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CONTRASTING MOVEMENT AND ACTIVITY OF LARGE BROWN TROUT AND RAINBOW TROUT IN SILVER CREEK, IDAHO

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ABSTRACT.—Recent radiotelemetry studies demonstrated that stream-dwelling trout are mobile, but few have compared sympatric species. We used radiotelemetry to simultaneously monitor positions of 20 brown trout and 21 rainbow trout from May or June 1994 to February 1995 in Silver Creek, a small spring-fed stream in south central Idaho. Our biweekly observations from May to September indicated that rainbow trout had larger home ranges (medians, 606 m v. 131 m) and moved greater distances (medians, 1109 m v. 208 m) than brown trout. Furthermore, rainbow trout used more positions than brown trout (means, 7 v. 3) over this interval. Hourly diel monitoring revealed no significant difference in 24-h home ranges of rainbow trout and brown trout (means, 77 m v. 105 m). However, activity patterns of the 2 species differed; rainbow trout activity was usually highest during the day, whereas brown trout activity tended to peak at night. Differences in foraging strategies and response to disturbance may be responsible for differences in mobility.

Key words: diel activity, home range, movement, brown trout, Salmo trutta, *rainbow trout,* Oncorhynchus mykiss.

Until recently stream-dwelling trout often were considered relatively sedentary, with home ranges <50 m (Gerking 1959, Northcote 1992). Rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*) were thought to exemplify this pattern (Klein 1974, Solomon and Templeton 1976, Hesthagen 1988). In part because of the advent of radiotelemetry, stream trout mobility has received greater notice, and seasonal movement may be more prevalent than previously believed (Gowan et al. 1994). For example, mean summer/fall home range of very large (>435 mm) brown trout exceeded 4.9 km in the Au Sable River in Michigan (Clapp et al. 1990), median summer home range of large (>340 mm) brown trout was >400 m in North Platte River tributaries in Wyoming (Young 1994), and median home range of small (<240 mm) Colorado River cutthroat trout (*O. clarki pleuriticus*) was 233 m in a small Wyoming stream (Young 1996). No seasonal radiotelemetry study of rainbow trout in streams has been reported.

Most movement studies have focused on long temporal scales, i.e., movement over weeks, seasons, or years (Miller 1957, Mense 1975, Riley et al. 1992). But distances moved within a diel period have been largely overlooked (but see Clapp et al. 1990). Trout movement may vary between day and night due to changes in light intensity, prey availability, and water temperature. Other behaviors change during the diel cycle. Campbell and Neuner (1985) and Hill and Grossman (1993) noted that rainbow trout move inshore and become less active at night, and feeding by rainbow trout apparently declines at night (Angradi and Griffith 1990). Brown trout were reported to feed primarily in the evening (Elliott 1973) or during the day (Bachman 1984). Clapp et al. (1990) noted that large (>430 mm) brown trout tend to be more active at night, but patterns fluctuated monthly.

There are few comparisons of diel and seasonal mobility of sympatric salmonids. Bjornn and Mallet (1964) evaluated movements of rainbow trout, westslope cutthroat trout (*O. c. lewisi*), and bull trout (*Salvelinus confluentus*) in the Middle Fork Salmon River, Idaho, but results were based on angler recoveries of tagged fish over several years. Matthews et al. (1994) used radiotelemetry to monitor diel changes in rainbow trout and brown trout habitat use, but monitoring lasted only a month and only 1 brown trout was tagged.

Our objectives were to examine rainbow trout and brown trout position changes from late May to early February and to compare

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their movement and activity over several diel periods in a small stream with naturalized populations.

