Summer Movements within the Fish Community of a Small Montane Stream

DAVID A. SCHMETTERLING*

Montana Fish, Wildlife, and Parks, 3201 Spurgin Road, Missoula, Montana 59804, USA

SUSAN B. ADAMS

U.S. Forest Service, Southern Research Station,
1000 Front Street, Oxford, Mississippi 38655, USA

Abstract.—We studied movements by fishes in Chamberlain Creek, Montana, from 24 July to 16 August 2001. We operated six weirs with two-way traps and one additional upstream trap, separated by 14–1,596 m, to quantify the timing, direction, and distance of movements and to estimate fish populations in the study reaches. We trapped and marked 567 fish of seven species, including 368 westslope cutthroat trout *Oncorhynchus clarkii lewisi* and 172 sculpin (slimy sculpin *Cottus cognatus* and an unidentified species similar to mottled sculpin *C. bairdii*). We recaptured 173 westslope cutthroat trout and detected net movements as long as 1,581 m (median, 91 m). Bidirectional movements for 116 westslope cutthroat trout ranged from less than 18 to more than 1,581 m (median, 64 m). Sculpin moved as far as 209 m (median, 26 m). We estimate that 14% of sculpin and 48% of westslope cutthroat trout were mobile during the study. We captured all species more frequently at night or twilight ($n = 296$) than during the day ($n = 83$) and more frequently moving downstream ($n = 419$) than upstream ($n = 277$). These results demonstrate considerable summer movement by the fish community in a small stream.

Movements are critical to the ecology and demography of many lotic fish populations. Movement of fish can affect population gene frequencies, create metapopulation connectivity, and contribute to the flux of energy and nutrients through stream networks (Hall 1972; Rieman and Dunham 2000). The spatial and temporal scales over which fish movements occur vary widely, and at all scales, movements can vary within and among individuals and populations (Kahler et al. 2001; Rodríguez 2002), as well as among taxonomic groups. Quantifying animal movements, including within-population variability, is fundamental to understanding community ecology and effectively conserving populations in the face of anthropogenic impacts. In addition to more subtle effects, barriers to fish movements can lead to loss of life history types or even population extirpation, accompanied by loss of the potential for recolonization (Hanski 1999; Rieman and Dunham 2000; Neraas and Spruell 2001).

Although sculpin are often important components of communities in small, coldwater streams, making up as much as 85% of the fish abundance (McCleave 1964; Freeman et al. 1988), the ecology, movements, and population structure of most strictly freshwater sculpin species are poorly understood. Spawning movements by adult sculpin ranged from 0 to more than 100 m in one freshwater species (Natsumeda 1999) and up to 5 km in an amphidromous species (Goto 1988). Summer home range movements typically average less than 20 m (McCleave 1964; Greenberg and Holtzman 1987; Natsumeda 1999), although Shetter and Hazzard (1939) suspected greater vagility. Moreover, some of the conclusions regarding limited movements probably resulted from study designs biased against finding long-distance movements (see Gowan et al. 1994; Gowan and Fausch 1996).

Some early and much recent work suggests that many stream-resident trout move extensively (Gowan and Fausch 1996; Young 1996; Hilderbrand and Kershner 2000); other work, however, implies that movements are more limited (restricted movement paradigm; see Gowan et al. 1994 for review; Rodríguez 2002). Movements are usually attributed to spawning, dispersal, or seasonal habitat changes (Young 1996; Young et al. 1997; Hilderbrand and Kershner 2000; Gowan and Fausch 2002). For example, many cutthroat trout *Oncorhynchus clarkii* move soon after spawning, when flows remain high (Young 1996; Hilderbrand and Kershner 2000); generally, however, movement of salmonines (including cutthroat trout) decreases greatly during late summer (Gowan and Fausch 1996; Hilderbrand and Kershner 2000). Yellow-

stone cutthroat trout *O. c. bouvieri* and westslope cutthroat trout *O. c. lewisi* commonly make autumnal movements to overwintering habitats (e.g., Northcote 1992; Brown and Mackay 1995; Jakober et al. 1998).Without an impetus for movements, such as spawning or habitat changes, summer movements of cutthroat trout are reportedly minimal (Shepard et al. 1984; Schmetterling 2001; Hilderbrand and Kershner 2000).

