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Habitat utilization and diel behavior of juvenile bull trout (*Salvelinus confluentus*) at the onset of winter

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Abstract – Underwater observations were used to describe habitat use and diel behavior of juvenile bull trout (*Salvelinus confluentus*) at the onset of winter (0.8°C) in a second-order central Idaho stream. All fish observed during daytime counts were concealed beneath "home stones" (mean dimensions 32.3 by 21.9 cm) in primarily pool and run habitats. Focal point depths and velocities averaged 57.2 cm and 4.7 cm/s (home stone removed). Fish maintained stations over substrate with low percentages of fine (<2 mm, mean=5.2%) sediment. Concealed bull trout were not evenly distributed across the stream channel. Significantly more home stones were distributed near the midline of the channel, compared to the channel margins. Fish size was positively correlated with home stone size. At night, bull trout exhibited a diel behavioral shift, some fish moved out of daytime concealment cover into the water column. At night, bull trout were observed feeding and resting, primarily in pool and run habitats. During both day and night, bull trout used riffles significantly less frequently than those habitats were available.

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Key words: habitat utilization; diel behavior; bull trout

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Un resumen en español se incluye detrás del texto principal de este artículo.

Introduction

Overwinter ecology of stream-dwelling salmonids is perhaps the least understood aspect of their life history, and the need for winter investigations has long been recognized (Hubbs & Trautman 1935). Many species of juvenile salmonids occupy different habitats in winter than in summer (Hartman 1965; Everest 1969; Bustard & Narver 1975; Rimmer, Paim & Saunders 1983). At the onset of winter, stream-dwelling salmonids in the Intermountain West typically adopt two overwintering strategies, migration and concealment. As water temperatures decline below 10°C, fish may migrate from summer habitat into other portions of watersheds (Bjornn 1971). Distances fish move may be influenced by the proximity of suitable overwintering habitat; some fish migrate more than 100 km (Bjornn & Mallet 1964). After locating suitable overwinter habitat, juvenile salmonids typically select areas of low water velocity and enter concealment cover (Edmundson, Everest & Chapman 1968; Hillman, Griffith & Platts 1987; Cunjak 1988).

Despite increased investigation of overwinter habitat during the past decade (McMahon & Hartman 1989), knowledge of the winter behavior and ecology of important native salmonids is incomplete. In one of the few winter studies of bull trout (*Salvelinus confluentus*), Jakober (1995) observed a diel shift in behavior and cover utilization as water temperatures declined. Other researchers have observed bull trout concealed during winter days and resting on the substrate during winter nights (Bonneau 1994; Goetz 1994).

Bull trout are the only char native to the Intermountain West. Some local populations are extinct, and many populations have declined throughout the range (Rieman & McIntyre (1995). Concern for the persistence of bull trout culminated in petitions for review of the species status, and in June 1995, the U.S. Fish and Wildlife Service determined that listing under the Endangered Species Act was warranted but precluded. Data are necessary to describe the winter ecology and critical habitats used by bull trout. This article describes the characteristics of overwinter habitat used by juvenile bull trout and their diel behavior in a second-order stream.

Study area

Bull trout were observed in Profile Creek, a tributary to the East Fork of the South Fork Salmon River near Yellowpine, Idaho. Profile Creek flows through the central Idaho Batholith, an area of granitic bedrock characterized by steep slopes and highly erodible soils (Megahan, Platts & Kulesza 1980). Peak stream discharges are caused by snowmelt, typically in May or June. August 1991 discharge was 0.71 m^3/s. Base flows occur from September through January. Most annual precipitation falls as snow and may exceed 1.5 m. Freezing temperatures can occur every month. Winter air temperatures occasionally drop below −5°C.

Profile Creek supports resident and fluvial bull trout. Mature fluvial fish migrate from lower reaches of the South Fork Salmon and main Salmon rivers to spawn in Profile Creek. Other native fish include steelhead (*Oncorhynchus mykiss*), west slope cutthroat trout (*O. clarki lewisi*), mountain whitefish (*Prosopium williamsoni*), dace (*Rhinichthys* sp.), and sculpin (*Cottus* sp.).

