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Winter Diel Habitat Use and Movement by Subadult Bull Trout in the Upper Flathead River, Montana

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Abstract.—We evaluated the diel habitat use and movement of subadult bull trout *Salvelinus confluentus* by use of radiotelemetry during winter in the upper Flathead River, Montana. Of the 13 monitored bull trout, 12 (92%) made at least one diel movement to other habitat locations during their respective day–night tracking surveys and moved an average of 73% of the time. The median distance moved from day to night locations by the mobile fish was 86 m (range, 27–594 m). Diel shifts in habitat use by nine of the tagged fish were related to light intensity; nocturnal emergence generally commenced immediately after the onset of night, and daytime concealment occurred at daybreak. When diel shifts in microhabitat use occurred, subadult bull trout moved from deep, midchannel areas during the day to shallow, low-velocity areas along the channel margins without overhead cover at night. Resource managers who wish to protect the overwintering habitat features preferred by subadult bull trout in the upper Flathead River should use natural flow management strategies that maximize and stabilize channel margin habitats at night.

Populations of bull trout *Salvelinus confluentus* have declined throughout their range (Rieman et al. 1997). Consequently, biologists have focused on identifying and protecting important habitat and unique life history forms. Winter habitat conditions may limit the production of stream-dwelling salmonid populations, and the availability of suitable overwintering habitat during their early life history may limit recruitment to the adult population (Chapman and Bjornn 1969; Bustard and Narver 1975). Several investigators have quantified habitat use by juvenile bull trout during winter (Goetz 1997; Sexauer and James 1997; Thurow 1997; Bonneau and Scarnecchia 1998; Jakober et al. 1998), although these studies have focused primarily on small fish (<200 mm) inhabiting headwater tributaries.

Declining temperatures (to below 10°C) during fall and winter can induce salmonids to make extensive movements from tributaries to larger systems where conditions are more hospitable for overwintering (Bjornn and Mallet 1964; Bjornn 1971). Little information exists regarding the habitat requirements of migratory (i.e., fluvial and adfluvial) subadult bull trout rearing in large river systems during winter. In smaller systems, juvenile bull trout were generally concealed beneath the substrate during winter days and moved into the water column at night (Thurow 1997; Bonneau and Scarnecchia 1998). Goetz (1997), studying a tributary to the Metolius River, Oregon, found that juvenile bull trout (age 1 and age 2) moved from deep water with cover during the day to shallow areas at dusk.

The Flathead River upstream of Flathead Lake in Montana provides critical overwintering areas for native bull trout and westslope cutthroat trout *Oncorhynchus clarki lewisi* populations (Shepard et al. 1984; Fraley and Shepard 1989). Hydropower and flood control operations from Hungry Horse Dam regulate the lower 69 km of the Flathead River. Sporadic flow fluctuations during winter may adversely impact the growth and survival of native fishes inhabiting the dam-influenced reaches of the river (Marotz et al. 1999). We initiated a study to determine how changes in river discharge (e.g., seasonal flow regimes and discharge change rates) influence the availability of suitable habitat to subadult bull trout, using a modified version of the Instream Flow Incremental Methodology (IFIM; Bovee 1982; B. Miller, Miller Ecological Consultants, Inc., personal communication). An accurate characterization of the depths, velocities, cover types, and substrate particle sizes used by subadult bull trout during winter is critical in developing reliable habitat suitability functions for the IFIM model.

No information has been published regarding the habitat use by subadult bull trout rearing in large river systems during winter. Knowledge of