On the basis of previous research, we expected summer fish movement to be minimal in a small coldwater stream. Our objectives were to quantify the timing, direction, and distance of summer movements by fish in a small Montana stream. We used mark–recapture with weirs to sample the mobile fraction of the entire community and estimated population sizes by electrofishing.

Methods

Study area.—Chamberlain Creek is a second-order, perennial tributary to the Blackfoot River (elevation at confluence, 1,180 m) and is a principal spawning tributary for fluvial westslope cutthroat trout (Schmetterling 2000, 2001). Sculpins (slimy sculpin *Cottus cognatus* and an unidentified species similar to mottled sculpin *C. bairdii*) are the most abundant fishes in the stream, and westslope cutthroat trout (including both stream-resident and fluvial life history types) are the most abundant salmonid species (D. A. Schmetterling, unpublished data). At the time of the study, it was thought that there was only one sculpin species in Chamberlain Creek, the slimy sculpin. However, recent genetic and morphological data (unpublished) suggest the presence of the two species named above. Because we did not distinguish between them, we refer to both species together as ''sculpin.''

Chamberlain Creek drains an 87.2-km^2 watershed, composed predominantly of belt series geology, and flows through a gravel-dominated alluvial valley (Schmetterling 2000). The study area (Figure 1) is in a moderately confined channel with gradients ranging from 1.5% to 2.0%. Mean base flow is approximately 0.1 m^3/s (Bureau of Land Management [BLM], unpublished data); during the study, wetted stream widths averaged 1.5–2.0 m. Habitat units, such as riffles and pools (Armantrout 1998), are generally short, approximately 6 m long. Aquatic habitat variables (including habitat type, substrates, channel dimensions, fish cover, and pool quality) were similar between upper and lower trapping sites (see below, unpublished data).
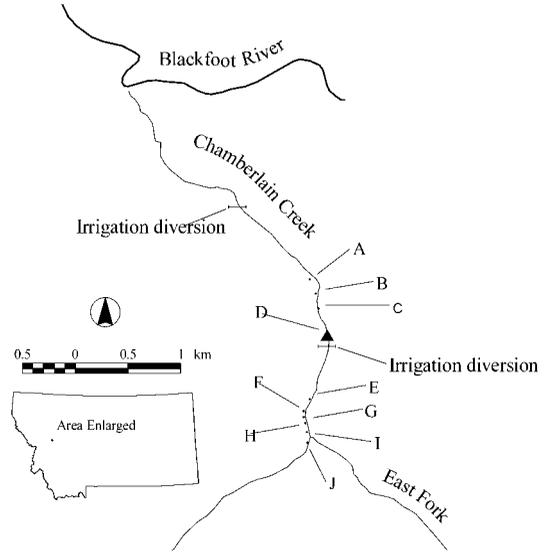

FIGURE 1.—Study area on Chamberlain Creek, Montana, showing lettered weir locations (circles), upstream-only trap (triangle), and irrigation diversion dams. Weirs were operated at locations F, G, and I for 1 week and then moved to locations A, B, and C.

We recorded stream stage height at least daily with a staff gauge at stream km 6.0 (measured upstream from the mouth) and converted stage to discharge by means of a conversion technique developed for the site (unpublished data, BLM). A thermograph (Tidbit; Onset Computer Corp.) recorded stream temperature every 18 min near weir G during the study. Stream flows in Chamberlain Creek were very low through most of summer 2001 (approximately 50% of normal, according to 18 years of data).