I selected two study reaches (A, B) in the lower 5 km of Profile Creek. Reach A was 88 m long with an average width of 4.7 m; Reach B was 174 m long with a mean width of 5 m. I estimated habitat availability by classifying consecutive habitat types as pool, riffle, run, or pocket-water (Bisson et al. 1982). Reach A contained 3 pools and 2 runs. Reach B contained 14 pools, 6 riffles, 2 runs, and 2 pocket-water habitats. Surface ice was present along stream margins but did not span the channel; about 10% of the surface area of each habitat unit was ice covered. Anchor ice was uncommon and found primarily in riffles.

Material and methods

Before counting fish, I installed a continuously recording thermograph to measure hourly water temperatures. Using a drysuit, mask, snorkel and recording sleeve, I made day and night underwater surveys in each reach on 19–20 November 1991. Dives began at the downstream end of the lowest habitat in each reach. I proceeded slowly upstream through each habitat searching for fish in the water column (Thurow 1994). I searched all areas of the channel above the substrate, including beneath woody debris, undercut banks, or ice. Daytime surveys were made between 1000 and 1600 h. When no fish were visible, I swam back to the start of the habitat and zigzagged upstream while randomly selecting substrate and overturning it in search of fish. I applied a similar sampling effort in each habitat and overturned more than 100 stones. If no fish were encountered beneath the randomly selected substrate, I did not record any information and moved upstream to another location.

When I encountered a fish beneath the substrate, I marked its focal point with a weight and flag (Fausch & White 1981). I estimated fish size by approaching fish, aligning their snout and tail with adjacent objects and measuring the distance with a rule (Cunjak & Power 1986a). Bull trout were classified into 50-mm length groups, excluding age-0 fish. Griffith (1981) reported that trained underwater observers were able to estimate fish size within 25 mm of the true length in most trials. An assistant on shore followed, called out habitat boundaries, and recorded data. The habitat type and the percentage of the habitat covered by surface ice were recorded. Fish behavior was recorded as resting (maintaining a position on or above the substrate), hidden (beneath the substrate), or active (moving through the water column). If I disturbed a fish, I did not search the area where it reentered the substrate. Fish that darted from cover before I was able to determine species, focal point, or size were not included.

I followed procedures outlined by Cunjak (1988) to describe microhabitat conditions. I labeled the substrate under which the fish lay as the "home stone" (Rimmer, Paim & Saunders 1984). Using a wading rod and Marsh-McBirney current meter, I measured water depth to the surface of the home stone, focal point depth below the substrate surface, and focal point velocity. Focal point velocities were measured after the home stone was removed. Water temperatures were measured with a hand-held thermometer at the focal point and 4 cm below the water surface. I measured home stone dimensions, the distance from the home stone to the nearest shore, and the stream width perpendicular to the fish's location. I used a grid described by Overton, Chandler & Pisano (1994) to measure the percent of the substrate less than 2 mm at the fish's location.

I evaluated the association of each fish to cover above the substrate. Cover was defined as surface turbulence, woody debris, boulders, riparian canopy within 1 m of the water surface, undercut banks, or ice (Cunjak & Power 1986a). A fish was considered under cover if one of these components was directly overhead.

I made night counts after day counts using the same procedures between 2200 and 0200 h. A hand-held halogen light was used to detect fish. When a fish was encountered, its species, size, and behavior were recorded. At night, fish remained oriented to the substrate and I used the same technique to estimate fish size. I did not measure night microhabitat characteristics and did not attempt to locate fish hiding beneath the substrate.

I plotted the distributions of water depths, velocities, temperatures, and home stone sizes used by fish during daytime. Linear regression analysis was used to evaluate the relationship between fish size and depth, velocity, and substrate. The daytime distribution of fish in the channel was evaluated by dividing the channel into thirds. The areas from each shoreline to 33% of the width were defined as nearshore. The remaining portion of the channel was labeled mid-channel. I used chi-square analysis (Zar 1974) to test for differences between observed and expected use of the channel.

To evaluate diel habitat, I compared total numbers and sizes of fish observed by habitat type by day and night. I calculated and compared length-frequency distributions of bull trout observed during day and night using a Kolmogorov-Smirnov two-sample test (Steel & Torrie 1980). Habitat selection during day and night was evaluated by comparing the availability of different habitats with the frequency they were used by fish. I used chi-square analysis to test for differences between observed and expected habitat use.