STUDY AREA

Silver Creek is a spring-fed tributary of Little Wood River on the northern edge of the Snake River plain, south central Idaho. Mean monthly discharge for 1994 ranged from 1.7 $m^3 \cdot s^{-1}$ in September to 5.1 $m^3 \cdot s^{-1}$ in March. Discharge increased in autumn after irrigation of farmlands ended. Stream gradient of the study area is 0.8–1.0 $m \cdot km^{-1}$ and stream width is 15–30 m. Aquatic macrophytes, especially *Chara vulgaris* and *Potamogeton* spp., are abundant in summer, and silt is the predominant substrate, with areas of gravel and marl. Much of the riparian habitat consists of dense, overhanging stands of willow (*Salix* spp.) and birch (*Betula* spp.). Other fish species are brook trout (*Salvelinus fontinalis*), mountain whitefish (*Prosopium williamsoni*), bridgelip sucker (*Catostomus columbianus*), redside shiner (*Richardsonius balteatus*), longnose dace (*Rhinichthys cataractae*), speckled dace (*Rhinichthys osculus*), Paiute sculpin (*Cottus beldingi*), and Wood River sculpin (*Cottus leiopomus*; Wilkison 1996).

We investigated trout movement in 2 noncontiguous reaches of Silver Creek. The upper reach is 4.1 km long and largely on a Nature Conservancy preserve where angling is permitted but no harvest allowed. The lower reach is 5.1 km long, and harvest is state regulated; 2 fish <305 mm or >406 mm can be kept. An intervening 3.8-km reach was periodically visited to determine presence of fish with transmitters.

METHODS AND MATERIALS

We collected rainbow trout (mean total length [TL] 419 mm, range 357–475 mm, n = 21) and brown trout (mean TL 494 mm, range 342–622 mm, n = 20) by angling or electrofishing and implanted transmitters on 13–15 May and 12–14 June 1994. We surgically implanted sealed, coiled-antenna transmitters in anesthetized fish in the body cavity immediately anterior to the pelvic girdle and released fish at or near the point of capture after recovery (see Young 1995 for details). We monitored fish by radiotelemetry until early February 1995. Only healthy fish were implanted.

To define the longitudinal position of each telemetry location, we staked the bank at 50-m intervals on a line parallel to the thalweg. Fish initially were located from a canoe, then from the stream bank where we measured distance to the nearest stake. Fish were generally located once or twice every 2 wk May–September; once or twice each month in October, November, and December, and once on 9 or 10 February 1995.

Diel observations of fish activity and movement began on 22 June, 12 July, 17 August, and 23 September. Groups of up to 7 fish (up to 4 fish per species) were monitored for 24 h. All positions were identified from the bank, and observers did not disturb fish. We attempted to monitor each fish every hour for at least 1 min, and longer if a fish was active. Number of fluctuations per minute in transmitter signal strength was used as an index of activity (Clapp et al. 1990); fluctuations resulted from changes in transmitter antenna orientation (caused by fish movement) relative to the receiver antenna. Sunset and sunrise were 2121 h MDT and 0558 h MDT on the 1st observation and 1933 h MDT and 0727 h MDT on the last observation.

We used telemetry to determine home range (difference between furthest up- and downstream points) and total distance moved (sum of all observed movements) from the 1st location after implanting to the end of September (summer) and to early February (overall), and during each 24-h cycle. For these calculations we disregarded initial capture position because some fish may have been displaced during electrofishing. We also excluded fish that were followed for fewer than 50 d (n = 5). Positions ≥10 m apart were considered different.

Biweekly movement data were nonnormal (Kolmogorov-Smirnov one-sample test; $P < 0.001$; n = 257 observations). To determine whether there were differences in movement among 2-wk intervals and between species from May to September 1994, we used 2-way Kruskal-Wallis tests. Home ranges and distances moved were analyzed by season: summer (May–September; n = 36) and overall (May–February; n = 23). Because most data also were nonnormal, differences in seasonal home ranges and distances moved between species were compared using Mann-Whitney tests. Number of positions occupied in summer was normally distributed and analyzed using t tests.

Water temperature was measured on a Ryan thermograph in the middle of the upper reach. We used daily maxima to calculate a mean maximum temperature for each 14-d period. We used rank correlation to relate mean biweekly maximum water temperature to median biweekly movement.