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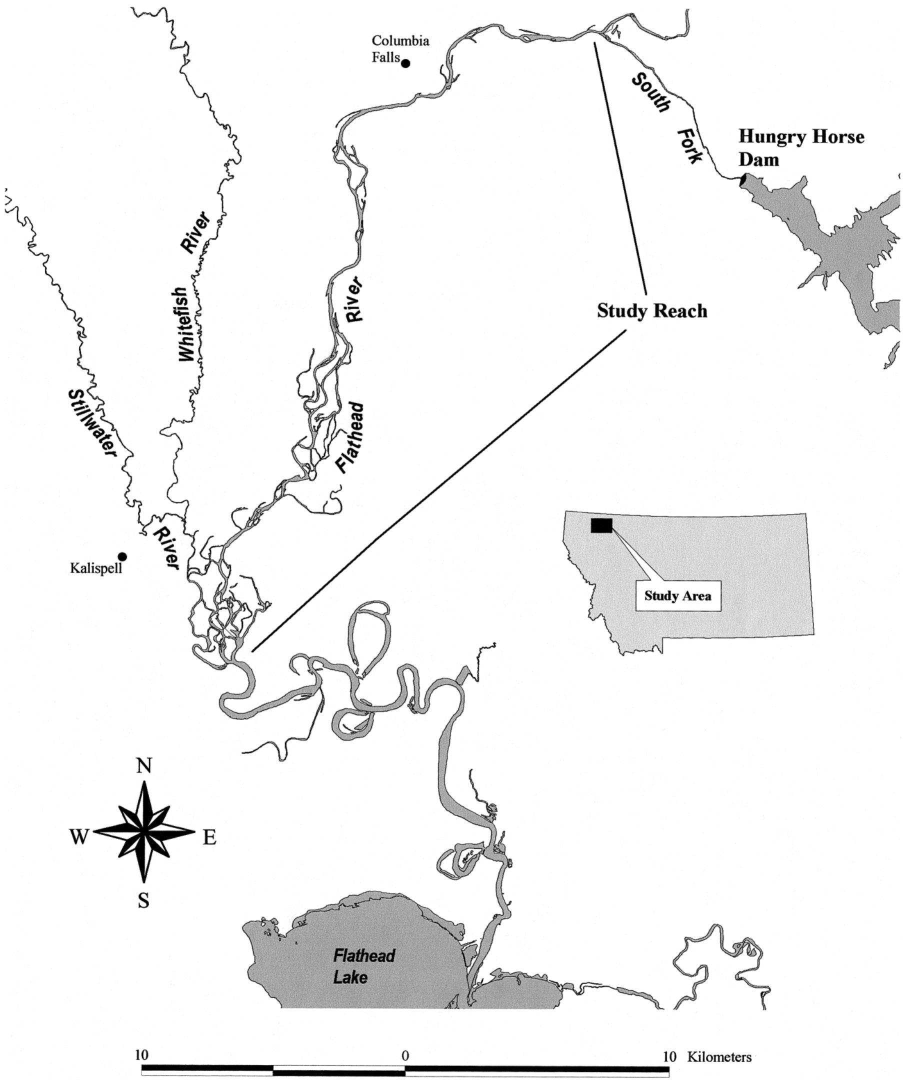

FIGURE 1.—Study reach in the upper Flathead River, Montana.

the seasonal habitat requirements of all life history stages of bull trout is critical for developing successful conservation and recovery programs. If dam operations and winter conditions indeed limit migratory bull trout populations, an understanding of winter habitat selection is critical in developing successful streamflow and habitat management programs that balance the needs of native fish and the power demands in the river system. Our objectives were to quantify the winter diel movement and habitat use by migratory subadult bull trout (<400 mm) in the upper Flathead River downstream of a dam.

Study Area

Our study was conducted in the main-stem Flathead River between the South Fork Flathead River and the Stillwater River (Figure 1). Hungry Horse Dam, on the South Fork, regulates river discharge, precludes upstream fish migration, and isolates fish populations upstream. Dam operations store spring runoff for later release to generate power during the fall and winter, periods when unregulated flows were formerly low. This 38-km section of the Flathead River is unconfined and characterized by gravel and cobble substrates, run and riffle habitat types (with braided channel inclusions), low stream gradients of 0.5–1.5%, and an average stream width of approximately 75 m.

Bull trout exhibit migratory life history strategies in the Flathead River system (Fraley and Shepard 1989; C. Muhlfeld, unpublished data). Fish grow to maturity in Flathead Lake or the Flathead River and migrate upstream as far as 250 km into tributaries to spawn. Juveniles emigrate from natal rearing tributaries during late spring and summer after 1–4 years of residence, generally arriving downstream of the South Fork Flathead River mouth during fall and winter (Fraley and Shepard 1989).

Methods

We examined the diel habitat use and movement of subadult bull trout (<400 mm) using radiotelemetry during nine day–night tracking surveys from 14 December 2000 to 22 February 2001 and nine day–night tracking surveys from 8 November 2001 to 2 January 2002. Fish were captured by boat electrofishing, surgically implanted with radio transmitters, and released near their capture locations. Fish tracked from 14 December 2000 to 22 February 2001 (group 1) were implanted and monitored in the lower portion of the main stem near Kalispell, and fish tracked from 8 November 2001 to 2 January 2002 (group 2) were implanted and monitored in the upper portion near Columbia Falls (Figure 1). Fish were not relocated during every diel survey for the following reasons: the transmitter failed prematurely; the fish exhibited frightened behavior; or the fish moved out of the study area.