Result

Seventeen juvenile bull trout were observed during the day and all were concealed beneath substrate. No fish were visible in the water column. Water temperatures ranged from 0.8 to 1.4°C. I measured microhabitat conditions for 15 age-1 and older fish. Fish ranged from 50 to 250 mm long; 13.3% were less than 100 mm, 53.3% were 100–149 mm, 26.7% were 150–199 mm, and 6.7% exceeded 200 mm (Table 1).

No more than one fish was observed beneath a single home stone. When uncovered, bull trout typically remained motionless for 1 to 3 seconds, allowing me to observe the focal point and estimate fish size. All fish subsequently darted up into the water column, swam away, and dove beneath another stone. Bull trout used habitats containing deep water, large substrate with interstices, and slow water velocities. Water depths over home stones averaged 42.6 cm. Home stone dimensions averaged 32.3 cm by 21.9 cm by 12.6 cm high (Table 1). Focal point depths averaged 14.6 cm below the substrate surface at velocities averaging 4.7 cm/s (home stone removed). Bull trout lay hidden about 57.2 cm below the water surface. Fish rested beneath the home stone on gravel and larger substrate with few fines; 5.2% of the grid intersected material <2 mm.

The type of habitat influenced the likelihood of locating concealed bull trout. Most fish were beneath home stones in pools or runs. Ten fish (67%) were in pools, three (20%) in runs and two in pocket-water. Bull trout were concealed in pools and pocket-water proportional to the availability of those habitats (Fig. 1). Bull trout were in runs significantly ($P<0.05$) more frequently and riffles significantly ($P<0.05$) less frequently than those habitats were available (Fig. 1).

Home stones provided concealment cover and I found no evidence that home stones were associated with the other cover types I assessed. I did not observe any home stones that were directly beneath surface turbulence, woody debris, riparian canopy, or ice.

Fish size and home stone surface area were correlated ($P<0.1$). Larger trout used home stones with larger areas (Table 1). Fish size explained less than 18% of the variability ($r=0.42$) in home stone size, however. No significant correlations were found between fish size and water depth or water velocity ($P>0.1$).

Table 1. Characteristics of the winter microhabitat of juvenile bull trout, by length group, Profile Creek, Idaho. Means±standard errors are shown. Ranges are in parentheses.

Length group (cm)	Sample size	Water depth to substrate (cm)	Focal point depth below substrate (cm)	Focal point velocity (cm/s)	Home stone dimensions: Length (cm)	Width (cm)	Height (cm)	Area (cm^2)	Percent fines <2 mm (grid intercepts)
5–10	2	39±4.2 (36–42)	26.5±7.8 (21–32)	3.5±2.1 (2–5)	37±1.4 (36–38)	21±2.8 (19–23)	18.5±6.4 (14–23)	779±134 (684–874)	7.1±1.4 (6.1–8.2)
10–15	8	44.4±14.6 (25–71)	11.4±2.7 (5–13)	5.3±3.8 (2–14)	27.9±5.2 (20–37)	19.8±7 (12–35)	11.4±3.7 (7–18)	578±322 (276–1295)	5.6±5.2 (0–14.3)
15–20	4	41.8±14.0 (21–50)	13.8±3.9 (8–16)	2.2±1.5 (1–4)	35.8±8.6 (29–47)	24.2±5.6 (19–32)	11.2±5.6 (5–16)	901±430 (551–1504)	4.6±3.5 (0–8.2)
20–25	1	39	20	2	44	31	16	1364	0
Pooled	15	42.6±12.4 (21–71)	14.6±6.3 (5–32)	4.7±4.1 (1–14)	32.3±7.6 (20–47)	21.9±6.5 (12–35)	12.6±4.8 (5–23)	743±379 (276–1504)	5.2±4.3 (0–14.3)

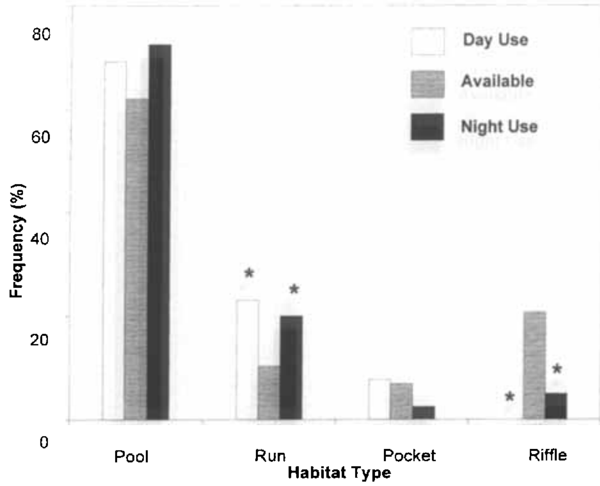

Fig. 1. Frequency of habitat types used by juvenile bull trout during the day and night compared to the frequency of available habitat types, Profile Creek, November 1991. Asterisks denote significant differences between use and availability at $P<0.05$.

