Habitat Use and Movements of Western (Boreal) Toads in Ryan Park, Wyoming

Wendy A. Estes-Zumpf, Herpetological Coordinator, Wyoming Game and Fish Department, Laramie, WY 82070
William Baer, North Zone Fisheries Biologist, United States Forest Service, Medicine Bow-Routt National Forests, Saratoga, WY 82331
Katrina Cook, Research Assistant, Wyoming Natural Diversity Database, University of Wyoming, Laramie, WY 82071
Steve Loose, Wildlife Biologist, United States Forest Service, Medicine Bow-Routt National Forests, Saratoga, WY 82331

ABSTRACT

Western (Boreal) Toad (*Anaxyrus boreas*) populations in the southern Rocky Mountains in southeast Wyoming, Colorado, and northern New Mexico are highly susceptible to amphibian chytrid fungus (*Batrachochytrium dendrobatidis*; Bd). Following the arrival of Bd to an area, most populations decline precipitously and many become locally extinct. Although the species once occurred throughout portions of the Medicine Bow and Sierra Madre mountain ranges of southeastern Wyoming, only three known breeding sites remain. Of these, only Ryan Park, Wyoming has consistent breeding and relatively high numbers of toads despite being Bd-positive since at least 2004. However, substantial beetle-kill surrounding the area necessitates vegetation and fuel reduction treatments in the forest adjacent to this Bd-tolerant population of Boreal Toads. To better understand habitat use by Ryan Park toads and inform treatment methods, biologists radio-tracked adult toads from mid-June through mid-September 2018. Of the seven toads relocated more than ten times using radio-telemetry, five were tracked to the end of the season in September. The longest distance moved by a toad between relocations was 537 m (1,762 ft) and the longest cumulative distance moved was 945 m (3,100 ft). Toads primarily remained in the riparian corridor throughout much of summer. Across the duration of the study, willows (*Salix* spp.) were the most common habitat component associated with toads; toads were located within 1 m (3 ft) of willows 57% of time. However, three toads were found within 1 m of upland vegetation types (e.g., conifers, aspen, sagebrush) more frequently later in the season after moving away from the main riparian corridor and toward hibernation sites in mid-August and September. Toads also stayed close to refugia. On average, toads were found 0.5 m from burrows or dense shrub cover and were tracked to small mammal burrows 30% of the time. The longest movements occurred in late August when several toads moved out of the riparian corridor toward winter hibernation sites in upland forest. Upland sites used by toads were typically downed logs, burrows, or leaf litter near seeps, springs or streams, but several toads also used slash piles in forest clearings. Hibernation sites included a cut bank with a seep along a small tributary approximately 300 m (984 ft) from the main riparian corridor, a decomposing slash pile in a forest clearing, and burrows under a stump approximately 15 m (49 ft) from the main creek channel. Untagged toads were also found at the two upland hibernation sites. These results will help inform fuel treatment methods implemented adjacent to this important breeding site. We recommend pre-treatment surveys to identify and establish buffers around water

sources and potential hibernacula. Because slash piles provide late season and overwintering habitat for toads, we also recommend either initially building and burning piles in winter after toads have already found other hibernacula, thus minimizing the risk of attracting toads prior to burning, or keeping slash piles small so they do not need to be burned.

INTRODUCTION

Amphibians are declining worldwide and currently are considered one of the most threatened vertebrate classes in the world (Stuart et al. 2004; Hof et al. 2011). Forty-one percent of all amphibian species are threatened with extinction or are already extinct (Pimm et al. 2014). One the leading threats to amphibians is the chytrid fungus *Batrachochytrium dendrobatidis* (Bd), which is responsible for population declines in over 500 amphibian species, including 90 likely species' extinctions (Stuart et al. 2004; Skerratt et al. 2007; Lips 2016; Scheele et al. 2019). Susceptibility to Bd, however, can differ both among and within species (Lips 2016). Variation in susceptibility among populations has been documented in the Western Toad (*Anaxyrus boreas*; USFWS 2017), a complex of species and genetic groups in the western United States and Canada (Goebel et al. 2009).

The Eastern Clade of the Western Toad (hereafter Boreal Toad), is comprised of montane-dwelling toads in portions of Wyoming, Idaho, Colorado, Utah, and (previously) New Mexico (Goebel et al. 2009; USFWS 2017). Although still locally common in some parts of their range despite the presence of Bd, Eastern Clade Boreal Toad populations in the southern Rocky Mountains (southeastern Wyoming, Colorado, and northern New Mexico) are highly susceptible to Bd and have declined (USFWS 2017). Following the arrival of Bd to an area, most southern Rocky Mountain populations decline precipitously and many become locally extinct (USFWS 2017). In southeastern Wyoming, population declines were first reported during the early 1990s and by 1993 Boreal Toads declined to the point of being exceedingly rare (WGFD 1993). Currently, only three known breeding sites remain in southeastern Wyoming, all of which occur in the Medicine Bow Mountain Range. Of these, only the breeding site immediately east of the community of Ryan Park, Wyoming, has consistent breeding and relatively high numbers of toads, despite being Bd positive since at least 2004.

Mature lodgepole pine (*Pinus contorta*) throughout the Medicine Bow National Forest have been heavily impacted by the recent mountain pine beetle (*Dendroctonus ponderosae*) epidemic. Due to the substantial amount of beetle-killed trees surrounding Ryan Park, the U.S. Forest Service (USFS) is planning vegetation and fuel reduction treatments to minimize wildfire risk to the community and its inhabitants. Treatments would also benefit the Ryan Park population of Boreal Toads by reducing the chance of a severe wildfire capable of destroying critical riparian and upland habitat. However, better knowledge of specific habitats used by Ryan Park Boreal Toads at different times of the year is critical to informing vegetation and fuel reduction efforts that successfully reduce wildfire risk, while minimizing impacts to this Bd-tolerant population of Boreal Toads.

Previous studies suggest Boreal Toads typically emerge from hibernation sites and move toward aquatic breeding sites in May or June depending on elevation, characteristics of breeding sites, and weather patterns (McGee and Keinath 2004). After breeding, toads are capable of moving long distances (over 6 km (3.7 mi)) from breeding sites and moving through and using a variety of terrestrial habitats (Bartelt et al. 2004; Bull 2006; Barrile et al. 2018). Toad selection of terrestrial habitats and microhabitats is complex and varies with season, sex, and available habitat (Bartelt et al. 2004; Bull 2006; Goates et al. 2007; Browne and Paszkowski 2014 and 2018; Barrile et al. 2018). Furthermore, microhabitats selected by toads are not always identifiable by available Geographic Information System (GIS) layers, complicating efforts to conserve critical habitat (Goates et al. 2007). Thus, USFS fisheries and wildlife biologists and Wyoming Game and Fish Department (WGFD) herpetologists worked with Ryan Park landowners to radio-track adult Boreal Toads in 2018 to determine movement patterns and habitat use at this important breeding site. Of particular importance was determining if Boreal Toads use habitat outside of the riparian corridor, and if so, which habitat features and when.