Although not the focus of this study, Chamberlain Creek has two concrete irrigation diversion dams, one at stream km 1.5 (upstream from mouth), and one at stream km 3.0 (Figure 1). The lower diversion dam remains in operation and is fitted with a Denil fish ladder to facilitate salmonid passage (Schmetterling et al. 2002). The irrigation diversion at km 3.0 is not currently used but creates a 25-cm plunge during low flows. The drop is not an impediment to upstream-migrating adult, fluvial westslope cutthroat trout (Schmetterling 2000, 2001), but its effects on passage of smaller westslope cutthroat trout and on nonsalmonine species are unknown.

Trapping.—We operated weirs in Chamberlain Creek from 23 July to 16 August 2001, except for about 24 h beginning on 1 August during high stream flows. Weirs consisted of two hoop nets

(Young and Schmetterling 2004), one that trapped fish moving upstream (''upstream trap'') and one that trapped fish moving downstream (''downstream trap''); these nets were connected to each other and to both banks by 1–4-m leads. Each hoop net, constructed of 6.3-mm nylon mesh netting (Delta heavy 44), was 1.4 m long with four 30–38-cm hoops, two leads, and a throat with a 5.0–7.5-cm opening. We attached traps (hoop nets) to rebar driven into the streambed and the banks, and sealed the bottom edges with rocks to minimize the possibility of fish passing under the weirs. We checked for gaps between weirs and the streambed at least daily and immediately repaired any gaps.

We operated six weirs in 10 locations (Figure 1) and used one additional hoop net as an upstream trap that did not span the stream (Figure 1, trap D). On 23 July, we installed six weirs in the upper section and the upstream trap (trap D) in the lower section, 2.0 m downstream of the diversion dam (Figure 1). The six weirs were spaced at least two riffle pool sequences apart (14–114 m), and trap D was 1,096 m downstream of the upper section (Figure 1). In order to trap more sculpin, we moved three weirs downstream of the irrigation dam on 30 July and spaced them one riffle pool sequence apart (16–177 m). Three weirs in the upper section and trap D remained in place, so weirs encompassed 1.6 km of the creek (Figure 1).

We checked traps at least daily, sedated captured fish with clove oil, and measured (total length) and marked all fish. After batch-marking fish, we released them in the direction in which they were moving when captured. Observers approached the traps from the bank perpendicular to the traps rather than from within the stream to avoid scaring fish into the traps. We marked sculpin with visible implant elastomer (VIE; Northwest Marine Technologies) on the ventral side of the mandible (Schmetterling et al. 2002). Other fish were marked with either VIE or a fin clip (anal, pelvic, caudal, or pectoral). All marks were unique to each weir location. We marked fish at initial capture and again if they changed directions at a different weir, so many individuals received multiple marks. To distinguish between nocturnal/crepuscular and diurnal movements, we checked traps in mornings and evenings from 24 July to 1 August.

Population estimates.—On 16 August, we conducted single-pass electrofishing between weirs A and C and between weirs E and J after removing intervening weirs. Using previously trapped fish as the marked individuals, we used Chapman's modification of Petersen's mark–recapture index (Ricker 1975) to estimate population sizes of sculpin in the lower section and westslope cutthroat trout in both sections. Because we marked only two sculpin in the upper section, we did not attempt a population estimate there. We netted sculpin for the first 114 m of the upper section to determine catch rate (number/m) for comparison of relative abundance between sections. We calculated the number of marked fish remaining in a section at the time of electrofishing, using the following equation:

Number of marked

= (number of marked individuals released)

  − (number of marked individuals that emigrated)

  + (number of marked individuals that immigrated)

  − (known mortalities).

All fish captured during electrofishing were identified, measured, and checked for marks.

Analysis of movement data.—Although marks were unique to weirs, not individuals, most of our analyses are based on movements of individuals. We distinguished among marked individuals by using a combination of capture date and location, direction of movement, previous marks, and body length. Generally, we could identify individual fish; only eight individuals were excluded from analyses because of ambiguities.

