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Instream Movements by Boreal Toads (*Bufo boreas boreas*)

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Determining the nature and extent of bufonid movements is critical to understanding the autecology of each species, as well as to developing effective conservation strategies. Within many toad (*Bufo* spp.) populations, individuals must migrate considerable distances to reach habitats essential for fulfilling requirements that change seasonally and ontogenically (deMaynadier and Hunter 2000; Sinsch 1990). Summer home range movements (*sensu* deMaynadier and Hunter 2000) are often necessary to allow individuals to meet multiple resource needs (e.g., food and thermoregulation sites; Zug et al. 2001). Documenting movement patterns helps biologists determine the nature, timing, spatial extent, and distribution of habitat use by a species. Moreover, understanding movements can be essential to predicting the population-level effects of some ecosystem alterations (e.g., habitat alteration, creation of barriers to movements, or introduction of predators along travel corridors) and to planning habitat restoration that will conserve toad populations. Boreal Toads (*Bufo boreas boreas*) are declining throughout much of their range in western North America (Corn 2000); documenting their movement patterns may prove integral to understanding and arresting the declines.

Studies of toad movements often have documented long seasonal migrations and very limited summer home range movements, but the studies have focused on terrestrial travel and have not explored distances moved in aquatic habitats. Toads of many species make extensive movements, the longest are typically migrations up to several kilometers among spring breeding areas, summer foraging areas, and overwintering sites (deMaynadier and Hunter 2000; Kusano et al. 1995; Miaud et al. 2000; Sinsch 1988, 1990, 1992). Post-breeding movements within summer home ranges typically are restricted to several hundred meters (deMaynadier and Hunter 2000; Kusano et al. 1995; Sinsch 1988, 1990, 1992).

Several studies indicate that Boreal Toads, like other toad species, sometimes make long seasonal migrations (0.9–2.4 km; Bartelt 2000; Campbell 1970a; Muths 2003), but make considerably shorter summer home range movements (Campbell 1970b). Although metamorphosed Boreal Toads are considered "largely terrestrial" except during the breeding season (Nussbaum et al. 1983), they do occur along the edges of rivers and streams (Carpenter 1954; Olson et al. 1997; Robinson et al. 1998). Evaluating Boreal Toad travel via streams could enhance our understanding of home range size, dispersal distances and routes, and the effects of disturbance on dispersal (McGee et al. 2002). We evaluated instream movements in northern Rocky Mountain populations of Boreal Toads. Our objectives were to determine the prevalence, distance, and diel timing of summer movements by juvenile and adult Boreal Toads in three western Montana streams.

Materials and Methods.—In Summer 2001, we studied Boreal Toad movements in Chamberlain Creek, a second-order perennial tributary to the Blackfoot River, Powell County, Montana, draining 87.2 km^2 (Fig. 1). The study segment had channel slopes of 1.5–2.0%, a mean wetted width of 4.1 m, substrate dominated by gravel and cobble (2–64 and 64–256 mm diameter, respectively), and an elevation of 1180 m at its mouth. During the study, mean discharge was 0.09 m^3/s, and maximum water temperature was 17.3°C.

In Summer 2002, we studied movements in Little Blue Joint and Slate creeks, second-order streams in the West Fork Bitterroot River basin, Ravalli County, Montana (Fig. 1). Little Blue Joint Creek had a mean wetted width of 3.2 m, mean channel slope of 3.2%, median substrate particle size of 36 mm, and elevation of 1449 m at its mouth. The riparian zone adjacent to the study reaches in Little Blue Joint Creek burned in Summer 2000, but contained abundant coarse woody debris and lush regrowth of forbs and grasses in 2002. Slate Creek had a mean wetted width of 6.3 m, mean channel slope of 2.2%, median substrate particle size of 41 mm, and elevation of 1441 m at its mouth. Mature conifers and deciduous shrubs bordered the Slate Creek study reaches. Maximum water temperatures during the study were 17.9°C in Little Blue Joint Creek and 14.1°C in Slate Creek.