METHODS

Study Area

The Ryan Park Boreal Toad population is located on the west slope of the Snowy Range just east of the community of Ryan Park in Carbon County, Wyoming (Figure 1). The site consists of a willow (*Salix* spp.)-dominated riparian corridor along an unnamed creek and adjacent conifer forest uplands dominated by lodgepole pine. The main creek flows northwest through the site and merges with Barret Creek near the eastern edge of the Ryan Park community. The northwestern (downstream) portion of the riparian corridor is approximately 140 m (459 ft) wide and consists of numerous beaver ponds. Although the ponds and downstream portion of the creek retain water through the summer, the southeastern (upstream) portion of the creek is largely dry with only intermittent puddles and moist areas during late summer. Sagebrush (*Artemisia* sp.) occurs along a swath of varying width between the riparian area and forest. Aspen (*Populus tremuloides*) occurs in small pockets along tributaries and seeps. Land ownership of the riparian area is primarily private, with dispersed residential structures occurring in uplands immediately adjacent to the riparian corridor on both the north and south sides of the creek. The southeastern (upstream) portion of the creek and most upland forest habitat is managed by the Medicine Bow National Forest. Other amphibian species in the study area include the Wood Frog (*Lithobates sylvaticus*) and the Boreal Chorus Frog (*Pseudacris maculata*).

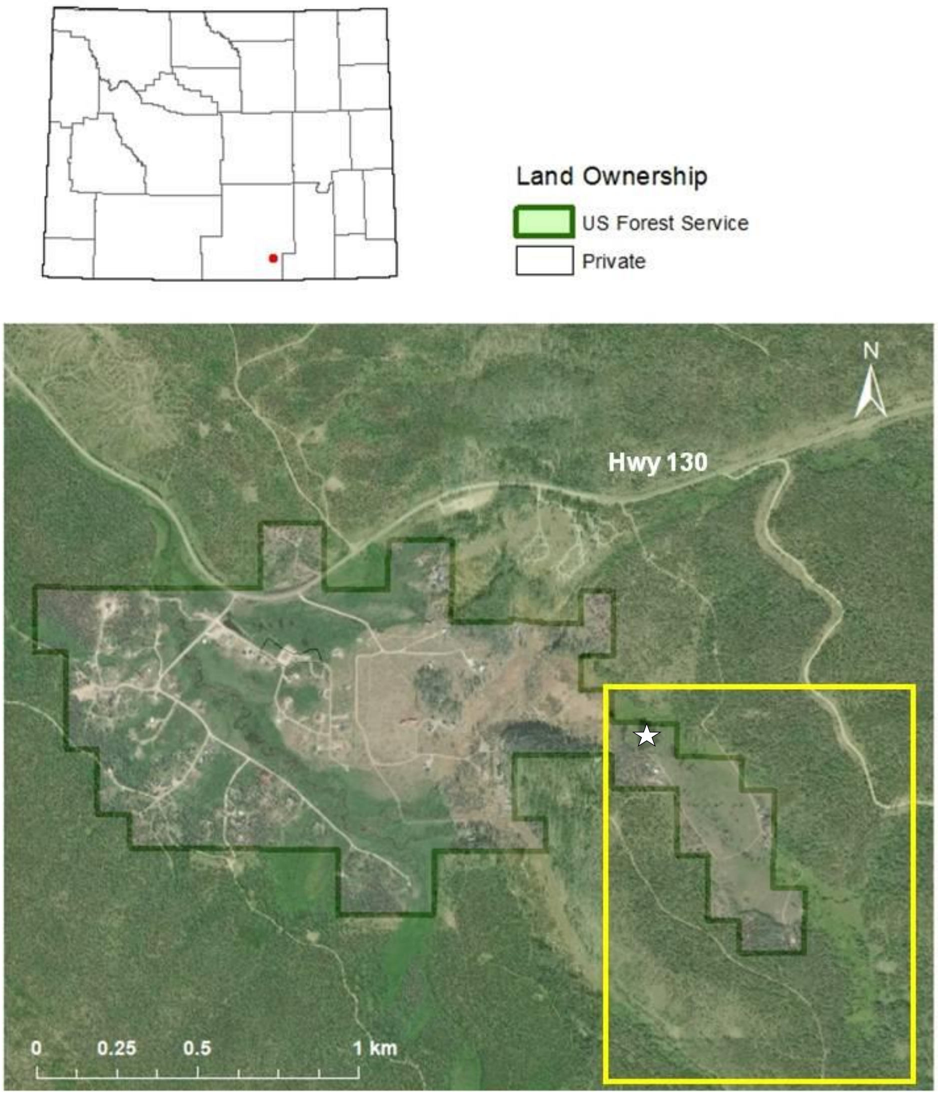

FIGURE 1. Map of Ryan Park, Wyoming, showing study area (outlined in yellow) along an unnamed creek on the east side of the community. The white star marks the primary Boreal Toad breeding pond.

Radio-telemetry

Adult Boreal Toads were captured from June 18 through August 7, 2018 during the spring breeding and summer foraging seasons. The majority of toads were captured from mid-June through mid-July. Toads were captured by hand during targeted searches at potential breeding ponds in June and opportunistically throughout the season during radio-tracking activities. We weighed and measured snout-vent length (SVL) of each captured toad. Toads large enough to carry a radio-transmitter (transmitter/body weight ratio < 0.05) were marked with a uniquely coded Passive Integrated Transponder (PIT tag), swabbed for Bd, and assigned an individual toad ID number. We used a belt attachment (Burow et al. 2012) to secure 1.4g (battery life = 9 weeks) or 1.9g (battery life = 16 weeks) BD-2 radio transmitter (Holohil

Systems Ltd., Carp, Ontario, Canada) to toads depending on body weight. Belts were made of 28 gauge copper wire covered by two sections of flexible PVC tubing (Heilind Electronics, Inc., Heiland, Colorado, USA) and joined with silicone tubing (Cole Parmer, Vernon Hills, Illinois, USA; Figure 2). Thin copper wire ensured that belts would wear or corrode and fall off in the event a radio-transmitter failed before the end of the study (Burow et al. 2012). We later modified transmitter attachments by lining the junction between the transmitter and the PVC tubing with a thin bead of silicone caulking. The modification significantly reduced skin abrasions at the junction.

FIGURE 2. Belt attachment method (Burow et al. 2012) used to secure radio-transmitters to adult Boreal Toads.