We defined net movement as the distance between the two farthest capture locations for an individual. Mobile fish were somewhat arbitrarily defined as those captured in more than one weir; because distances between weirs varied, so did the distance fish had to move to be categorized as mobile. However, to be considered mobile, fish had to move at least one riffle pool sequence (at least 16 m), which was the minimum spacing between weirs. Fish captured at one weir (whether captured or recaptured) were considered nonmobile, but this does not imply that they did not move throughout the length of stream between weirs or move farther during other seasons. We defined bidirectional movement as the net distance traveled by a fish that we detected moving both up- and downstream, assuming it passed at least two weirs.

We used various statistics to test characteristics of fish movements and considered differences to be significant at $P \leq 0.05$. To determine the proportion of a population that was mobile, we divided the number of mobile fish by the point estimate of population size. We used t-tests to de-

TABLE 1.—Species, number of individuals captured, recaptured, and mobile (captured at >1 weir), total lengths of captured fish (mean and range), and absolute net distances moved (median and range) in Chamberlain Creek, Montana, from 23 July to 16 August 2001.

Species	Number captured	Number recaptured	Number mobile	Length (mm)	Net distance moved (m)
Westslope cutthroat trout	368	173	91	108 (66–250)	91 (14–1,581)
Sculpin	172	51	34	75 (51–130)	18 (16–209)
Brown trout	11	5	1	126 (78–193)	18
Brook trout	10	6	3	145 (96–190)	34 (18–1,248)
Bull trout	3	3	3	224 (216–233)	180 (34–1,596)
Longnose sucker *Catostomus catostomus*[a]	3			157 (139–178)	

[a] Not marked.

termine whether body length differed significantly between various groups of sculpin and trout (mobile versus nonmobile, unmarked versus marked, and long distance movers [>1,200 m] versus all mobile individuals). To compare the number of up- versus downstream captures and morning versus evening captures, we used the exact binomial test in S-Plus 6.0. Validity of all tests depends on the possibly erroneous assumption that each animal's behavior after release was independent of its behavior before capture.

Results

We captured 567 fish of seven species in 24 d of trapping and marked nearly all of them (Table 1). Westslope cutthroat trout and sculpin had the greatest number of captures and recaptures. Both westslope cutthroat trout and sculpin were captured more frequently in downstream than upstream traps and more often during night/twilight than during day (Table 2). With data from trap D excluded, westslope cutthroat trout moved downstream more often than upstream during the night (127 versus 69, respectively, $P < 0.0001$), but during the day they moved downstream less often than upstream (25 versus 48, respectively, $P < 0.0001$). We found no significant differences in lengths among any of the groups of westslope cutthroat trout or sculpin (Table 3).

Westslope Cutthroat Trout

We recaptured 47% of the marked westslope cutthroat trout in traps (Table 1), including 41 fish that were recaptured more than three times, and 53% of the recaptured fish were mobile. Eighty-two nonmobile fish were captured moving in two directions but had net movements of less than 83 m, the maximum distance between weirs included in this analysis. Net movements by mobile fish ranged up to 1,581 m (Figure 2A), and the longest upstream movements were 293 m (five fish). No westslope cutthroat trout marked in the lower section was recaptured in the upper section, though 12 were marked in the upper section and recaptured in the lower section (movements >1,200 m; Figure 2A). Of all recaptured fish, 57 moved unidirectionally (21 upstream, 36 downstream; $P = 0.06$), and 116 moved bidirectionally. Bidirectional movements ranged from less than 18 to 1,581 m (median, 64 m).

Estimated population sizes for westslope cutthroat trout in the upper and lower sections were 384 and 60 fish, respectively (Table 4). Based on those estimates, 14% and 48% of the westslope cutthroat trout were mobile in the upper and lower sections.

Sculpin

Of the 172 sculpin we captured and marked, 30% were recaptured in weirs (Table 1), and 67%

TABLE 2.—Upstream versus downstream captures of westslope cutthroat trout and sculpin in traps (excluding trap D [see text]) throughout the study and night–twilight versus day captures (including trap D) over 8 d in Chamberlain Creek, Montana. Significance values are from exact binomial tests.