In both years, we captured Boreal Toads in streams using two-way weirs made of two hoop nets facing opposite directions that were connected to each other and to both banks by leads (0.5–4.0 m long). Hoop nets, constructed of multifilament nylon netting (0.6-cm bar length), were 2.0 m long. Minimum diameters of the funnels were 4.0–7.5 cm, and hoop diameters ranged from 30 to 38 cm, depending on stream size. We refer to the hoop nets that captured animals moving downstream as "downstream traps."

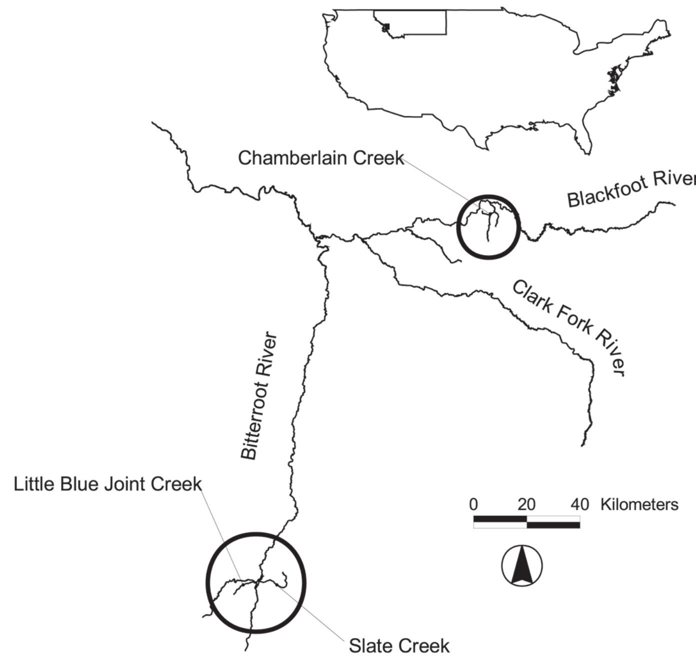

FIG. 1. Locations of the three study streams (circles) in western Montana, USA.

We operated the weirs in Chamberlain Creek from 23 July to 16 August 2001, except for 24 h beginning on 1 August during high stream flows. We divided the study segment into upper and lower sections, separated by a nonoperating, low-head diversion dam. On 23 July, we installed six two-way weirs, spaced 8–114 m apart (at least two riffle-pool sequences), in the upper section (Schmetterling and Adams 2004). On 30 July, we moved three of the weirs to the lower section and spaced them 16–18 m apart (one riffle-pool sequence). Three weirs in the upper section remained in place, so after 30 July, the six weirs encompassed 1.6 km of the creek. In all streams, we chose weir locations based on fish distributions and habitat features, but not on toad distributions.

During summer 2002, we operated eight weirs in both Little Blue Joint (11 July–16 August) and Slate (16 July–16 August) creeks. Spacing between weirs ranged from 185 to 2496 m, and weirs enclosed 4.5 km of Little Blue Joint Creek and 3.1 km of Slate Creek.

We checked all traps at least daily (except 5 August 2002), counted all and measured most boreal toads (snout–vent length, SVL) on a measuring board, and released toads in the direction they were moving when captured. To distinguish nocturnal or crepuscular from diurnal movements, we checked traps in mornings and evenings from 24 July to 1 August 2001 in Chamberlain Creek.

We distinguished juvenile from adult toads a posteriori based

Table 1. Number of juvenile and adult Boreal Toad captures and mean SVL (range) in three western Montana streams. Captures and mean lengths include multiple captures of individual toads.

Stream	Year	Juveniles		Adults	
		Captures	Length (mm)	Captures	Length (mm)
Chamberlain	2001	0	—	19[a]	93 (79–107)
Little Blue Joint[b]	2002	49	32 (24–47)	43	89 (67–110)
Slate	2002	21	31 (15–47)	119[c]	95 (55–125)

[a]Includes five captures of toads that were not measured but were known to be adults.
[b]One toad was not measured and is not included in counts.
[c]Includes one toad that was not measured but was known to be an adult.

on length. Length-frequency histograms showed two distinct groups; therefore, we classified toads < 55 mm SVL as juveniles and larger individuals as adults (Table 1; consistent with Nussbaum et al. 1983; Olson et al. 1986).