We relocated toads using radio-telemetry twice each week throughout the active season and recorded UTM coordinates (NAD83 Zone 13) at each toad relocation site. Whenever possible, relocated toads were captured and briefly examined for abrasions resulting from the belt. Minor abrasions were treated topically with vitamin E oil and belts were adjusted. We removed transmitters from toads with persistent abrasions or sores. If we were unable to visually observe relocated toads (i.e., toad was inside a deep burrow or dense shrub) we assumed toads were alive unless they did not move from that spot after several relocation events. We weighed and swabbed radio-tagged toads for Bd every two weeks to assess changes in weight and disease status over time. A decrease in weight could indicate that the transmitter is adversely affecting the health of the toad, and because Bd grows best in cool wet conditions, some studies have documented higher rates of infection in spring than in summer (Pullen et al. 2010; Kinny et al. 2011). We removed transmitters when toads began settling into winter hibernacula in mid-September.

Habitat Measurements

To assess habitat use by radio-tagged Boreal Toads, we collected information at several spatial scales. All personnel responsible for tracking toads attended a joint training at the beginning of the field season to standardize habitat data collection across observers. At each toad relocation site, we recorded percent soil moisture, water depth, and air, ground, and water temperatures (as applicable). We also recorded information on frequency of burrow use, visibility/exposure, distance from cover, and distance to water or land. We recorded body temperature and adjacent ground temperature of toads with an infrared temperature gun.

Microhabitat characteristics were measured in a 1-m (~ 3-ft) square plot centered on each relocated toad and extending 1-m above the toad. We visually estimated the percent of grass, woody debris, forbs or moss, rock, bare ground, leaf litter (dead grass or leaves), water, shrub, and tree cover surrounding each toad. We also recorded the average height of grasses, shrubs, and trees and the species of shrubs or trees that occurred within each 1-m square plot around a relocated toad. Lastly, we visually estimated the percent tree canopy cover within a 20-m radius of each relocated toad. Canopy cover was divided into categories (0%, 1-40%, 41-70%, >70%). Habitat photos were taken at each relocation site. When error-checking data, if habitat measurements did not add up to 100% or we found discrepancies between values for relocations at the same coordinates, we reviewed habitat photos and adjusted values accordingly. If a toad went into a hibernation site before the end of the study and thus was relocated multiple times in the same location, we only used microhabitat covariates from the first relocation at that site to not bias results.

Data Analysis

To determine movements of each toad throughout the summer, we calculated the linear distance between initial capture and each relocation as well as the linear distance moved between each relocation. Cumulative distance moved was calculated by summing all distances moved between relocations for each toad. We mapped toad movement patterns across the study area using ArcGIS (ESRI, Redlands, CA, USA). We summarized characteristics of habitats used by each toad and across all toads. Analyses of movement and habitat data were conducted in Program R (R Core Team 2017).

RESULTS

Radio-telemetry

We radio-tagged 11 Boreal Toads (9 males, 2 females) during the spring and summer of 2018 (Table 1). The number of observations of radio-tagged toads ranged from 2 to 27. Transmitter belts initially resulted in abrasions at the junction between the transmitter and the PVC tubing on numerous toads. Belts were removed from three toads (2A, 3A, and 4A) in June and July due to severe abrasions; however, modifications to transmitter attachments successfully minimized abrasions. Two toads lost their transmitters: one slipped out of a loose belt (9A) and the other dropped its transmitter when the copper wire on the belt broke prematurely (2B). The fate of one toad (1A) remains unknown. That toad was last seen alive under a willow on July 5, after which the signal continued to come from the same location but the toad was never seen and the transmitter could not be recovered. Weights of individual toads regularly varied above or below the previously measured weight throughout the duration of the study, likely due in part to difficulty of weighing toads in windy conditions. Only two toads (1A and 2A) showed consistent declines in weight. We were unable to retrieve 1A (see above) to remove the transmitter. We removed the transmitter from 2A. We followed five toads to the end of the study in mid-September, three of which were tracked to winter hibernacula. However, movement information across the majority of the field season was collected for only one toad (5A) since the remaining four were captured later in the field season (mid-July to early August).

TABLE 1. Summary of distances (m) moved by radio-tagged adult Boreal Toads at Ryan Park in 2018. Toad identification number, sex, initial capture date, final date the transmitter was removed or recovered, and number of times a toad was located are provided. Bold font indicates toad was tracked through the end of the study season or to winter hibernacula.

					Distance from initial capture		Distance btw relocations		
Toad ID	**Sex**	**Capture Date**	**Release Date**	**# Locations**	**Mean**	**Max**	**Mean**	**Max**	**Cumulative Distance**
10A	**M**	**18-Jul**	**13-Sep**	17	**229**	**405**	**44**	**232**	**621**
1A	M	18-Jun	8-Jul[1]	11	70	94	47	90	186
2A	F	18-Jun	28-Jun	3	26	29	16	22	31
2B	M	8-Jul	16-Aug	12	7	18	5	13	59
3A	M	19-Jun	5-Jul	5	137	172	61	121	184
3B	**M**	**18-Jul**	**12-Sep**	16	**322**	**743**	**68**	**537**	**945**
4A	M	19-Jun	23-Jul	10	392	625	76	446	683
4B	**M**	**23-Jul**	**12-Sep**	14	**237**	**377**	**59**	**373**	**768**
5A	**F**	**21-Jun**	**20-Sep**	27	**48**	**93**	**18**	**55**	**442**
8A	**M**	**7-Aug**	**20-Sep[2]**	14	**255**	**362**	**37**	**222**	**485**
9A	M	7-Aug	8-Aug	2	7	7	7	7	7

[1] Last date seen alive.
[2] Unable to retrieve toad from hibernacula. Transmitter not removed.

The majority of radio-tagged toads stayed in the riparian corridor adjacent to the main stream or its tributaries throughout most of the summer (Figure 3). However, three toads (2B, 4A, and 4B) moved to or were first found near a residence on the east side of the study area on the edge of the forest. Toads relocated in this area were typically found in or near small mammal burrows along a terrace surrounding a small log cabin or underneath the cabin.

Because abrasions resulted in the removal of transmitters from most of the toads initially caught near the breeding ponds, we have little data on movements away from breeding ponds to summer foraging areas. The only toad (4A) captured near the breeding ponds whose radio-tag was not removed until mid-summer remained within 30 m (98 ft) of its original capture location until early July, when it made a large movement (446 m or 1463 ft) upstream and away from the breeding area (Table 1; Figure 4). In general, radio-tagged toads moved upstream (southeast) over the course of the summer (Figure 5). Of the toads captured on summer foraging grounds, the longest distances moved between radio-locations often occurred during the second half of August when toads began moving to winter hibernacula (Figure 4).