We compared percentage of fish active, mean signal fluctuations per minute, and mean distance moved in each 2-h period among 3 diel intervals: night, crepuscular periods (intervals containing sunset and sunrise), and day (remaining light hours). We used an arcsin transformation on the percentage of active fish. To correct for heteroscedasticity, we used a square root transformation on mean signal fluctuations per minute and mean distance moved. We examined differences between species and among times of day using 2-way analysis of variance, and we used Tukey's HSD test to compare activity at different times of day for each species. Data on diel home ranges and distances moved by each species were normal and were compared using *t* tests.

We used Biostat I, version 2.0 (Pimentel and Smith 1990), to perform the Kruskal-Wallis tests and the nonparametric Tukey's HSD tests for multiple comparisons, and SPSS/PC+, version 5.01 (SPSS 1992), for all other analyses. Throughout, we considered $P \leq 0.05$ as indicating significance.

RESULTS

Biweekly observations demonstrated that brown trout moved less than rainbow trout from May to September. In summer brown trout had smaller home ranges (medians, 131 m v. 606 m; $P = 0.046$) and moved shorter distances (medians, 208 m v. 1109 m; $P = 0.018$) than rainbow trout. Brown trout also used fewer positions than rainbow trout (means, 3 v. 7; $P < 0.001$). There were no significant differences ($P > 0.89$) in the overall home range (medians, 1158 m v. 941 m) and distance moved (medians, 1971 m v. 1687 m) between brown trout and rainbow trout, which we attributed to greater mobility of brown trout from October to February, possibly associated with spawning. Nonetheless, rainbow trout had the largest summer (3865 m v. 2530 m) and overall home ranges (10,390 m v. 3452 m).

Biweekly movement of brown trout was less than rainbow trout from May to September (medians, 6 m v. 46 m; $P < 0.001$; Fig. 1). Brown trout movement peaked in late May and then declined rapidly, whereas rainbow trout were relatively active throughout the summer, with peak movement 14–27 July. Median biweekly movement of rainbow trout was positively correlated with mean biweekly maximum water temperature ($r_s = 0.80$; $P = 0.001$), though this relationship may represent a threshold response to high temperature more than a consistent trend at all temperatures. Water temperature peaked on 21, 22, and 25 July at 19.5°C. Median biweekly movement of brown trout was not related to mean biweekly maximum water temperature ($r_s = 0.26$; $P = 0.49$).