The study period for each group lasted approximately 60 d because this was the guaranteed life of most of the transmitters. Group 1 included four fish (mean length = 282 mm; range, 267–301) implanted with transmitters that weighed 3.7 g in air and three fish (mean length = 369 mm; range, 353–399) implanted with transmitters that weighed 6.7 g in air (models MCFT-3D and MCFT-3CM, respectively; Lotek Wireless Inc., Newmarket, Ontario); the mean transmitter:body weight ratio was 2.0% (range, 1.4–2.4%). Group 2 consisted of six fish (mean length = 332 mm; range, 271–365) implanted with transmitters that weighed 3.7 g in air (MCFT-3D); mean transmitter:body weight ratio was 1.5% (range, 1.0–2.4%). Each tag emitted a unique code in the frequency of 148.730 MHz (12 pulses per minute). Fish were anesthetized with a 60-mg/L solution of tricaine methanesulfonate (MS-222) and placed in a padded, V-shaped trough, where their gills were irrigated with either more of the MS-222 solution or pure water during surgery. We made a 10-mm incision approximately 25 mm anterior of the pelvic girdle within 10 mm of the midventral line. A sterilized transmitter was placed in the body cavity, and the antenna was extended through the body wall immediately posterior to the pelvic girdle. Each incision was closed with three synthetic absorbable sutures.

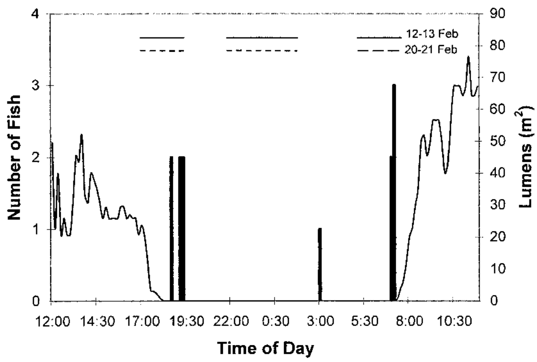

FIGURE 2.—Timing of diel movements as related to light intensity (lm/m^2) by six radio-tagged juvenile bull trout monitored in the Flathead River during 12–13 and 20–21 February 2001. Vertical bars represent the number of fish that moved during each 30-min monitoring period. Horizontal solid and dashed lines represent the periods when fish were monitored during each survey.

Diel surveys were conducted on 18 dates. Group 1 fish were surveyed on 14, 19, and 20 December 2000; 10, 17, 24, 25, and 31 January 2001; and 6, 13, 14, and 22 February 2001. Group 2 fish were surveyed on 8, 13, 14, 20, and 28 November 2001; 5, 6, 12, 19, 26, and 27 December 2001; and 2 January 2002. Night surveys were systematically conducted during one of the following times on each survey date: 1900–2200 hours (N = 6); 2200–0200 hours (N = 6); or 0200–0600 hours (N = 6). Because the fish generally moved to the same areas during the three night survey periods and no differences in habitat use were detected among the groups, the data were pooled for subsequent analyses.

Fish were tracked from a jet boat equipped with a scanning receiver (Lotek model W30) and a whip antenna. Once a signal was detected, we triangulated fish locations from the boat or stream bank by using a directional yagi antenna. To obtain a more accurate location, we positioned the boat downstream of the fish and slowly proceeded upstream, decreasing signal gain on the receiver until a final location was determined. Pilot tests revealed that location accuracy was within 2 m^2 of the transmitter. Radio-tagged fish frequently were