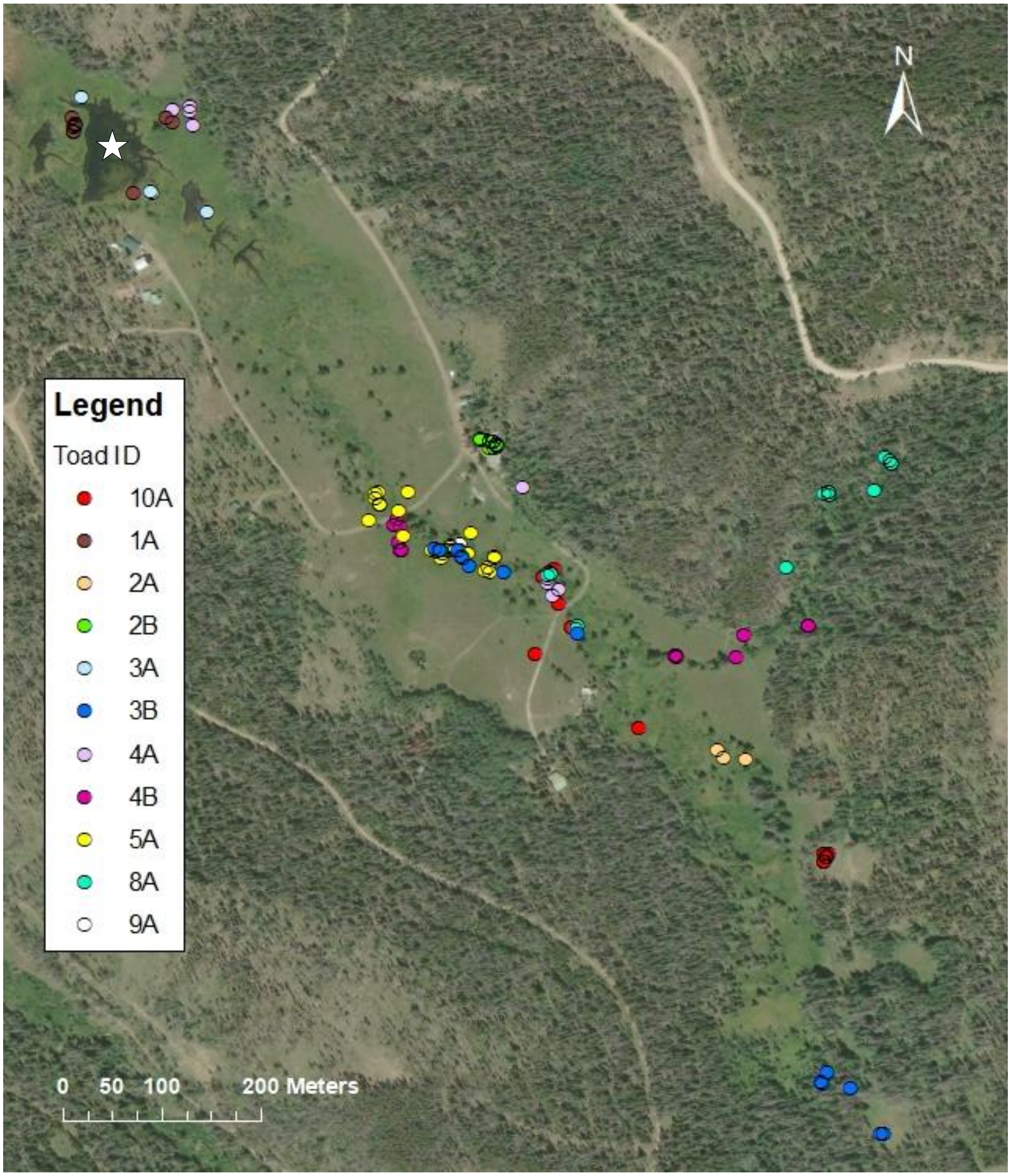

FIGURE 3. Observations of all Boreal Toads radio-tagged along an unnamed stream east of the community of Ryan Park in 2018. The white star marks the primary Boreal Toad breeding pond. Observations are color-coded by individual toad. The stream flows northwest.

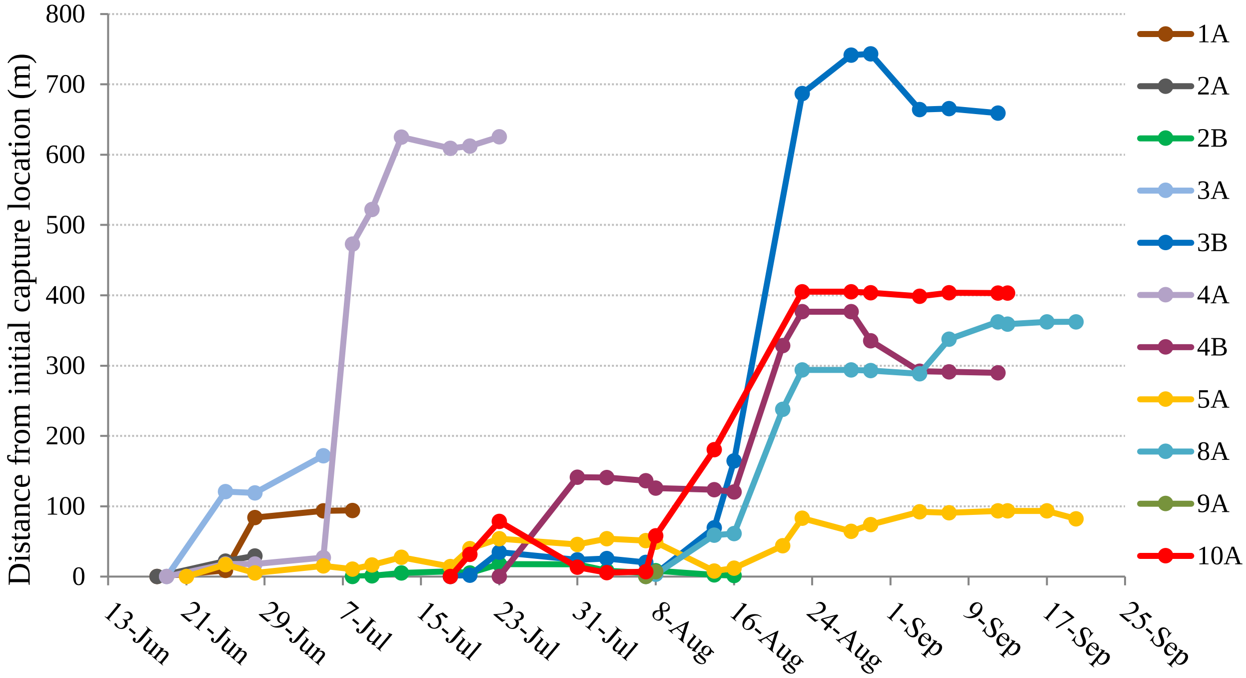

FIGURE 4. Linear distances moved by individual radio-tagged Boreal Toads from spring through early fall 2018 in Ryan Park, Wyoming. Lines represent the distance moved from the initial capture location to each relocation for each toad. Circles represent each relocation for a given toad. Movement histories end at either the location for where a transmitter was removed or the last location for which the toad was known to be alive.