Species	All traps except D for duration of study			All traps 24 Jul–1 Aug 2001		
	Up	Down	P	Day	Night	P
Westslope cutthroat trout	238	296	0.0136	73	204	<0.0001
Sculpin	25	86	<0.0001	6	75	<0.0001

TABLE 3.—Mean total length comparisons and significance values from *t*-tests comparing various groups of westslope cutthroat trout and sculpin. Unmarked fish were captured by electrofishing; SDs are given in parentheses.

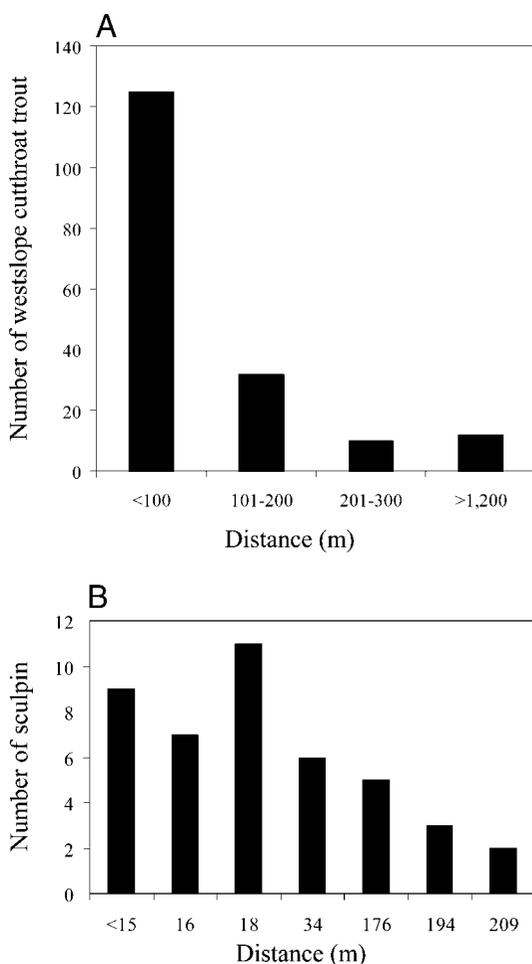| Groups compared	Lengths (mm)	P
Westslope cutthroat trout[a]		
Marked vs. unmarked	112 (38) vs. 109 (32)	0.29
Mobile vs. nonmobile	108 (33) vs. 109 (31)	0.59
Moved >1,200 m vs. mobile	107 (22) vs. 105 (24)	0.21
Sculpin[b]		
Marked vs. unmarked	73 (10) vs. 72 (15)	0.41
Mobile vs. nonmobile	80 (17) vs. 77 (19)	0.25

[a] Fish in upper section.
[b] Fish in lower section.

FIGURE 2.—Distribution of net distances moved by **(A)** westslope cutthroat trout and **(B)** sculpin marked and recaptured in fish traps over 1.6 km of Chamberlain Creek during 3 weeks in summer 2001. Because of the spacing of the weirs, we could not detect movements between 300 and 1,200 m in length.

of those recaptured were mobile. The longest movement detected in each direction was 209 m (one fish in each direction), the total distance enclosed by traps in the lower section. Median movement distance was 18 m (Table 1; Figure 2B). Eighteen sculpin made net bidirectional movements from less than 18 to at least 176 m (median, 26 m). No sculpin marked in the lower section were recaptured in the upper section. Of all recaptured sculpin, 26 moved in one direction (3 upstream, 23 downstream; $P < 0.01$), and 25 moved bidirectionally (including 8 recaptured only at upstream trap D, their original marking location).

The estimated population size of sculpin in the lower section was 266 fish (Table 4). Catch rates of 1.2 and 0.5 fish/m in the lower and upper sections, respectively, indicate that sculpin were abundant in the upper section, although only two were captured in traps.