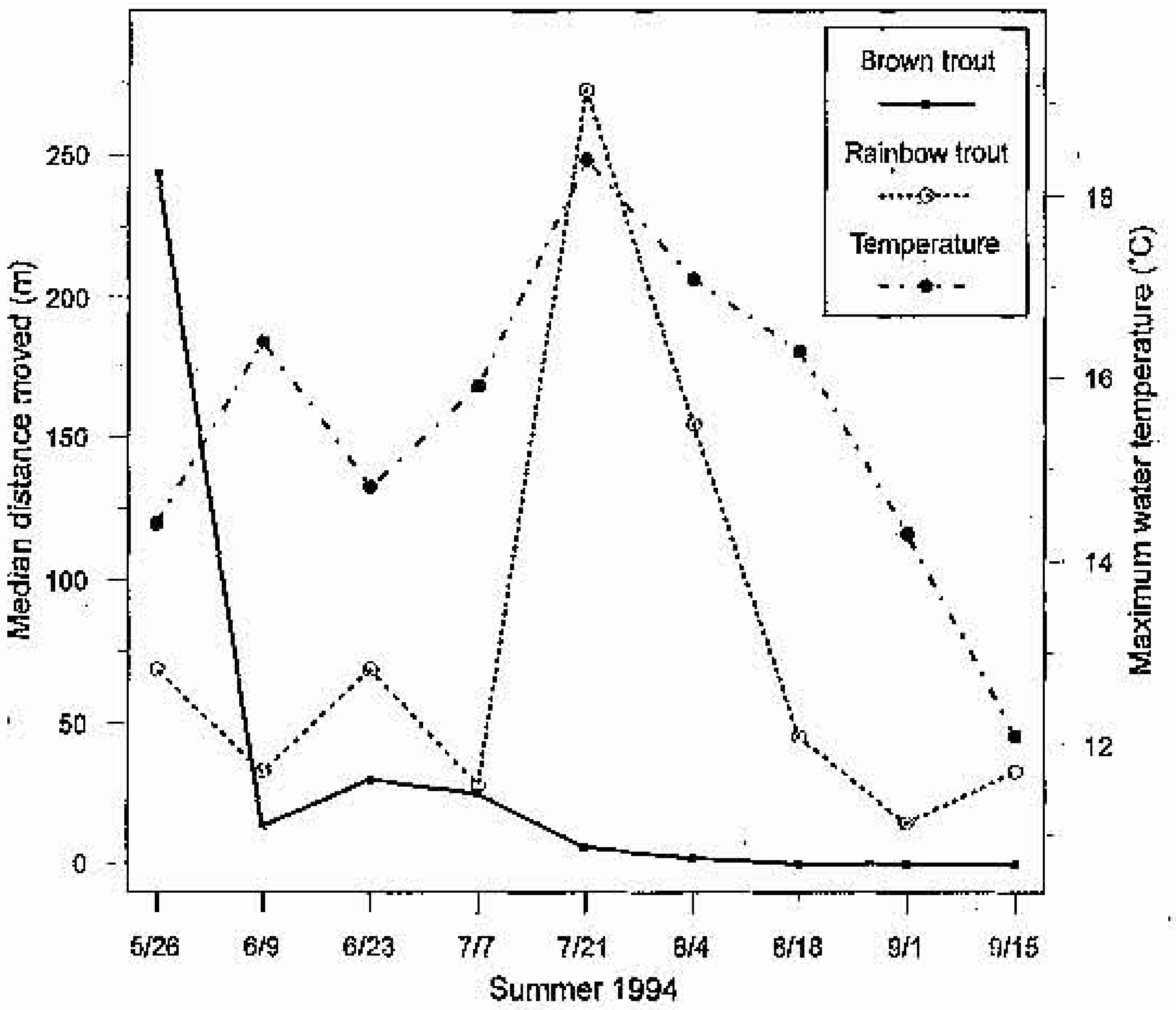

Fig. 1. Median biweekly movement of brown trout ($n = 18$) and rainbow trout ($n = 18$) from late May to late September 1994, Silver Creek, ID. Labels on the horizontal axis represent 2-wk midpoints.

Directional trends in movement were not evident. Nine of 36 trout followed in summer had moved up- and 7 had moved downstream >100 m. Eight of 22 trout followed until December or February had moved up- and 6 had moved downstream >100 m. Species differed, however, in fidelity to the site where first located. By September and by late winter, >60% of brown trout were found within 100 m of their first location. By September, <40% of rainbow trout were within 100 m of such sites, and by late winter, only 3 of 14 fish were. Such patterns suggest that brown trout use the same sites during the day throughout much of the year, whereas rainbow trout are less likely to use the same position consistently.

There were differences in diel activity between species. Throughout the diel cycle, rainbow trout had more signal fluctuations per minute than brown trout (means, 5 v. 4; $P = 0.003$), and a greater percentage of fish were active during 2-h observations (means, 87% v. 51%; $P < 0.001$). Furthermore, we observed contrasting behavior between species at different times (Table 1, Fig. 2). For brown trout the peaks in percentage of fish active and signal fluctuations per minute were at night; for rainbow trout these values were highest during the day and crepuscular periods. Whereas brown trout moved most during crepuscular periods and night, rainbow trout failed to demonstrate a significant diel pattern for this variable. There were no significant species differences ($P > 0.13$) in diel home range (means, 77 m v. 105 m) or diel distance moved (means, 192 m v. 274 m). Maximum diel home range for brown trout was 238 m and 352 m for rainbow trout.

Diel movements of brown trout were more predictable than those of rainbow trout. Brown trout left daytime locations each evening, and 8 of 10 returned before 0800 h the next day. In contrast, rainbow trout patrolled diel home ranges irregularly, often visiting the same positions throughout the 24-h cycle.