Boreal Toads in this study were capable of moving relatively long distances in a short amount of time. Several toads moved approximately 0.5 km (0.3 mi) in less than one week. The maximum distance moved by a toad (3B) between relocations was 537 m (1,762 ft) in seven days. The total distance moved by 3B from initial capture in mid-July through the end of the study period was 945 m (3,100 ft; Figures 4 and 5). Other toads, however, remained relatively sedentary. Female 5A remained in the center portion of the study area throughout the study period (Figure 5). Male 2B never moved more than 20 m (66 ft) from the cabin near where he was initially found; however, his belt broke prematurely in mid-August and it is unknown if he moved later in the season in search of a wintering site (Figure 5).

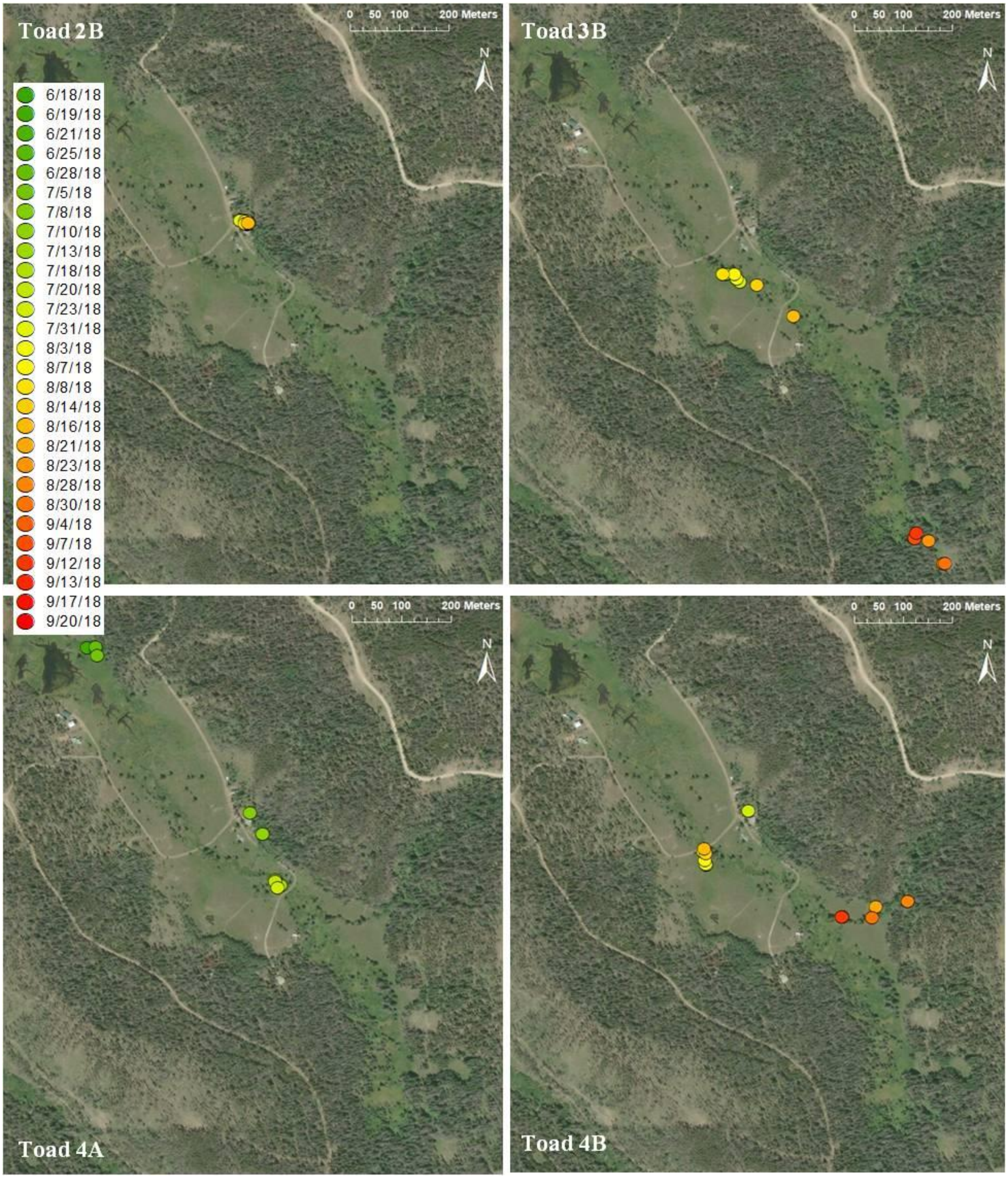

FIGURE 5. Daily movements of individual radio-tagged Boreal Toads from June to September 2018. Toad identification number is located at the top or bottom left of each picture. Color of symbol reflects date of observation. Locations for 7/2/2018 are not depicted due to issues with GPS error.

