m into a highly degraded, braided stream channel (D channel type) below the last pool inhabited by trout. However, stream flows of about 0.01 m³ s⁻¹ continued another 4.3 km below the last pool inhabited by redband trout in Castle Creek. Trout were present in Shoofly Creek to at least an elevation of 1113 m, at the lower limit of public land on the stream. Flows in Shoofly Creek of 0.005 m³ s⁻¹ continued about 2 km downstream onto private land, and trout were likely present a portion of this distance to an elevation of about 1090 m.

Redband trout were distributed to lower elevations in 1995-96 when stream flows were about 5 times greater than in 1994 (Table 2, Fig. 1). Big Jacks Creek flowed 8.3 km farther downstream in 1995 than in 1994, with trout recolonizing about 1/3 (2.7 km) of this distance. Trout in Castle Creek were distributed 4.9 and 5.8 km farther downstream in 1995 and 1996, respectively, than in 1994. In 1996 trout in Castle Creek were distributed at least to a diversion at a private land boundary and may have occurred downstream of the diversion. Similarly, in 1995-96 trout in Shoofly Creek were distributed 2-3 km farther downstream than in 1994, to an elevation of 998 m where stream flows were diverted into an irrigation canal. Flows in Big Jacks Creek were greater in 1996, but the lower limit of trout distribution was unchanged from 1995 (Table 2).

Trout distribution in Little Jacks Creek in 1995-96 differed only slightly from 1994, with their distribution ending at the upper end of a highly degraded, braided stream channel. Even with greater stream flows in 1995 (Table 2), surface flows continued just 0.8 km into the degraded segment and did not provide pool habitat more than 200 m into the segment. Surface flows in 1996 continued about 2.5 km

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<tr>
<td>Castle Creek</td>
<td>972</td>
<td>0.01</td>
<td>871</td>
</tr>
<tr>
<td>Little Jacks Creek</td>
<td>934</td>
<td>0.03</td>
<td>934</td>
</tr>
<tr>
<td>Big Jacks Creek</td>
<td>920</td>
<td>0.06</td>
<td>981</td>
</tr>
<tr>
<td>Shoofly Creek</td>
<td>1090</td>
<td>0.005</td>
<td>998</td>
</tr>
</tbody>
</table>

*Streams gaged late summer (August-September) to estimate base flow
b Measured at U.S. Geological Survey gage station 8.3 km downstream of fish distribution limit in 1994

No data
into the degraded channel and trout were distributed 150 m farther downstream.

The elevation to which trout were distributed was dependent on the area of the drainage basin of the stream in 1995 ($R^2 = 0.95$, df = 1.2; $P = 0.03$) and 1996 ($R^2 = 0.96$, df = 1.2; $P = 0.02$), but not in 1994 ($R^2 = 0.41$, df = 1.2; $P = 0.36$). Generally, the larger drainage basins provided flows that allowed occupancy of lower elevations. However, Castle Creek had the largest basin area (Table 1), but in 1994 trout extended their distribution to lower elevations in 2 of 3 other drainages.

Stream temperatures.—Daily maximum temperatures ranged from 17.9°C to 29.0°C during 1994 (Fig. 2a). I may have missed sampling the maximum temperature in Castle Creek; due to equipment failure the thermograph did not operate until 5 August 1994. The median daily maximum temperature was 24.5°C, and the 95th percentile of daily maximum temperatures for 3 streams monitored from late June through August was 28.0°C. Maximum water temperatures for individual streams ranged from 26.7°C to 29.0°C (Table 3). Because trout in Shoofly Creek in 1994 were likely distributed downstream onto private land, they probably tolerated maximum temperatures >26.7°C, which were the maximum temperatures measured at the lower boundary of public land. Water temperatures fluctuated 9.5–11°C during the 24-h period maximum temperatures were observed in 1994. Average daily temperatures ranged from 21.0°C to 23.0°C (Table 3). Temperatures remained within 3°C of the maximum for 4–9 h (Fig. 3). For daily maximums ≥27°C, temperatures were above 26°C for 2.9–4.4 h.

In 1995 daily maximum temperatures ranged from 18.0°C to 28.0°C (Fig. 2b). I could not relocate the thermograph in Big Jacks Creek; the maximum temperature was measured with a maximum-registering thermometer. The median daily maximum temperature was

Fig. 2. Frequency distribution of daily maximum water temperatures at lower distributional limits of redband trout in 4 southwestern Idaho streams: (a) 29 June–31 August 1994, (b) 29 June–2 August 1995, (c) 29 June–31 August 1996. Number of days sampled is shown above the bar for each stream. Shoofly Creek was monitored at the same site in 1994–95 (5.7 km upstream of lower distributional limit in 1995). Big Jacks Creek was not monitored in 1995 due to equipment failure.
Table 3. Water temperatures during the 24-h period maximum temperatures were observed at the lower distributional limits of redband trout in 4 southwestern Idaho streams, 1994–1996.