Response to High Flows

Stream discharge and temperature were relatively constant throughout the study except from 31 July to 1 August, when heavy rain dramatically increased discharge and reduced stream temperatures (Figure 3). After the storm, stream discharge and temperature quickly returned to prestorm levels. Although westslope cutthroat trout captures increased slightly from previous days as discharge rose (Figure 3), we observed no dramatic changes in westslope cutthroat trout movements after the event (Figure 3). After the storm, recapture locations of marked fish did not indicate that a large number of fish had moved during peak flows while the weirs were inoperable.

Discussion

Our results show that a portion of the fish community in a headwater stream is mobile during summer and that some fish travel considerable dis-

TABLE 4.—Population estimates and densities for westslope cutthroat trout and sculpin in two sections of Chamberlain Creek in August 2001. The number marked is the number of marked fish expected to be in each section during electrofishing. The number captured by electrofishing and the number of those that were previously marked (number recaptured) are shown, as are percentages of populations that were mobile (captured at >1 weir). For this analysis, the lower section was between weirs A and C and the upper section between weirs E and J (Figure 1).

Section	Species	No. marked	No. captured	No. recaptured	Population estimate[a]	Density (fish/m)	% mobile
Lower	Westslope cutthroat trout	29	10	9	60 ± 25	1.76	48
Lower	Sculpin	37	36	5	266 ± 185	7.80	14
Upper	Westslope cutthroat trout	54	305	50	384 ± 98	0.76	14

[a] Mean and 15% confidence interval.

tances. Furthermore, nearly half of the sculpin and more than two-thirds of westslope cutthroat trout recaptured moved bidirectionally. Because of the midsummer timing and the bidirectionality of movements, we suggest that much of the movement we detected was not out-migration but rather movement maintaining or defending a home range. However, for most individuals, we did not have enough recaptures to fully characterize a home range (Natsumeda 2001); thus, our estimates of home range size are crude.

Although direct comparisons to other movement studies are difficult (owing to different monitoring methods, timing, and duration of studies), we encountered longer median home range movement by cutthroat trout than the median, or average,

movements in other studies (4 m: Heggenes et al. 1991; 18 m: Miller 1957; 45 m: Young 1996; and 55 m: Hilderbrand and Kershner 2000). Generally, authors (including those cited above) conclude that cutthroat trout movement (if detected) decreases after spawning; fish that are mobile during spring become more sedentary during summer. Studies of other age-1+ salmonines indicate that upstream movements may predominate during summer (Gowan and Fausch 1996; Adams et al. 2000; Kahler et al. 2001), but we observed slightly more downstream movement, as did Young (1996, 1997). Sculpin movements were dramatically different between the upper and lower study sections. Our recent genetic and morphological data (unpublished) suggest that the mottled sculpin–like
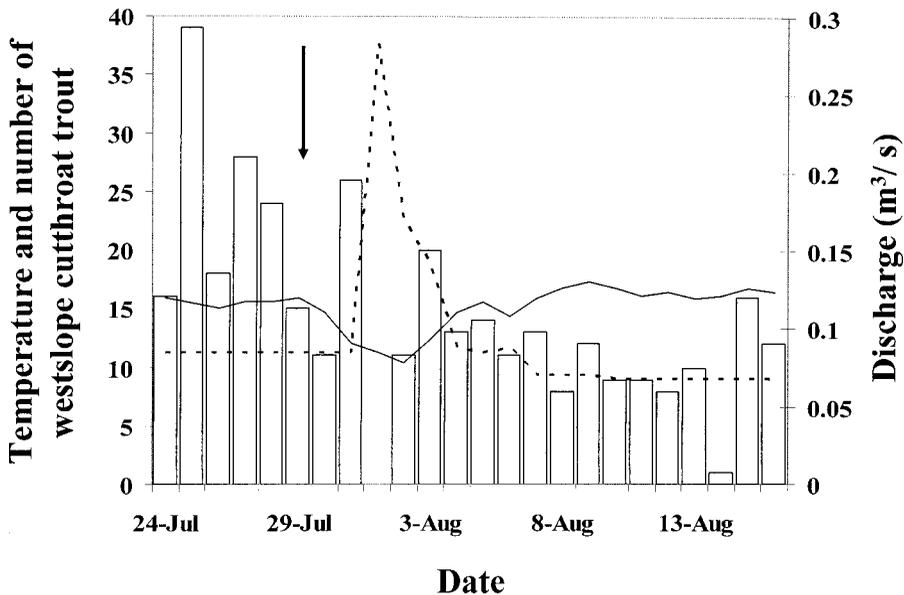