Concealed bull trout were not evenly distributed across the stream channel; significantly ($P<0.001$) more fish were near the midline of the channel compared to the channel margins. Eighty percent of the fish were observed near the midline of the channel and from 1.9 to 3.1 m from shore. The rest were 1.1–1.28 m from the nearest shore.

Night

At night, some bull trout moved out of day hiding locations into the water column. I observed 40 fish over the substrate in the same areas where all fish were concealed in substrate during the day. Water temperatures ranged from 1.1 to 1.3°C.

Bull trout were observed in active and resting states. Two fish were actively feeding on benthos. The other 38 fish were resting on or near the substrate, typically in areas of low velocity with large substrate, bedrock outcrops, or submerged debris. Bull trout were not disturbed by my presence; I approached within 0.3 m and estimated size. Fish observed at night were similar in size to those observed during the day; the length frequency distributions did not differ significantly ($P>0.9$). Fish ranged from 50 to 250 mm long; 5% were less than 100 mm, 50% were 100–149 mm, 37.5% were 150–199 mm, and 7.5% exceeded 200 mm.

The type of habitat also influenced the likelihood of finding bull trout at night. I observed fish in similar habitats during day and night, most were in pools or runs (Fig. 1). Twenty-nine fish (73%) were in pools, 8 (20%) in runs, 2 in low gradient riffles, and 1 in pocket-water. Fish were in pools and runs proportional to the availability of those habitats (Fig. 1). Fish were in pocket-water significantly ($P<0.05$) more frequently and riffles significantly ($P<0.03$) less frequently than those habitats were available (Fig. 1).

Discussion

My observations were consistent with those of others who reported that juvenile bull trout were concealed during the day at low (<6°C) water temperatures (Bonneau 1994; Goetz 1994; Jakober 1995). I found all bull trout concealed in substrate during the day at water temperatures less than 2°C. Juvenile Dolly Varden (*Salvelinus malma*) and Arctic char (*Salvelinus alpinus*) were also observed hiding in debris and substrate during the day (Armstrong & Elliot 1972; Stenzel 1987). Winter movement into substrate interstices has been documented for many other juvenile salmonids (Hartman 1965; Edmundson et al. 1968; Everest & Chapman 1972; Bustard & Narver 1975; Rimmer et al. 1983; Hillman et al. 1987; Cunjak 1988; Griffith & Smith 1993).

Factors influencing concealment are undefined. Some bull trout use concealment cover during seasons other than winter (Griffith 1979; Oliver 1979; Pratt 1984; Shepard, Pratt & Graham 1984). Movement of all or most bull trout into concealment, however, may be related to declining water temperatures and photoperiod (Rimmer & Paim 1990; Jakober 1995).

Concealed bull trout behavior was similar to that of Atlantic salmon (Rimmer et al. 1984; Cunjak 1988). After being uncovered, both species remained motionless for 1 to 3 seconds, darted into the water column, and dived beneath another rock.

My observations of concealed bull trout support conclusions that unembedded large substrate, water depth, and water velocity are important for overwintering salmonids (Rimmer et al. 1983; Cunjak & Power 1986a; Bonneau 1994). Most bull trout were concealed beneath home stones at least 20 cm across, similar to stones reported for Atlantic salmon (Rimmer et al. 1983; Cunjak 1988). Home stone size increased with fish size, suggesting bull trout selected home stones large enough for complete concealment. Concealed fish were most abundant in pools (Bonneau 1994; Jakober 1995) and runs, habitats that typically sustain deep water and low-velocity areas (Bisson et al. 1982). Fish may select lower water velocities to reduce energetic costs (Cunjak & Power 1986a). In summer, bull trout also select low-velocity areas associated with the substrate or submerged debris (Pratt 1992). The mean focal point velocities I observed were less than half those reported in summer (10 cm/s) (Pratt 1984). Because I measured focal point velocities after removing the home stone, actual velocities may have been lower. I do not assume, however, that focal point velocities beneath home stones were near zero, as Cunjak (1988) and Bonneau (1994) proposed. I located bull trout beneath loose stones; home stones were not compacted, and interstices allowed water to flow around home stones. Higher velocity areas adjacent to fish may also influence winter microhabitat selection (Cunjak 1988). The advantages of selecting home stones adjacent to higher velocity areas would be reduced sediment deposition and less substrate compaction (Cunjak & Power 1986b; Cunjak 1988). Jakober (1995) concluded that critical overwinter habitat contained overhead cover, deep water, low velocity areas, a lack of anchor ice, and stable water temperatures.