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</thead>
<tbody>
<tr>
<td></td>
<td>Max</td>
<td>Min</td>
<td>Avg</td>
<td>Max</td>
<td>Min</td>
<td>Avg</td>
<td>Max</td>
<td>Min</td>
<td>Avg</td>
</tr>
<tr>
<td>Castle Creek</td>
<td>27.0</td>
<td>17.0</td>
<td>22.5</td>
<td>26.5</td>
<td>18.5</td>
<td>21.0</td>
<td>27.0</td>
<td>19.0</td>
<td>22.5</td>
</tr>
<tr>
<td>Little Jacks Creek</td>
<td>29.0</td>
<td>17.9</td>
<td>23.0</td>
<td>25.0</td>
<td>18.5</td>
<td>21.0</td>
<td>26.0</td>
<td>19.2</td>
<td>22.1</td>
</tr>
<tr>
<td>Big Jacks Creek</td>
<td>27.9</td>
<td>18.5</td>
<td>21.3</td>
<td>28.0</td>
<td>29.0</td>
<td>19.0</td>
<td>23.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoofly Creek</td>
<td>26.7</td>
<td>15.5</td>
<td>21.0</td>
<td>25.5</td>
<td>19.0</td>
<td>20.1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

22.5°C, and the 95th percentile of daily maximum temperatures for the 3 streams monitored with thermographs was 26.0°C. Maximum water temperatures for individual streams ranged from 22.5°C to 28.0°C (Table 3). Water temperatures fluctuated 7–8°C during the 24-h period maximum temperatures were observed in 1995. Little Jacks and Shoofly creeks temperatures were monitored at the same sites in 1994–95. With greater stream flows in 1995 (Table 1), maximum water temperatures were about 4°C lower for the 2 streams (Fig. 2, Table 2). Because of poor stream channel conditions (wide and shallow with no pools), trout could not take advantage of the higher stream flows and move farther downstream in Little Jacks Creek in 1995–96.

Daily maximum temperatures in 1996 ranged from 18.5°C to 29.0°C between 29 June and 31 August (Fig. 2c). The median daily maximum temperature was 24.0°C, and the 95th percentile of daily maximum temperatures for all 4 streams was 28.0°C. Maximum water temperatures for individual streams ranged from 25.5°C to 29.0°C (Table 3). Water temperatures fluctuated 7–10°C during the 24-h period maximum temperatures were observed in 1996. The maximum temperature of 25.5°C observed in Shoofly Creek in 1996 was more representative of the maximum water temperatures experienced by trout at the lower end of their distribution. In 1995 temperatures were monitored in Shoofly Creek at the public land boundary 5.7 km upstream from the lower end of the distribution of trout. Maximum water temperatures observed at the lower distribution of trout in Big Jacks and Castle creeks were similar for all 3 yr (Table 3). Channel conditions were adequate in these 2 drainages to allow trout to move farther downstream during increased flows in 1995–96.

Discussion

Pools at the lower ends of the 4 streams were shallow and did not thermally stratify. The continuous distribution of trout at the lower end of the drainages indicated thermal refugia from seeps were not present. Additionally, in 1994 I observed redband trout actively foraging at a temperature of 26.2°C in Big Jacks Creek 1 day before the stream reached its highest daily maximum temperature of 27.9°C. These observations indicate that trout were tolerating the temperatures measured at the lower limits of their distributions and not moving in and out of thermal refugia.

This is the first study to systematically document that redband trout in streams other than those in the Owyhee River basin tolerate extreme temperature fluctuations. Maximum temperatures tolerated by redband trout in this study (29°C) were slightly higher than Behnke (1992) observed for redband trout in Chino Creek in Nevada (28.3°C). Maximum water temperatures from this study were measured in streams with flowing water in contrast to Behnke’s (1992) observation made at a pool remaining after stream flows stopped. Behnke (1992) states that tolerance of high temperatures shown by redband trout populations evolved through natural selection in streams of hot, arid regions over thousands of years. Redband trout inhabiting tributary streams to the Snake River in southwestern Idaho also demonstrated tolerance of low dissolved oxygen concentrations (1.6–4.0 mg L⁻¹) during periods of low stream flows (Vinson and Levesque 1994).