FIGURE 3.—Daily stream discharge (dashed line) and maximum daily water temperature (°C; solid line) of Chamberlain Creek, Montana, and total number of westslope cutthroat trout captures from weirs E, H, and J in the upper trapping section during the 2001 study. Arrow indicates date when we relocated weirs. Traps were not operational from the afternoon of 1 August until the morning of 2 August.

species is restricted to the section downstream of the diversion dam, whereas slimy sculpin are only located near the upper study section. Therefore, behavioral differences (including summer movement patterns) may be attributable to there being two different species in Chamberlain Creek.

In the lower study section, we documented sculpin movements as long as 209 m, longer than previously reported for any freshwater sculpin in North America. Most earlier papers report that mean (for populations) movements during the non-breeding season were shorter than 50 m (e.g., McCleave 1964; Greenberg and Holtzman 1987; Natsumeda 1999), sometimes as limited as 1.2 m (in a Montana stream, Brown and Downhower 1982). The mean reported home ranges of other freshwater sculpin species (<18 m) are smaller than the median bidirectional movement distances we observed (26 m), and the maximum home range size we observed (176 m) was much longer than the longest reported previously (45 m: McCleave 1964; Hill and Grossman 1987; Natsumeda 1999). Furthermore, for three reasons, we infer that summer movements in the sculpin population were even longer than those we detected: (1) 209 m was the maximum distance between weirs in the lower section; (2) many upstream movements ended at the diversion dam, which we believe acts as a barrier to sculpin movement (Utzinger et al. 1998); and (3) the weirs in the lower section were in place for fewer than 3 weeks.

Although real differences in movements undoubtedly exist among various sculpin populations and species, we suggest that our use of weirs is a major reason why we observed longer movements. Nearly all of the studies cited used mark–recapture methods and generally recaptured fewer than 30% of marked individuals. Thus, the conclusions of limited movements were based on the assumption that marked individuals had not left the study area. Of the sculpin marked in our lower study section, 23% moved farther than 100 m in less than 3 weeks. Conversely, 21% did not pass more than one weir. Many of the mark–recapture studies on sculpin have recapture rates of less than 30%. Our results imply that many of the fish that were not recaptured in other studies may have left the study area, as recognized by Shetter and Hazzard (1939) and modeled for salmonines by Gowan and Fausch (1996).

The high density of sculpin does not necessarily explain the extensive movements we observed, as has been argued for salmonines (Bjornn 1971). Densities in the lower section of Chamberlain Creek were similar to densities of mottled sculpin in populations whose observed movements were shorter (McCleave 1964). Moreover, in another study, sculpin (*C. gobio*) movements were inversely related to density (Downhower et al. 1990).

Sculpin typically show a strong tendency toward nocturnal foraging (Greenberg and Holtzman 1987), banded sculpin *C. carolinae* moving from the undersides to the tops of rocks at dusk and back at dawn (Greenberg and Holtzman 1987). During diel comparisons, we caught many sculpin in trap D, but lack of a downstream trap at D precluded making diel directional comparisons. We concluded that at least upstream movements were much more common at night/twilight than during day. The sculpin in Chamberlain Creek may have been making foraging movements but over longer distances than shown in other studies.

Whereas cutthroat trout are generally considered diurnal foragers (Young 1997), they make some movements between day and night habitats. We observed westslope cutthroat trout diel movements similar to those of Bonneville cutthroat trout, which Hilderbrand and Kershner (2000) reported moving at dawn or dusk but not during the day. Bonneville cutthroat trout moved into low velocity areas at night and higher velocity areas during the day for feeding (Hilderbrand and Kershner 2000). However, Colorado River cutthroat trout *O. c. pleuriticus* did not exhibit any such pattern (Young 1997).