Bull trout may use other types of daytime concealment cover in winter. Jakober (1995) reported that small (<20 cm) bull trout used large woody debris and trout too large to find concealment aggregated in low velocity areas in deep pools. Woody debris was available in Profile Creek; however, all fish up to 250 mm were concealed in substrate.

Bull trout exhibited a diel behavioral shift; some fish that were concealed during the day moved into the water column at night. Nocturnal emergence of fish from concealment provides fisheries workers an opportunity to locate overwintering area. Consistent with the night observations of others, bull trout of all sizes moved into the water column, and most (95%) rested on the substrate (Bonneau 1994; Goetz 1994; Jakober 1995). Pools continued to support the largest numbers of bull trout, however, night focal positions were on the substrate, farther from cover, and in shallower water than day positions (Bonneau 1994; Jakober 1995). A similar diel behavioral shift has been observed in other salmonids (Campbell & Neuner 1985; Stenzel 1987; Contor 1989; Griffith & Smith 1993). The authors suggested that nighttime emergence was related to feeding and predator avoidance. Griffith & Smith (1993) reported that 38% of the age-0 trout remained concealed each night, possibly because of slow digestion at low water temperatures.

This study has some important limitations. The sample size is small, although more than 100 stones were searched, only 15 bull trout were located in concealment cover. I searched for fish primarily in upper substrate strata. Some bull trout may have used deeper strata (Cunjak & Power 1986b). Because there was a physical limit to the size of home stones I could overturn, home stone dimensions may be biased against very large rocks.

Identifying and describing overwinter habitat is an important step in maintaining critical habitat for bull trout. The abundance and quality of overwinter habitat may limit fish abundance (Chapman 1966; Bustard & Narver 1975; Campbell & Neuner 1985; Heifetz, Murphy & Koski 1986; McMahon & Hartman 1989), although the role of winter conditions in regulating salmonid abundance is poorly understood. Chapman & McLeod (1987) suggested juvenile salmonids seek overwintering areas in the most upstream locations near summer rearing areas. If once-suitable overwinter habitat is degraded, carrying capacity may be reduced and fish may move to other locations (Bjornn et al. 1977). We do not know if fish that move from once-suitable habitat suffer higher mortality or if mortality is related to the distance fish move. Additional studies are warranted to describe overwinter habitat and to evaluate the role of overwinter habitat in regulating native salmonid abundance.

Resumen

1. En un canal secundario del río Idaho (Idaho, USA), llevé a cabo observaciones subacuáticas para determinar la utilización del hábitat y el comportamiento circadiano de juveniles de *Salvelinus confluentus* al principio del invierno. El rango de temperaturas del agua osciló entonces entre los 0.7 y los 1.6°C.
2. Todos los individuos observados durante el día aparecieron escondidos en el sustrato bajo una "piedra-hogar", básicamente en pozas y en tablas. El tamaño de los peces estuvo correlacionado con el tamaño de las piedras-hogar, cuya media fué de unos 32×22 cm. Durante el día, las profundidades y las velocidades focales en la posición de cada individuo fueron 57 cm y 4.7 cm $\cdot$ s^{-1} (una vez descontado el tamaño de la piedra-hogar). Los individuos permanecieron sobre sustratos con bajo porcentaje (5%) de sedimentos <2 mm y no se distribuyeron de manera uniforme a lo largo del canal sino que las piedras-hogar fueron más abundantes en el centro del canal que en los márgenes.
4. Durante la noche, los peces cambian su comportamiento circadiano. Algunos abandonan el refugio diurno y se mueven hacia la columna de agua. También por la noche, observamos juveniles alimentandose y descansando en pozas y tablas.

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