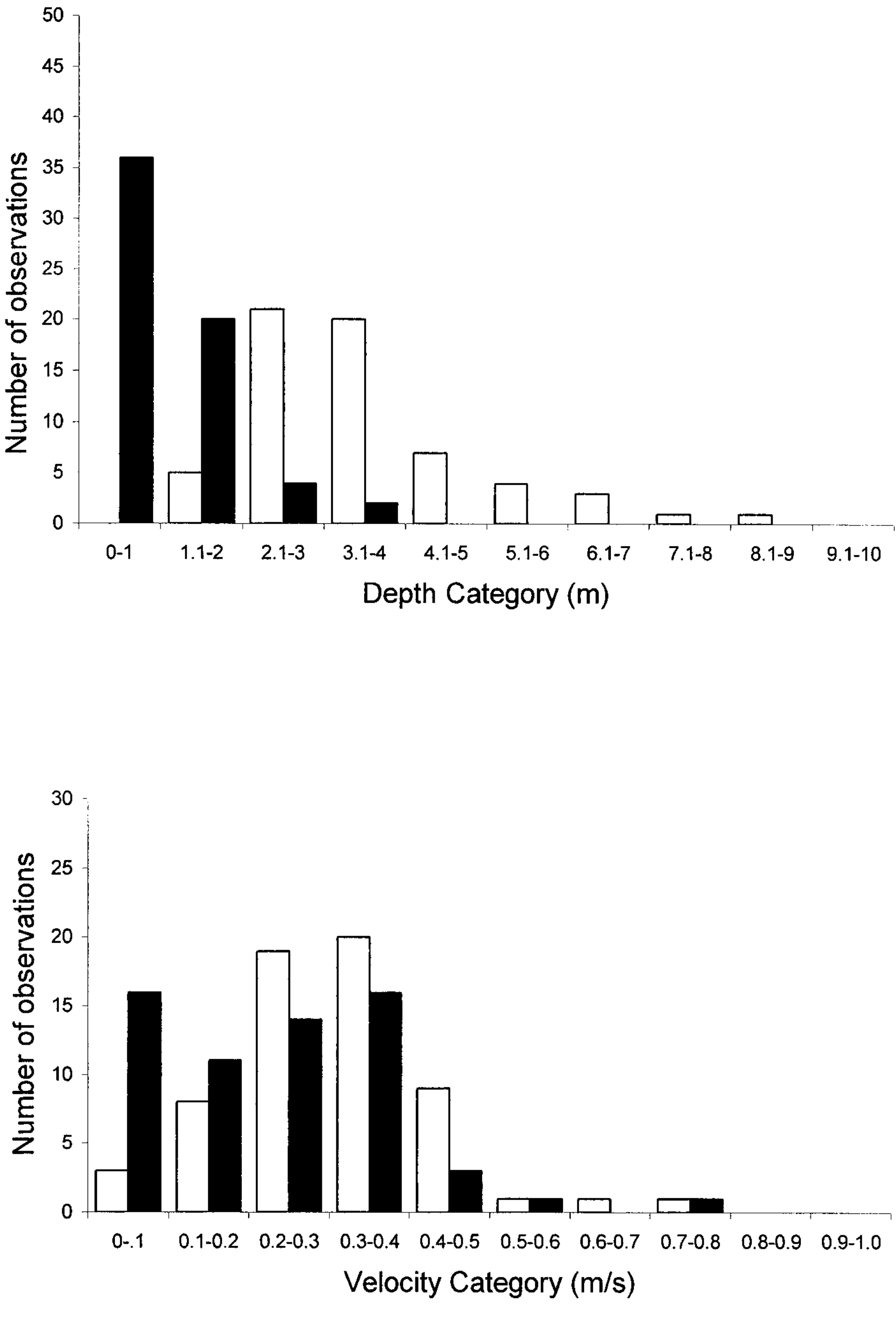

FIGURE 3.—Water microhabitat use by juvenile bull trout during the day (white bars) and at night (black bars) in the upper Flathead River, Montana, with respect to depth (first panel), velocity (second panel), and substrate type (third panel).

observed from the boat with a spotlight. Fish were tracked 15–30 min during each contact.

We determined the timing of diel movements during four tracking surveys: on 13–14 (n = 4 fish) and 20–21 February 2001 (n = 2 fish), 19–20 December 2001 (n = 3 fish), and 2–3 January 2002 (n = 3 fish). Tracking surveys began at 1700 hours and continued until all monitored fish had moved from their day locations; the surveys resumed at 0500 hours the next day and continued until fish