We marked adult toads with visible implant elastomer or acrylic paint on the ventral side of the mandible; most juvenile toads were too small to mark using this method. Although marks were unique to weirs, not individuals, we distinguished among marked individuals via a combination of marks, capture date, and SVL. In Chamberlain Creek, we marked all adult toads, beginning on the third day of trapping. In Little Blue Joint and Slate creeks, although we recorded captures and measured toads daily at all traps, we marked toads on only four days (Table 2) and at four traps in each stream. The four traps were each 195–607 m from neighboring traps and included the upstream-most trap on both streams. We checked toads for previous marks at all traps on four days (Table 2). Thus, the sample sizes for mark-recapture data were much smaller than for frequency-of-capture data in Little Blue Joint and Slate creeks.

We used capture data to describe the frequency and temporal patterns of toad movements in streams and to determine the ratio of juvenile to adult captures. We used linear regression to test for temporal trends in the number of captures of juvenile and adult toads in Little Blue Joint and Slate creeks. We used mark-recapture data to characterize the distances and directions moved by individual adult toads in all three streams. "Net movement" is the distance between the most distant captures for an individual.

Results.—We observed frequent movement by Boreal Toads in all streams. We made 252 captures (70 juveniles, 181 adults, 1 unknown; Table 1), all in downstream traps, and captured some toads more than once (e.g., see Table 3). During the eight days of diel movement comparisons in Chamberlain Creek, all six Boreal Toad captures (all adults) were made during night or twilight.

Recaptures of marked toads indicated that some adult toads moved hundreds of meters during both summers and in all three streams, although most recaptures were from Chamberlain and Slate creeks (Table 3). In Chamberlain Creek, we recaptured 5 of 11 marked toads, and the median net distance moved by recaptured individuals was 294 m (median daily movement, 73 m). In Little Blue Joint and Slate creeks, we recaptured 7 of 18 marked toads, and median distance moved was 353 m (median daily movement, 71 m). Two juvenile toads were marked, but neither was recaptured.

Toads traveled both up- and downstream, but downstream movements predominated. Although all recaptures were made in downstream traps, four recaptured toads had traveled upstream, bypassing weirs. The longest movement we documented (1.5 km in 6 days) was directed upstream, and the toad bypassed four weirs. In addition, at least two toads bypassed a weir while moving downstream.

The ratio of juvenile to adult toads captured varied among streams (Table 1, Fig. 2). We did not capture any juvenile toads in Chamberlain Creek. The proportion of juvenile-to-adult toad captures differed significantly between Little Blue Joint and Slate creeks, even when we restricted analysis to captures made during the same time period (15 July–15 August, $\chi^2 = 14.04$, $P < 0.001$). Although the numbers of juvenile toad captures made after 15 July were similar between the two streams, about three-fold more adult captures were made in Slate Creek.

Table 2. Number of Boreal Toads marked and recaptured by date in three western Montana streams. Number of recaptures includes repeat recaptures of the same individual, whereas cumulative number recaptured includes only the number of unique individuals recaptured.

Date	Cumulative number marked	Number recaptures	Cumulative number recaptured
Chamberlain Creek			
26-Jul-01	2	—	—
31-Jul-01	4	0	—
3-Aug-01	6	0	0
5-Aug-01	7	0	0
9-Aug-01	8	1	1
10-Aug-01	8	1	2
11-Aug-01	8	1	2
14-Aug-01	9	1	3
15-Aug-01	11	0	3
16-Aug-01	—	2	5
Little Blue Joint Creek			
29-Jul-02	1	—	—
30-Jul-02	1	0	—
3-Aug-02	2	0	0
4-Aug-02	4	1	1
9-Aug-02	—	0	1
Slate Creek			
29-Jul-02	6	—	—
30-Jul-02	11	2	—
3-Aug-02	12	2	4
4-Aug-02	14	4	6
9-Aug-02	—	1	6