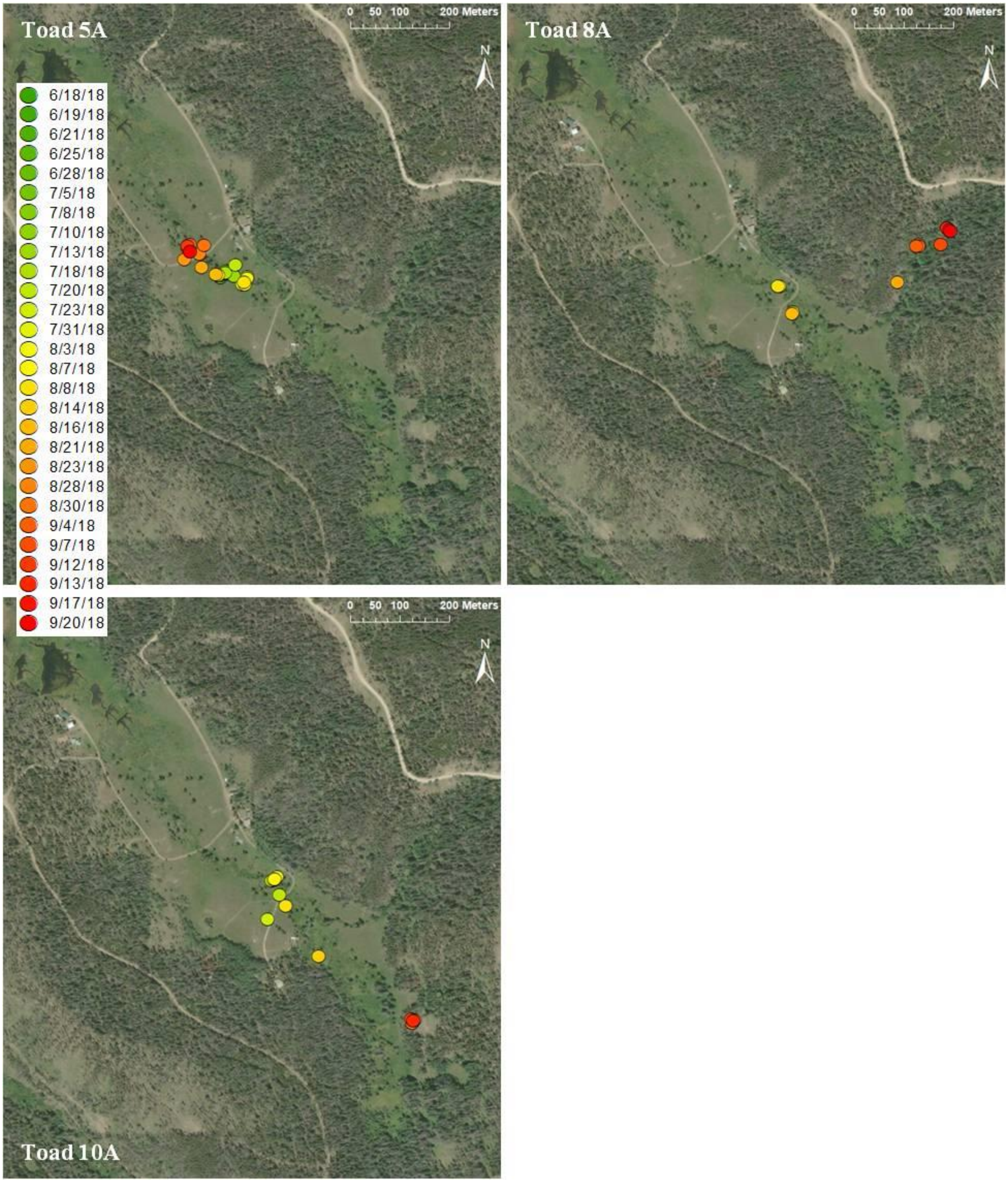

FIGURE 5. Continued.

Characteristics of wintering sites differed across the three toads tracked to hibernacula in the fall. We also found unmarked toads using the same hibernacula as two of our radio-tagged toads. Toad 10A moved out of the riparian area to an old slash pile in an adjacent forest opening approximately 85 m (279 ft) from the main creek channel in mid-August (Figures 5 and 6a). The toad (as well as another toad) was found in a tunnel under a pile of decaying logs when the transmitter was removed on September 13. Toad 8A moved up a tributary to a seep in the bank of a small creek approximately 350 m (1,148 ft) from the main creek channel (Figures 5 and 6b). Unmarked toads were found outside this hibernation site on two different occasions in September. Toad 8A could not be retrieved without substantial damage to the hibernacula and was left undisturbed because 8A never developed abrasions from the belt. We feel confident, however, that the thin copper wire used as the belt-release mechanism will work as planned and allow 8A to shed the radio-tag, as the wire of another toad's belt wore through and broke earlier in the summer. The hibernation site chosen by 5A was a series of small mammal burrows under a tree stump approximately 10 m (33 ft) from the main creek channel (Figure 6c). We attempted to carefully dig 5A out of this site in mid-September because she had a history of persistent abrasions from the transmitter belt. Although unsuccessful, this disturbance likely caused 5A to move from the hibernation site. We found her 12 m (39 ft) away in the undercut bank of the main creek channel on September 20 and removed her transmitter.

The other two toads tracked into mid-September likely had not settled into hibernation sites before transmitter removal. However, toad 3B was found within a few meters of the same location for the last three relocations. The area was in the forest just above the creek's source at the top of the main riparian area. Burrows under decaying logs where 3B was found might serve as a hibernation site (Figures 5 and 6d). The final toad, 4B, had originally moved up the same small tributary as 8A in late August, but then moved back to the main riparian corridor by the time the transmitter was removed (Figure 5).

FIGURE 6. Winter hibernation sites for radio-tagged Boreal Toads in Ryan Park, Wyoming, 2018. Hibernation sites consisted of a) a burned slash pile used by toad 10A and at least one unmarked toad, b) a seep under a stream bank used by toad 8A and at least one unmarked toad, and c) small animal burrows under a tree stump used by toad 5A. Toad 3B was found within a few meters of the same location for the last three relocations, which could suggest burrows under a decomposing log (d) were potential hibernacula.

Habitat Use

Radio-tagged Boreal Toads primarily remained within the main riparian corridor and associated vegetation on privately owned lands until mid-August when the majority of toads began moving into surrounding forested uplands. Across the duration of the study, willows were the most common habitat feature associated with toads. On average, toads were relocated within 1 m of willows 57% of the time (Table 2). However, three toads were found within 1 m of upland vegetation types (e.g., conifers, aspen, sagebrush) more frequently later in the season after moving away from the main riparian corridor and toward hibernation sites in mid-August and September. Burrows, typically made by small mammals, were also a relatively common habitat feature. Toads were found inside burrows 30% of the time, on average. Although not often found in water, toads were found within 10 m of water 30% of the time (Table 3), suggesting that water, or habitat aspects associated with water (such as riparian vegetation) are important habitat components. Even toads that moved into upland forest habitat in late summer were often located along small tributaries or near seeps or springs in the forest. In general, toads did not tend to use areas in close proximity to trees until later in the summer. Throughout the study, trees (aspen and conifer) occurred within 1 m of toads 16% of the time and the overall average tree canopy cover within 20 m (66 ft) of toads was 0%; although average canopy cover for several individual toads ranged from 1 to 40% (Tables 2 and 3).

TABLE 2. Summary of tree and shrub types found within 1 m of radio-tagged adult Boreal Toads at Ryan Park in 2018. Values are the percent of relocations for each toad where the individual was found within 1 m of each tree and shrub type.