DISCUSSION

Home ranges of brown trout in Silver Creek were larger than in many other studies (Mense 1975, Bachman 1984, Hesthagen 1988), but differences may be attributed to differences in methods; i.e., tagging and mark-recapture techniques ignore behavior of marked fish that are not recaptured and tend to produce smaller home range estimates than radiotelemetry (Young 1994, Gowan and Fausch 1996). Yet the maximum home range of brown trout in Silver Creek was smaller than that of brown trout in other radiotelemetry studies (29 km, Hudson 1993; 34 km, Meyers et al. 1992; 96 km, Young 1994). Unlike those studies, we did not examine all downstream portions of Silver Creek, nor did we follow fish throughout an annual cycle; either factor could explain home range differences. Nevertheless, variables such as a greater food supply or environmental stability (e.g., reduced discharge variation or water temperature) may have rendered movement less advantageous than in other systems.

Feeding strategy and fish size may also contribute to differences in movement. Based on daytime bank observations in a Pennsylvania stream, Bachman (1984) contended that brown trout had small summer home ranges (ca 4 m long) and were active during the day. But brown trout in our study moved extensively and were largely nocturnal (also see Regal 1992, Hudson 1993). The largest fish in Bachman's (1984) study (330 mm) was smaller than the smallest brown trout in our study. Though both streams are productive spring creeks, brown trout >400 mm in Silver Creek forage primarily on large invertebrates and fish (Wilkison 1996), whereas adult brown trout in the Pennsylvania stream appeared to feed largely on drift. Piscivorous brown trout may forage more successfully at night and move to new habitats when prey become locally depleted or have fled to cover (Clapp et al. 1990). Drift-feeding juvenile brown trout in a New Zealand stream, however, were most active at night, perhaps in response to a nocturnal increase in macroinvertebrate drift (McIntosh and Townsend 1995).

TABLE 1. Activity patterns of brown trout and rainbow trout in Silver Creek, ID, May 1994 to February 1995, during the day ($n = 48$), crepuscular periods ($n = 16$), and night ($n = 32$) using means (standard deviations in parentheses) of untransformed variables. An asterisk (*) indicates a significant difference for the species main effect. For comparisons between different times of day for individual species, values followed by the same letter are not significantly different.

	Time of day		
Species	Day	Crepuscular	Night
Mean percentage of fish active*			
Brown trout	27(32)^{a}	60(43)^{ab}	83(32)^{b}
Rainbow trout	98(10)^{a}	92(15)^{ab}	69(35)^{b}
Mean fluctuations · min^{-1}*			
Brown trout	1(1)^{a}	2(2)^{a}	8(7)^{b}
Rainbow trout	5(2)^{a}	6(3)^{a}	3(3)^{b}
Mean distance moved (m) · 2 h^{-1}			
Brown trout	6(12)^{a}	56(73)^{b}	46(58)^{b}
Rainbow trout	15(13)^{a}	30(38)^{a}	12(6)^{a}