Rainbow and cutthroat trout (Oncorhynchus clarki) typically experience stress when water temperatures rise above 22°C. With gradual increases in temperature (1–2°C per day), loss
of equilibrium and death occur at about 28–29°C (Lee and Rinne 1980, Behnke 1992). Estimates of upper lethal temperatures for trout differ depending on the laboratory method used (Behnke 1992). Studies using long-duration exposures have estimated the upper lethal temperature for rainbow trout to be 26°C (Bidgood and Berst 1969, Charlon et al. 1970, Hokanson et al. 1977, Jobling 1981). Redband trout in the streams examined in this study tolerated greater daily fluctuations in temperature than used by Lee and Rinne (1980) to determine critical thermal maximum temperatures of 5 trout species. Rainbow, Apache (Oncorhynchus gilae apache), Gila (Oncorhynchus gilae gilae), and brown trout (Salmo trutta) tolerated fluctuations from only 21°C to 27°C when daily temperatures fluctuated 6°C over a 24-h period (Lee and Rinne 1980).

Redband trout in this study tolerated temperatures above 26°C for durations of up to 4.4 h. When the upper incipient lethal temperature of rainbow trout (25.6°C) was exceeded daily for 3 h under a fluctuating temperature regime (±4°C around a daily mean of 22°C), the daily mortality rate was 42.8% (Hokanson et al. 1977). Median resistance times from another laboratory study (Kaya 1978) indicated that 3 rainbow trout stocks acclimated to 17°C would tolerate a constant temperature of 26°C for 8.5–15.7 h with a 50% mortality rate and would tolerate 29°C for only 0.4 h.

The temperature range over which redband trout continue to feed and gain weight (functional feeding temperatures) may be a more important adaptation than an increase in the upper lethal temperature that is tolerated (Behnke 1992). Redband trout from a desert basin (Catlow Valley) in eastern Oregon had optimum growth efficiencies at temperatures >19°C, while growth rates of other Oncorhynchus mykiss stocks decrease with increasing temperatures above 16°C (Behnke 1992). Higher functional feeding temperatures would allow redband trout to maintain a competitive advantage over other fish species such as redside shiners (Richardsonius balteatus), which are common in warmer, low-elevation segments of streams in the Snake River basin.

During years of greater stream flows, redband trout were distributed farther downstream than during drought years, reoccupying 3- to 6-km sections of Castle, Shoofly, and Big Jacks creeks that had been totally dewatered 1 or 2 yr previously. However, the reoccupation of newly available sections of stream complicates determinations of whether or not maximum water temperatures limit distribution of redband trout. During years of greater snowpacks when surface flows continue farther down a drainage, trout may not be present because they have not yet recolonized the newly watered segment. In general, trout were distributed downstream to reaches with maximum temperatures of 27.0–29.0°C, provided channel conditions allowed trout to move downstream.

Poor channel conditions and subsiding of surface flows into streambed gravel limited trout distribution in Big Jacks Creek in 1994 and Little Jacks Creek during 1994–1996. Stream flows at the lower end of Big Jacks and Little Jacks creeks were <0.003 m³ s⁻¹; redband trout were essentially distributed the length of surface flows in these 2 streams in 1994. Similarly, trout in Shoofly Creek in 1995–96 were distributed down to a stream diversion, which was the lower limit of available habitat. However, redband trout were not
distributed the length of surface flows in Castle Creek in 1994–1996. In 1994, Castle Creek flowed at about 0.016 m³ s⁻¹ for another 4.3 km below the last pool inhabited by trout. Water temperatures may have been a factor influencing the lower limit of the distribution of redband trout in Castle Creek. Maximum water temperatures of 29°C may have also limited redband trout distribution in Big Jacks Creek in 1996, as surface flows continued >5.6 km downstream of the lower distribution of trout.

During years of greater flows and consequently lower stream temperatures, trout in Little Jacks Creek were not able to move farther downstream because of poor watershed conditions. A highly braided D stream channel stopped trout recolonization of the lower drainage, probably because the shallow riffle habitat did not provide resting or hiding cover and also was quickly heated by solar radiation. This indicates that stream restoration on the lower ends of drainages in southwestern Idaho has the potential to increase the range and numbers of redband trout populations.

Trout populations may also be reconnected by improving habitat conditions at the lower end of drainages so that fish can move between some drainages, such as Big and Little Jacks creeks. Given current land uses and irrigation diversions, trout populations probably cannot be interconnected via the Snake River. In 1995–96, during typical stream flows for Big and Little Jacks and Castle creeks, redband trout were distributed only down to 860–900 m elevation. The confluence of these streams with the Snake River was at about 750 m elevation. The lower elevation of trout distribution was not significantly related to drainage basin area during low flows in 1994. However, during normal flows in 1995–96, trout were distributed to lower elevations as drainage basin area increased, probably because larger basins provided greater stream flows and lower stream temperatures to lower elevations.

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Literature Cited


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