Toad ID	Willow	Sagebrush	Cinquefoil	Juniper	Aspen	Conifer
10A	62.5	0.0	0.0	0.0	0.0	0.0
1A	100.0	0.0	0.0	0.0	0.0	0.0
2A	50.0	0.0	0.0	0.0	0.0	0.0
2B	0.0	0.0	0.0	0.0	54.5	9.1
3A	50.0	0.0	0.0	0.0	0.0	0.0
3B	50.0	0.0	0.0	0.0	0.0	21.4
4A	55.6	11.1	0.0	0.0	0.0	33.3
4B	42.9	0.0	7.1	0.0	21.4	0.0
5A	90.0	15.0	15.0	5.0	0.0	0.0
8A	27.3	0.0	0.0	36.4	27.3	9.1
9A	100.0	0.0	0.0	0.0	0.0	0.0
Overall Avg.	**57.1**	**2.4**	**2.0**	**3.8**	**9.4**	**6.6**

Toads tended to use relatively lush microhabitats throughout most of the season. Shrubs, grass, and forbs made up 60% of the vegetation and ground cover within 1 m of toad locations, on average (Table 4). Leaf litter (dead grasses and leaves) made up an additional 15%. Average grass height within 1 m of toad locations was 40 cm (16 in). Toads also remained close to burrows, dense vegetation, or other forms of cover where they could be completely hidden from predators (i.e., refugia). On average, toads were found 0.5 m (1.6 ft) from refugia (Table 3) and were completely hidden in burrows or by vegetation 37% of the time. Interestingly, it was not unusual to find radio-tagged toads near other toads. We relocated toads within 5 m (16 ft) of another toad at least 9% of the time. In several instances, multiple toads were found using the same burrow system.

Due to our low sample size, we were unable to compare habitat use by Bd infected and uninfected toads. Low sample size also prevented us from determining seasonal patterns of Bd infection. However, the majority of toads (four of six) first captured in June or early July initially tested positive for Bd. Because we had to remove transmitters on most of these initial toads due to abrasions, we do not know if they later cleared the infection. Only one of five toads captured after mid-July tested positive for Bd. Toad 3B did not test positive for Bd when initially captured, but tested positive at the end of the season in September. None of the other toads sampled in September tested positive. Overall, five of the eleven radio-tagged toads tested positive for Bd at some point during the study.

TABLE 3. Characteristics of relocation sites used by radio-tagged adult Boreal Toads at Ryan Park in 2018. Site characteristics are summarized for each toad (Toad ID).

	Toad Body Temp (°C)		Ground Temp (°C)		Air Temp (°C)		Soil Moisture (%)		% located in	Dist. to Refuge (m)		% located in	Water Temp* (°C)		% located within 10m of	Dist. To Water** (m)		% located within 5m of other
Toad ID	**Avg.**	**Range**	**Avg.**	**Range**	**Avg.**	**Range**	**Avg.**	**Range**	**burrow**	**Avg.**	**Range**	**water**	**Avg.**	**Range**	**water**	**Avg.**	**Range**	**toad**
10A	21.6	(19.6-24.0)	22.8	(15.7-27.7)	23.1	(17.2-27.6)	15.4	(0.0-24.5)	12.5	0.9	(0.0-2.9)	12.5	16.6	(16.6-16.6)	18.2	0.1	(0.0-0.2)	18.2
1A⸸	20.9	(19.0-22.1)	21.3	(19.2-23.2)	23.5	(16.5-28.5)	15.5	(0.0-23.4)	0.0	0.2	(0.0-0.7)	25.0	15.6	(15.6-15.6)	66.7	0.9	(0.0-3.0)	0.0
2A	14.8	(14.8-14.8)	19.4	(16.5-22.3)	23.2	(19.6-26.7)	18.7	(16.4-20.9)	0.0	0.0	(0.0-0.0)	0.0			0.0			0.0
2B⸸	22.7	(16.4-27.9)	24.8	(13.2-41.0)	22.3	(15.3-30.8)	4.2	(0.0-21.1)	54.5	0.3	(0.0-1.0)	0.0			0.0			8.3
3A⸸	19.5	(14.2-27.4)	20.4	(16.3-23.7)	24.3	(22.4-27.2)	19.4	(16.6-23.1)	0.0	1.6	(0.9-2.3)	50.0	16.1	(15.2-16.9)	80.0	0.2	(0.0-0.4)	0.0
3B⸸	19.1	(10.7-31.7)	18.4	(5.2-33.4)	22.0	(14.1-29.2)	15.7	(0.0-49.5)	42.9	0.5	(0.0-3.0)	0.0	9.8	(9.8-9.8)	18.8	1.8	(0.3-3.0)	6.7
4A⸸	23.7	(19.2-27.2)	23.9	(16.6-30.2)	25.2	(23.0-29.9)	11.9	(0.0-20.9)	30.0	0.6	(0.0-1.7)	0.0			54.5	2.7	(0.3-7.0)	10.0
4B	20.7	(12.1-28.3)	20.5	(8.3-30.8)	21.1	(10.1-29.8)	13.4	(7.3-26.4)	23.1	0.6	(0.0-3.0)	0.0			28.6	2.7	(0.3-5.5)	7.1
5A	21.5	(12.1-28.2)	21.1	(12.3-34.0)	22.8	(10.0-30.4)	15.8	(11.2-30.2)	23.8	0.3	(0.0-1.6)	9.5	18.8	(17.7-19.9)	36.4	1.9	(0.0-6.0)	4.8
8A	19.6	(14.6-22.5)	20.5	(14.3-30.5)	20.9	(10.4-30.2)	10.7	(0.0-21.0)	60.0	0.3	(0.0-2.5)	0.0	9.1	(9.1-9.1)	27.3	1.2	(1.0-1.5)	27.3
9A			22.5	(18.3-26.7)	26.0	(22.2-29.8)	18.0	(16.3-19.6)	0.0	0.9	(0.3-1.6)	0.0			0.0			50.0
Overall Avg.	**21.0**		**21.3**		**22.6**		**13.5**		**30.3**	**0.5**		**6.3**	**15.1**		**30.1**	**1.6**		**9.4**

* When found in water
** When within 10m of water
⸸ Toad was Bd positive at some point during the study

TABLE 4. Microhabitat characteristics of sites used by radio-tagged adult Boreal Toads at Ryan Park in 2018. Average percent cover within a 1-m (~ 3-ft) cubic plot around each relocated toad is presented, as is the average height of vegetation in the plot and percent canopy cover by trees in a 20 m radius around the plot.