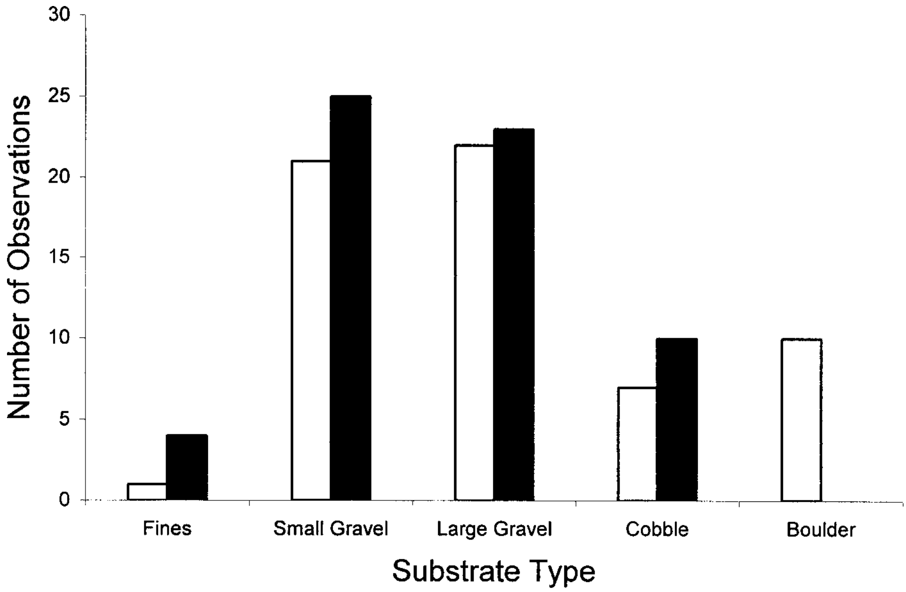

FIGURE 3.—Continued.

moved back to daytime locations. In addition, fish were tracked during the day and between 2200 and 0200 hours during the diel survey that was conducted on the same day as the timing survey. Observers walked along the stream bank and triangulated fish locations every 30 min.

During each diel survey, we obtained habitat use information once during the day (1000–1700 hours) and once the following night (1900–0600 hours) for each study fish that resided in the study area. Microhabitat variables were water depth (m), bottom velocity (m/s), substrate, and cover. Water depth and bottom velocity were measured from the jet boat by using a USGS A-55 sounding reel, a 13.6-kg sounding weight, and a Price AA current meter. Substrate composition (within a 1-m radius) was visually ranked as sand–silt (<0.2 cm diameter; rank = 1), small gravel (0.2–0.6 cm; rank = 2), large gravel (0.6–7.5 cm; rank = 3), cobble (7.5–30.0 cm; rank = 4), boulder (30.0–60.0 cm; rank = 5), and bedrock (rank = 6) and weighted by the proportional area to obtain a single value representative of each location (Baltz et al. 1991). Cover types identified within a 2-m radius of the location were categorized as large woody debris, undercut bank, overhanging vegetation, turbulence, substrate, and water more than 2.5 m deep. Mesohabitats at each location were classified as pool, run, riffle, backwater (Bisson et al. 1982), or shoal. Shoals were defined as shallow, low-velocity areas along the channel margins. Surveyors used a boat-mounted underwater camera (Sea-Drop Camera model 520; Seaviewer Cameras Inc., Tampa, Florida) to assess habitat features if deep water (>5 m) precluded visual identification of the stream bottom. Georeferenced locations (±1 m) were obtained at each fish location by using a global positioning system (GPS) unit (TSC1 Asset Surveyor; Trimble Navigation Ltd., Sunnyvale, California). Mean daily water temperature and discharge data were obtained from the U.S. Geological Survey station on the Flathead River at Columbia Falls, Montana. Mean daily water temperatures ranged from 1.9°C to 3.1°C during winter 2000–2001 and from 2.4°C to 4.6°C during winter 2001–2002. During the diel surveys, mean daily discharge was 99–114 m^3/s during winter 2000–2001 (except for one flow release of 160 m^3/s from Hungry Horse Dam on 22 February 2001) and 94–98 m^3/s during winter 2001–2002. Light intensities were monitored each tracking period with a light intensity data logger (Onset Stowaway Li, Computer Corp., Pocasset, Massachusetts) deployed near the downstream limit of the study reach. Light intensity data were unavailable during 19–20 December 2001 and 2–3 January 2002 because the data logger failed during deployment.

Because the data were nonnormal, we used nonparametric Mann–Whitney *U*-tests (two-tailed) to test the null hypothesis that there was no difference in use of depth, velocity, and substrate between day and night (Statistica 1995).

Individual fish movements were quantified by measuring the distance between the paired day–night relocations in ArcView, version 3.2 (Environmental Systems Research Institute, Inc. 1999). Total distance moved was considered the linear distance moved between locations. Fish were considered to have moved if the distance between locations exceeded 5 m.