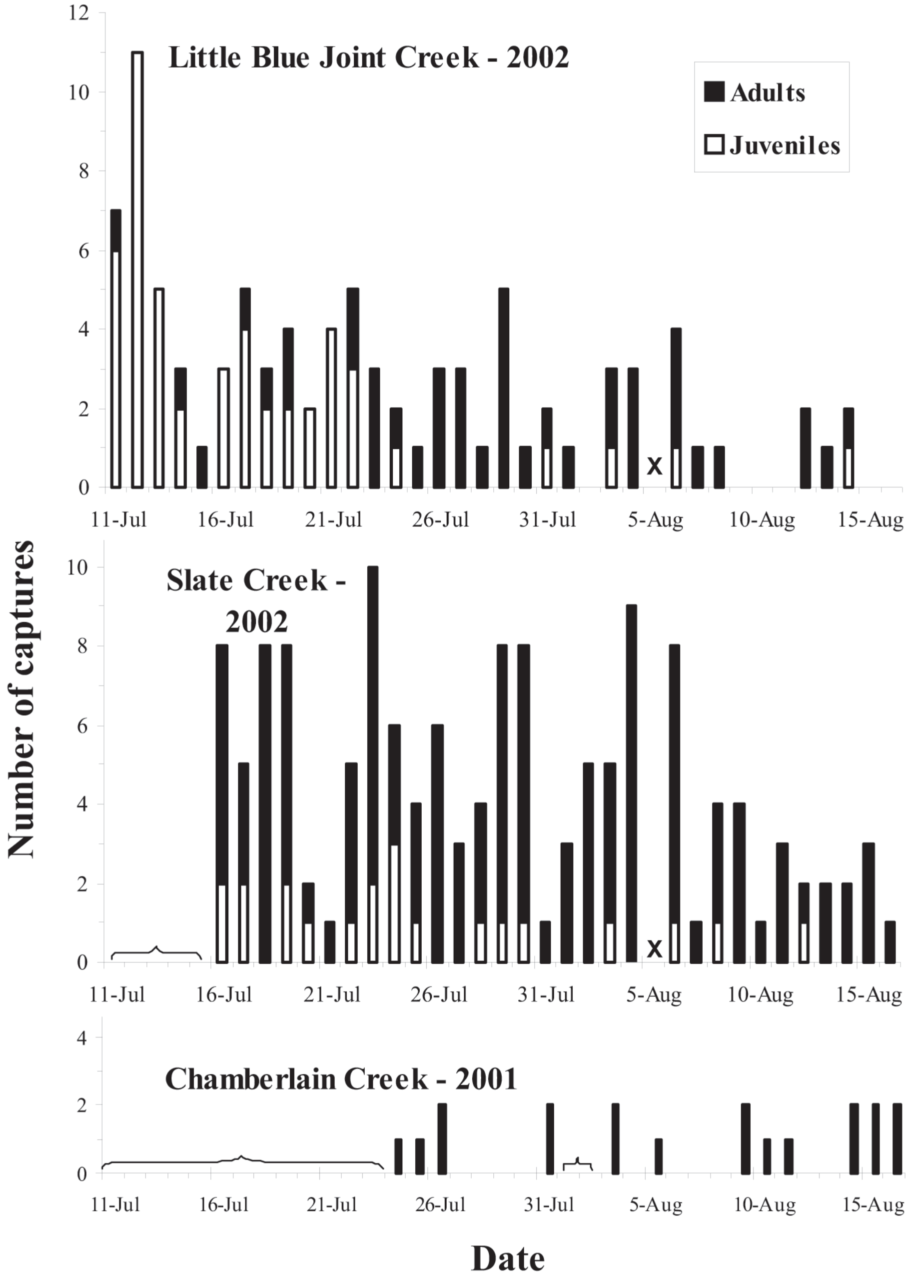

FIG. 2. Frequency of Boreal Toad captures in western Montana by stream, date, and life stage. Captures are from all traps in each stream. Brackets indicate dates when traps were not operated, and X's indicate when traps were operated but not checked. Although the Y-axis maximum varies among the graphs, the scales are identical.

Temporal trends in catch rates differed among streams. Captures of juvenile toads decreased significantly over the course of the study in Little Blue Joint ($N = 37$ days, $r = -0.65$, $P < 0.001$) and Slate creeks ($N = 32$ days, $r = -0.55$, $P = 0.001$). Captures of adult toads also decreased significantly as summer progressed in Slate Creek ($N = 32$ days, $r = -0.36$, $P = 0.04$), but not in Little Blue Joint Creek ($N = 37$ days, $r = -0.02$, $P = 0.89$). We made too few captures in Chamberlain Creek to test for trends.