We may have underestimated the proportion of fish moving and the distances moved because fish captured and marked at the end of the study had less time to move than those marked earlier. However, the short duration of the study minimized such effects. Similarly, we may have underestimated the mobile portion of the westslope cutthroat trout population in the upper section because some traps were more widely spaced (as much as 114 m apart) than in the lower section; as a result, fewer fish were marked and longer movement distances were required before a fish was categorized as mobile. Although our electrofishing capture efficiency for westslope cutthroat trout was high in the upper section, the small number of fish marked led to a wide confidence interval. In the lower section, wide confidence intervals resulted from low electrofishing capture efficiency for both westslope cutthroat trout and sculpin. Although we accounted for immigration, emigration, and some mortality (dead fish in traps), losses from undetected movements in and out of study sections are

a potential source of error in our estimates of population sizes and mobile portions of populations.

Mobile sculpin and westslope cutthroat trout did not differ in body length from the nonmobile fish, agreeing with results for other salmonines that suggest the mobile fish are not predominantly competitively inferior individuals forced out of their habitats (Chapman 1962; Gowan and Fausch 1996; Kahler et al. 2001). In Colorado streams, mobile brook trout were longer but in poorer condition than nonmobile fish, suggesting that mobile fish were seeking superior foraging sites (Gowan and Fausch 1996). Mobile and nonmobile fish may be displaying different foraging strategies (McLaughlin 2001).

Stream size may contribute to differences among studies in summer movements observed in stream resident or juvenile fluvial fish. Westslope cutthroat trout may have moved more in this than cutthroat trout in other studies (Miller 1957; Heggenes et al. 1991; Northcote 1992), in part because of Chamberlain Creek's small size. The median distances moved exceeded the median habitat unit lengths by at least 2.5 times for all species and by much more for westslope cutthroat trout, indicating that fish are moving among multiple habitat units. Movement between habitat units may be as meaningful as distance as a measure of movement (Kahler et al. 2001). Fish in larger streams may be able to fulfill their summer habitat and foraging needs by moving laterally, as well as longitudinally, all while staying within a discrete habitat unit (Young et al. 1997). However, in Chamberlain Creek, fish may have to move up- and downstream to obtain equivalent food or habitat resources.

Management Implications

In addition to the many existing barriers resulting from road crossings, dams, and water diversions, constructing barriers is becoming a common tool to protect or isolate native fishes from negative interactions with nonnative species (Young 1995). However, extensive fish movements potentially could lead to individuals moving downstream past some barriers and being unable to return. The movements we observed underscore the necessity of maintaining habitat connectivity for fish throughout the year. Continued research into aquatic movements by diverse taxonomic groups will improve awareness of the need to provide passage as well as suggest means for how to accomplish the goal.

Low-head water diversion dams, culverts, and other obstructions occur in many small tributaries throughout the USA, and many inhibit or prevent upstream fish movements, especially during low flows (Baker and Votapka 1990; Warren and Pardew 1998). Numerous efforts are underway to improve fish passage at such structures. However, in most coldwater systems, the emphasis has been on improving upstream salmonine passage to allow access for spawning fish. Less attention has been given to salmonine passage during low flows and virtually none to juvenile salmonid upstream passage or to passage of nongame fish in either direction at any time (Winter and VanDensen 2001). Because sculpin have poorer swimming and jumping abilities (Utzinger et al. 1998) than salmonines, sculpin may be a more appropriate target species for determining community impacts of potential migration inhibitors. The possible role of barriers in altering sculpin movement patterns and in segregating or isolating populations or species may be a fruitful avenue for future research. In studies involving stream weirs, we encourage investigators to include movements by as many species as possible rather than limit efforts to one target species.

Acknowledgments

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