Results

We obtained 95 day–night paired relocations ($N = 190$) on 13 subadult bull trout (mean [±SD] per fish = 7 ± 2) during 18 winter day–night tracking surveys. Most radio-tagged subadult bull trout exhibited diel movements to other habitat locations. Twelve radio-tagged fish made at least one diel shift in habitat location during their respective monitoring periods, whereas the single sedentary fish moved within a deep pool that contained extensive amounts of large woody debris. Mobile fish moved an average of 73% of their respective day–night paired relocations ($N = 62$; mean number of diel movements per fish = 5 ± 3). The median distance moved from day to night was 86 m (range, 27–594 m).

The timing of diel movements by nine of the radio-tagged subadult bull trout were related to light intensity (Figure 2). Light intensities ranged from 10 to 73 lm/m^2 during the day (0700–1700 hours) and were 0 lm/m^2 at night (1900–0600 hours). All nine fish moved from daytime habitats immediately after the onset of total darkness. Conversely, subadult bull trout generally moved from night locations back to their original day locations at daybreak (light intensity <1.0 lm/m^2), except for one fish that moved sometime between 0200 and 0500 hours.

When diel shifts in microhabitat use occurred, subadult bull trout moved from deep, midchannel areas during the day to shallow, low-velocity areas along the channel margins without overhead cover at night (Figure 3). Mobile trout were usually found in significantly ($U = 123.5$; $P < 0.0001$) shallower areas at night (mean depth = 1.0 ± 0.7 m) than during the day (mean depth = 3.6 ± 1.4 m), and utilized areas with significantly ($U = 1{,}239$; $P < 0.001$) slower velocities (mean = 0.22 ± 0.16 m/s) at night than during the day (mean = 0.31 ± 0.14 m/s). Further, use of substrate differed significantly ($U = 1{,}468.5$; $P < 0.01$) between day and night; bull trout tended to maintain positions over larger substrates during the day (mean score = 2.6 ± 1.0) than at night (mean score = 2.2 ± 0.8). During the day, 44 observations (71%) were in midchannel locations and 18 (29%) were in near-shore areas. In contrast, at night 55 observations (89%) were in near-shore areas and 7 (11%) were in midchannel locations. Thus, subadult bull trout showed a 60% increase in the proportional use of channel margins at night. During the daylight hours, mobile fish were near cover in the form of water deeper than 2.5 m ($N = 51$), substrate ($N = 5$), and large woody debris ($N = 1$).

At the mesohabitat scale, we found that mobile subadult bull trout used deep runs (81%) and complex pools (19%) during the day and moved to shoals (48%), shallow runs (39%), pools (10%), and backwaters (3%) at night.

Discussion

Our findings indicate that deep pools and runs are important to subadult bull trout during the day, whereas shallow areas along the channel margins provide critical habitat at night. If the habitat use assessments had been conducted only during the daytime, our results would have suggested that water resource managers should maximize the availability of deep, complex habitats during winter. However, nighttime tracking surveys revealed that channel margins are critical habitats at night, presumably for feeding. Thus, the importance of channel margin habitats to subadult bull trout at night would have been missed if habitat use were assessed only during the daytime.

Diel shifts in habitat use have been reported for other populations of bull trout (Baxter and McPhail 1997; Goetz 1997; Thurow 1997; Bonneau and Scarnecchia 1998; Jakober et al. 1998) and are common for other stream-dwelling salmonid species, including Arctic char *Salvelinus alpinus* (Stenzel 1987), rainbow trout (Campbell and Neuner 1985; Contor 1989), Yellowstone cutthroat trout *Oncorhychus clarki bouveri* (Griffith and Smith 1993), California golden trout *O. mykiss aguabonita* (Matthews 1996), brown trout *Salmo trutta* (Heggenes 1988), and Atlantic salmon *S. salar* (Cunjak 1988). Goetz (1997) and Thurow (1997) reported that nocturnal activity by bull trout occurs at cold water temperatures and is probably related to feeding, energy conservation, photoperiod, and predator avoidance. Bull trout longer than 110 mm are generally piscivorous in the Flathead River system (Shepard et al. 1984). Although we did not quantify the food habits of the study fish, we believe they moved into shallow, channel margin habitats at night to feed on small fishes such as juvenile mountain whitefish, which are readily available in these areas (Shepard et al. 1984; Muhlfeld, unpublished data). We concur with Griffith and Smith (1993), who suggested that use of channel margins by juvenile salmonids during winter may be an adaptation to living in low-gradient river systems that lack surface and anchor ice formation.