Discussion.—Boreal Toads made extensive movements in streams. In three streams during two summers, we trapped numerous individuals that were moving downstream. During mid-summer, we detected movements as long as 1.5 km and maximum movement rates greater than 500 m/day. Moreover, the daily movement rates underestimated distances that toads would have traveled had our traps not interrupted their activity. No previous publications document Boreal Toads traveling long distances via water.

The observed movement patterns suggest that adult toads were using streams during their home range activities and that we were not documenting mass dispersal or migration behavior. Post-breeding migrations by toads are characterized by relatively rapid, straight, and directed movements, whereas summer home range

Table 3. Number of days, distances moved, and average movement rates since previous capture for individual toads. The letter portion of the toad identification indicates the stream (Chamberlain Creek - C, Little Blue Joint Creek - L, or Slate Creek - S).

Recapture Date	Toad I.D.	Days	Distance moved (m)	Net distance moved (m)	Average rate ($m \cdot d^{-1}$)	Toad length (mm)
9-Aug-01	C-8[a]	6	1,458	1,458	243	—
10-Aug-01	C-6	10	1,270	—	127	—
11-Aug-01	C-6	1	18	1,288	18	93
14-Aug-01	C-9	9	0	0	0	103
16-Aug-01	C-3	21	0	0	0	102
16-Aug-01	C-13	1	294	294	294	84
4-Aug-02	L-1 or 2[b]	1 or 6	669	669	669 or 112	95
30-Jul-02	S-1	1	200	—	200	—
4-Aug-02	S-1	5	0	—	0	—
9-Aug-02	S-1	5	0	200	0	110
3-Aug-02	S-2	5	505	505	101	115
30-Jul-02	S-4	1	505	—	505	—
4-Aug-02	S-4	5	200	705	40	90
4-Aug-02	S-5	6	185	185	31	97
4-Aug-02	S-8	5	200	200	40	98
3-Aug-02	S-10	4	505	505	126	85
Median for all streams				400	71	97

[a]Recaptured upstream of initial capture location, although toad captured in downstream trap. Toad length not measured.

[b] Unsure which marked individual was recaptured.

movements are more haphazard (Kusano et al. 1995; Sinsch 1988, 1990). In our study, marked toads moved both up- and downstream, up to 21 days passed between captures of the same individual, and a fairly steady number of captures were made daily for more than a month.

Although the maximum detected movement distances we report are shorter than migratory or dispersal distances reported in other studies, these appear to be the longest home range movements yet observed. Female Boreal Toads in Idaho and Colorado made overland, post-breeding migrations of up to 2.3–2.4 km (Bartelt 2000; Muths 2003), but in Idaho, they subsequently established summer home ranges with a radius less than 100 m (P. Bartelt, pers. comm.). Likewise, in late summer, Campbell (1970a,b) observed movements of 900 m to overwintering sites, whereas summer home ranges averaged 317 m^2. In Wyoming, Carpenter (1954) documented total movements during July and August of up to 100 m and average daily movements of up to 13 m.

We might have observed longer summer home range movements for two reasons. First, toads inhabiting the moist riparian zone may tend to travel more extensively than those primarily using drier upland sites. Second, largely because of the confined, linear nature of streams, our methods might recapture toads moving long distances via streams more efficiently than traditional recapture methods on land (e.g., pitfall traps and drift fences).

Downstream movements via water might not be unusual, but merely overlooked, because nearly all bufonid movement studies have focused on terrestrial movements. Carpenter (1954) noted that some Boreal Toads in his study made "extended movements downstream." During the breeding season in Bulgaria, *Bufo bufo bufo* moved downstream at rates up to 568 m/day, similar to rates we observed, and traveled distances up to 2.5 km (Beshkov et al. 1986). During pre-breeding migrations, several *B. bufo* traveled downstream in a water-filled ditch to reach their breeding pond (Sinsch 1988 and pers. comm., February 2003).