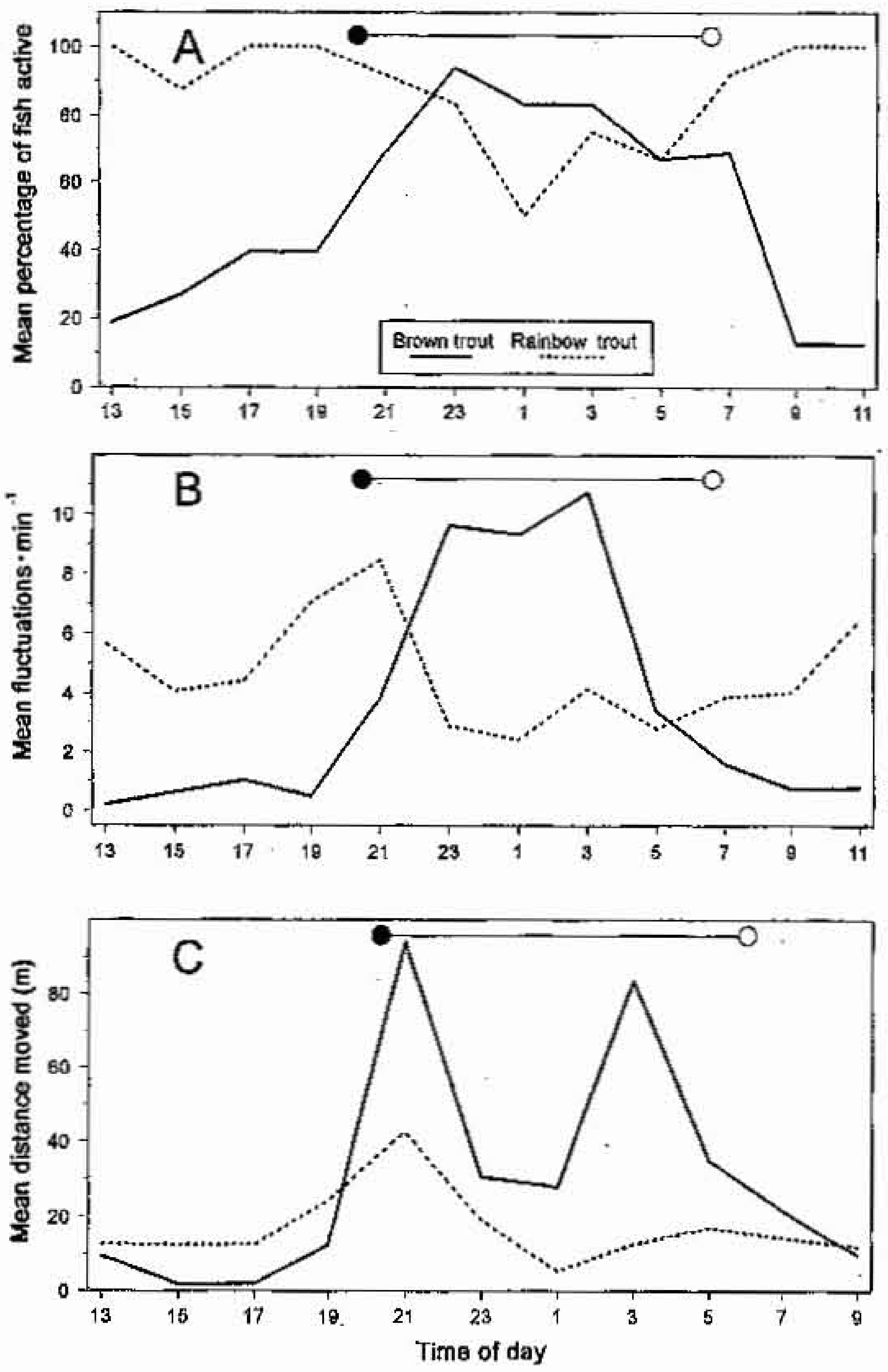

Fig. 2. Diel patterns of the (A) mean percentage of fish active; (B) mean signal fluctuations per min; and (C) mean distance moved per 2 h by species in Silver Creek, ID, on 22 June, 12 July, 17 August, and 23 September 1994 (n = 264 observations). Closed and open circles represent "average" times of sunset and sunrise, respectively. Note the change in the scale of the horizontal axis in C. Labels on the horizontal axis represent 2-h midpoints.

Rainbow trout in streams are assumed to feed primarily on drift (Elliott 1973, Tippets and Moyle 1978, Cada et al. 1987) and thus are unlikely to locally overexploit their prey. Stefanich (1952) also concluded that rainbow trout seemed more mobile than brown trout in a Montana stream. And unlike brown trout in this study and others (e.g., Clapp et al. 1990), rainbow trout showed little fidelity to daytime positions. Relative differences in movement in different streams may be related to stream size. For example, movements of rainbow trout in Silver Creek exceeded those of rainbow trout in a smaller Minnesota stream (Cargill 1980) but were less than those of rainbow trout in the larger Middle Fork Salmon River (Bjornn and Mallet 1964). Similarly, Young (1996) noted that Colorado River cutthroat trout isolated above a barrier moved less than fish in a larger connected stream segment below the barrier.