Our findings suggest that diel shifts in habitat use were most pronounced for water depth. Similarly, Sexauer and James (1997) found that juvenile bull trout (<300 mm) used channel margins and backwater areas that lacked overhead cover at night, and Thurow (1997) reported that juvenile bull trout used deeper areas during the day than at night.

Diel shifts in habitat use were correlated with changes in light intensity. Goetz (1994) suggested that juvenile bull trout (<200 mm) use cover during the daytime to avoid high light intensity because they are well adapted to low light conditions. Swanberg (1997) reported that most radio-tagged fluvial bull trout migrated at night in the Blackfoot River drainage in Montana. Movements possibly occurred at other times, however, because the study fish were not tracked throughout a continuous 24-h period.

Our results are consistent with previous studies that reported that juvenile bull trout move into slower water at night (Goetz 1997; Sexauer and James 1997). However, bottom velocity measurements were probably artificially inflated because the velocity meter was positioned approximately 15 cm above the streambed. Bull trout are bottom dwellers (Scott and Crossman 1973) and are highly substrate-oriented (Pratt 1984), which enables them to occupy near-zero velocities on and within the streambed material.

During winter days, bull trout inhabited deep water (>2.5 m) and cover (unembedded boulders, large woody debris). Subadult bull trout probably occupied these areas to maximize energy conservation (Fausch 1984), evade predation (Harvey 1991), or avoid high light intensities (Goetz 1994, 1997; Swanberg 1997). Concealment behavior by juvenile bull trout during winter days at low stream temperatures (<6°C) is consistent with findings of other researchers (Goetz 1997; Thurow 1997; Bonneau and Scarnecchia 1998; Jakober et al. 1998). Jakober et al. (1998) reported that small (<320 mm) radio-tagged bull trout used beaver ponds and pools with large woody debris in a third-order headwater stream, whereas fish selected pools with boulders and large woody debris in a fourth-order, midelevation stream. Fraley and Graham (1982) found that the density of juvenile bull trout was best related to the amount of cover in tributaries of the Flathead River drainage. In different stream systems, factors other than resource availability, such as stream temperature (Pratt 1984; Saffel and Scarnecchia 1995; Bonneau and Scarnecchia 1996), food supply (Shepard et al. 1984; Boag 1987; Nakano et al. 1992), and the presence of other species, may also influence habitat use by bull trout (Pratt 1984; Shepard et al. 1984).

We found that some fish did not always exhibit a diel shift in habitat location. Perhaps these fish found suitable prey availability and resting habitat in deep, complex areas of the river or they did not need to forage because of slow digestion rates at low stream temperatures. Griffith and Smith (1993) found that 38% of age-0 trout remained in concealment cover at night and speculated that slow digestion rates at low water temperatures were responsible. Elliott (1972) found that brown trout required 24 h to evacuate 15% of their stomach contents at 4°C, which may explain why fish did not move during every diel survey. Further research is needed to quantify predator–prey relations and digestion rates by subadult bull trout inhabiting large river systems during winter.

We found that radiotelemetry was a useful technique for accurately quantifying diel habitat use and movements by subadult bull trout inhabiting large rivers during winter. Day and night snorkeling and electrofishing techniques may be suitable to estimate bull trout abundance, size-class structure, and habitat use, although results are sometimes variable and depend on local conditions such as water temperature, conductivity, visibility, and habitat conditions (Thurow and Schill 1996). In the Flathead River, low water conductivity and deep areas precluded accurate assessments of fish-habitat relations by electrofishing or snorkeling during winter.

Managers who wish to protect the overwintering habitat features preferred by subadult bull trout in the Flathead River should use flow management strategies that stabilize and maximize the availability of channel margin habitats at night and deep, complex areas during the day to maintain or increase rearing capacity and survival. Dam operations that create sporadic flow fluctuations negatively impacting lateral areas of the channel at night may be detrimental to bull trout subadults. We suggest that restoration of the most natural flow regime possible under the current management constraints will protect key ecosystem processes and maintain or restore bull trout populations in the Flathead and elsewhere in the Pacific Northwest (Independent Scientific Group 1999).

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