All Boreal Toads were moving downstream when captured, which implies passive captures by downstream traps. *B. bufo bufo* also moved passively downstream, and males moving upstream in the water traveled short distances (up to 40 m, Beshkov et al. 1986). However, Boreal Toads occasionally bypassed downstream traps, indicating that they sometimes either traveled over land in a downstream direction or climbed over the nets while traveling downstream via water. Drifting downstream could provide several advantages to toads. Relatively passive downstream movements are energetically efficient. Also, during hot, dry weather (common during summers in the northern Rocky Mountains), the frequency and extent of anuran terrestrial activity is physiologically restricted by water balance and thermoregulation requirements (Sinsch 1990); traveling via water would allow for long-distance movements throughout summer, irrespective of weather or terrestrial conditions. Finally, aquatic movements may reduce exposure to terrestrial predators or provide an escape route.

We noted a weak decline in adult captures over time in Slate Creek but not in Little Blue Joint Creek, though sample size was smaller in the latter. In a southern Utah population, terrestrial captures of adults near streams and on moist riparian slopes were higher in June and July than in August and September (Robinson et al. 1998). Such temporal declines in captures might result from a gradual shift toward more terrestrial habitats as summer progresses.

Our captures of juvenile toads are noteworthy because the behavior and habitat use of juveniles represents a large gap in our knowledge of Boreal Toads (McGee et al. 2002). We inferred from the SVLs that most juveniles captured were at least one year old. McGee et al. (2002) reported that juveniles migrate away from aquatic areas and use primarily terrestrial habitats after metamorphosis, but Carpenter (1954) observed juveniles occupying summer home ranges along small streams in Wyoming. We observed that at least some juveniles use aquatic habitats in early summer in western Montana. Captures of juvenile toads decreased by late July in Little Blue Joint and Slate creeks, and the temporal trends were highly significant. Based on the pattern, we infer that the lack of juvenile captures in Chamberlain Creek might be because of our later initiation of trapping there (23 July). The juvenile movements might represent dispersal, but further research is necessary to confirm this.

Although we show unequivocally that Boreal Toads travel in streams and sometimes move relatively long distances during midsummer in western Montana, our conclusions are limited by small numbers of marked toads, a relatively short study duration each summer, and lack of information about the more terrestrial components of the populations and of individual movements. Further study will be necessary to determine the proportion of each population that moves via streams as well as to ascertain terrestrial habitat use and total distances traveled by toads that use streams. Studies in other regions and of other species are needed to determine the prevalence of instream movements among bufonids. Research illuminating the benefits derived from aquatic movements will help to identify the conservation implications of the behavior.

Extensive travel via streams implies that any instream alteration that interferes with downstream passage might reduce juvenile and adult survival and be detrimental to Boreal Toad populations. Water diversions might influence the distribution of Boreal Toads, as Reese (1972) hypothesized for Tiger Salamanders (*Ambystoma tigrinum*), and screened diversions might completely obstruct downstream passage. For example, after an irrigation ditch on a Blackfoot River tributary, Montana, was screened to eliminate fish entrainment, more than 20 adult Boreal Toads were found dead in a concrete collection facility immediately upstream of the screen (R. Pierce, Montana Fish, Wildlife and Parks, Missoula, pers. comm.). Toads moving passively downstream were probably impinged on the screen by high water velocities and could not ascend the smooth, vertical, concrete walls to escape.

Ecological sensitivity analyses indicate that *B. boreas* population growth rates are highly vulnerable to decreases in postmetamorphic vital rates (e.g., juvenile and adult survival or the probability of laying eggs; Biek et al. 2002). Biek et al (2002) placed a high priority on research and management aimed at documenting and preventing alterations of natural, post-metamorphic vital rates. We recommend that managers consider the consequences of any habitat alterations that may increase mortality rates or disrupt movements of post-metamorphic Boreal Toads traveling in streams and riparian areas. In particular, we recommend designing and testing water diversion screens that allow anurans to escape.

If instream movements prove to be widespread, trapping in streams during early summer may be an effective tool for detecting Boreal Toads in drainages. Furthermore, juveniles have proven to be particularly elusive to researchers. Instream trapping potentially provides an easy means to obtain juveniles for marking, genetic analyses, or other research needs. In drainages where breeding areas are unknown, highly variable, dispersed, or difficult to reach, trapping of juveniles in streams may provide an alternative for confirming recent reproduction within a population.

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