Different patterns of biweekly movement by each species were puzzling. We considered it unlikely that the early peak in brown trout activity was related to disturbance associated with electrofishing and surgery. Only 11 of 20 brown trout were implanted in mid-May. We implanted the remainder in mid-June, and the biweekly movement of this group in late June was less (median, 16 m) than that of brown trout implanted in May (median, 34 m). We speculate that brown trout movement in late May was associated with migration, possibly from outside the study area. We captured only 7 brown trout suitable for implanting during electrofishing of the lower reach of the study area in mid-May, but by mid-June large numbers of brown trout were observed and captured. Perhaps the fish captured in May were migrating to suitable summer positions, whereas brown trout captured in June had already selected such positions (see Bridcut and Giller [1993] for a similarly timed peak in brown trout emigration). Year-round tracking over a larger area would be necessary to test this assertion. The late July peak in rainbow trout movement may be attributed to fish moving to lower water temperatures, but we did not observe this species concentrating in particular areas. Clapp et al. (1990) and Meyers et al. (1992) attributed large-scale movements of brown trout to changes in water temperature, and Nielsen et al. (1994) noted that juvenile steelhead move to colder habitats as water temperatures increase. Rainbow trout also may have moved in response to decreases in dissolved oxygen. Summer fish kills attributable to hypoxia have been noted in several reaches of Silver Creek in previous years (Paul Todd, The Nature Conservancy, personal communication). Nonetheless, we cannot discount that variables such as food availability or macrophyte growth could have contributed to rainbow trout movement.

Adult rainbow trout tended to be most active during the day, which may reflect foraging preferences. Although rainbow trout can feed on drift at night (Jenkins 1969), evidence suggests this behavior is uncommon in summer (Edmundson et al. 1968, Campbell and Neuner 1985, Angradi and Griffith 1990, but see Matthews et al. 1994). Warner and Quinn (1995) noted that lentic rainbow trout moved less at night and remained inactive for long periods. Another drift-feeding species, Colorado River cutthroat trout, was consistently active only before dusk and after dawn (Young et al. in press).

In part, differences in the activity of brown trout and rainbow trout may have led to differences in summer home range and biweekly movement. Disturbed rainbow trout tended to move up- or downstream but did not seek cover. During electrofishing we observed schools of rainbow trout fleeing downstream, and we often chased them for >100 m. Because rainbow trout were active during the day, we believe that anglers frequently displaced these fish. But because brown trout often were concealed in cover during the day (see also Clapp et al. 1990, Young 1995), they were less likely to be disturbed by anglers, and those we monitored typically sought nearby cover when displaced. Lack of significant diel trends in rainbow trout movement, despite the customary trend in angler presence, suggests that angler disturbance explains only part of the difference between the 2 species. Factors such as site-specific variability in macroinvertebrate drift, inherent behavioral differences, or competitive displacement by brown trout (Gatz et al. 1987) also contribute to the greater movement by rainbow trout in summer.

Because of the growing use of radiotelemetry (Clapp et al. 1990), intensive electrofishing (Decker and Erman 1992), and 2-way fish traps (Riley et al. 1992), the prevalence of movement in stream-dwelling trout has begun to receive greater recognition. Use of radiotelemetry has enhanced the estimation of home range size and the distance that fish move, but inadequate temporal sampling may still overlook certain fish movements. For example, a 576-mm brown trout was observed in the same daytime position from 12 June 1994 to 10 February 1995; thus it had an overall daytime home range of zero. But on 3 occasions it had diel home ranges of 31 m, 121 m, and 141 m, respectively. Furthermore, median summer and mean diel home ranges (131 m v. 105 m) and distances moved (208 m v. 274 m) for brown trout were similar. These results highlight the importance of diel monitoring in evaluations of movement by stream fishes.

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