Toad ID	Avg. % Grass	Avg. % Woody Debris	Avg. % Forbs	Avg. % Rock	Avg. % Bare Ground	Avg. % Leaf Litter	Avg. % Shrub	Avg. % Water	Avg. % Tree	Avg. height (m) when present			Avg. % Tree Canopy Cover within 20m
										Grass	Shrub	Tree	
10A	16.1	18.1	20.4	2.1	10.9	14.9	12.5	5.0	0.0	0.4	1.1		0
1A	22.0	1.8	7.0	0.0	0.2	24.6	37.4	7.0	0.0	0.5	1.0		0
2A	12.0	1.5	10.0	0.5	1.0	7.5	67.5	0.0	0.0	0.3	1.6		0
2B	17.2	2.4	12.8	3.4	44.6	8.6	0.0	0.0	11.0	0.3		3-5	0
3A	28.0	0.3	19.3	0.0	1.3	33.3	8.3	9.3	0.0	0.4	0.5		0
3B	16.1	17.3	32.4	0.1	8.6	9.7	12.5	1.8	1.5	0.5	1.0	>10	1-40
4A	25.9	13.0	18.2	0.0	1.7	17.9	21.4	0.4	1.4	0.4	1.0	>10	0
4B	31.1	9.9	14.5	0.9	5.6	17.4	19.6	0.4	0.6	0.4	1.6	5-10	1-40
5A	17.3	5.1	22.9	0.0	7.1	12.1	32.3	3.3	0.0	0.3	1.0		0
8A	16.4	22.4	16.8	0.8	9.4	20.4	13.3	0.3	0.4	0.4	1.5	3-5	1-40
9A	4.0	17.5	26.5	0.0	15.5	1.5	35.0	0.0	0.0	0.2	1.8		1-40
Overall Avg.	**19.9**	**10.8**	**19.6**	**0.8**	**10.5**	**14.8**	**19.9**	**2.1**	**1.6**	**0.4**	**1.2**	**5-10**	**0**

DISCUSSION

Boreal Toads radio-tracked in this study were strongly associated with the riparian corridor surrounding the main creek throughout much of the spring and summer. Most radio-tagged toads moved upstream (southeast) along the riparian corridor over the course of the summer (Figure 5), and the majority of toads began moving into neighboring uplands in mid-August. Late summer movements likely corresponded with leaving summer foraging grounds in search of winter hibernacula, as three of five toads entered hibernation sites between August 23 and September 12.

During the majority of spring and summer, willows were the most common habitat feature associated with toads. This association could be due to the willows themselves, or to willows being the dominant shrub cover available in close proximity to the main creek channel. Although the creek largely dried up by late summer, intermittent mud and small pools remained throughout most of the summer. Toads were sometimes found in dense willow stands; however, on average, toads used microhabitats that contained roughly equal parts shrub cover, grass, and forbs. These areas often occurred along the edges of willow stands or bordering open areas within willow stands. Other studies have found that "soft edges" between habitat patches were important habitat features (Bartelt et al. 2004).

Toads were also closely associated with refugia, either in the form of small mammal burrows, dense vegetation, woody debris, or manmade structures and were typically found completely hidden or within 0.5 m (1.6 ft) of some form of refugia. Boreal Toads in Idaho selected microhabitats closer to refugia (mean = 0.6 m) and were found completely obscured by cover 50% of the time (Bartelt et al. 2004). In Oregon, Boreal Toads were detected in refugia 81% of the time (Bull 2006). Interestingly, three toads were detected at some point using small mammal burrows immediately adjacent to a cabin or taking refuge under the cabin itself. The landowner also reported that he consistently sees a toad near the foundation of a shed on his property, indicating toads use manmade structures despite periodic human activity.

Although toads tended to move away from willows in the main riparian channel and into adjacent uplands in late summer, proximity to refugia was still an important habitat characteristic. In late summer and fall, toads typically used burrows, logs, slash piles in small forest clearings, and even deep leaf litter as refugia. Use of slash piles has also been documented in Idaho where the piles were "important" for at least three toads and used as a hibernation site by at least one of those (Bartelt et al. 2004). Upland sites used by toads, other than slash piles, were loosely associated with water. Of the four toads that moved into uplands in late summer, three roughly followed the main creek or a small tributary (Figure 5). The two toads that followed the small tributary were always relocated within 40 m (131 ft) of the creek bed, though they sometimes used refugia on the dry forested slope above the creek. The toad that followed the main creek was most often relocated just beyond the seeps and springs at the headwaters of the creek. However, that toad (3B) was found on two consecutive occasions using an old slash pile in a small forest clearing approximately 85 m (279 ft) from the nearest known water source before moving back toward the headwaters of the creek.

Similar to other studies, we found that Boreal Toads are associated with water throughout the active season (Bartelt et al. 2004; Bull 2006; Goates et al. 2007; Schmetterling and Young 2008; Browne and Paszkowski 2014; Barrile et al. 2018). None of our radio-tagged toads were detected farther than 150 m (492 ft) from the main creek or small intermittent tributaries at any point during our study; however, we had a small sample size and all of our toads were initially captured in the spring or summer within the riparian corridor. Any toad that might have left the breeding ponds and moved into upland forest habitat before our capture efforts began would not have been available for radio-tagging. Our results also primarily apply to adult male Boreal Toads as we only have sufficient relocation data for one female (5A). Other studies have found that although Boreal Toads are associated with water, females are less closely associated with water than males (Bull 2006; Browne and Paszkowski 2014), spending significantly more time in terrestrial habitat >10 m (33 ft) from breeding ponds (Bartelt et al. 2004) and farther from water (Bull 2006; Goates et al. 2007) than males. Females also tend to move greater distances from breeding ponds than males (Bartelt et al. 2004; Bull 2006). For example, in Oregon, average distances moved by female and male Boreal Toads from breeding sites were 2.5 km (1.6 mi) and 1.0 km (0.6 mi), respectively. The maximum distance moved by a female toad in a season was 6.2 km (3.9 mi). Thus, because most of our data were from males, our study likely underestimates distances Boreal Toads will travel from water and total distances moved throughout the season.

Understanding habitat use and movement patterns of Boreal Toads near Ryan Park is essential to informing habitat management and forestry activities in and around this critical population. Vegetation and fuel reduction is urgently needed to reduce the risk of severe wildfire in the area. Information from this study can be used to guide vegetation treatments in such a way that effective vegetation and fuel reductions can be implemented while minimizing impacts to Boreal Toads. Planning the type and timing of vegetation treatments around seasonal habitat use by toads will increase the likelihood that this potentially Bd-tolerant population will not only continue to persist on the landscape, but also potentially recolonize other sites.

Recommendations

Many resource management agencies currently have standards or guidelines to buffer streams and riparian areas to protect ecosystem function and/or Threatened, Endangered, and Sensitive species (TES). The Medicine Bow National Forest Revised Land and Resource Management Plan (Forest Plan) Water and Aquatic Standard 15 establishes 300 ft stream-side buffers or the top of the inner gorge (whichever is greater) in watersheds containing aquatic, wetland, or riparian dependent TES species. In addition, a site-specific design criteria of a 1000 ft buffer around the breeding pond has been established (USDA Forest Service 2018). Based on results of this study, Ryan Park Boreal Toads should be largely protected by these buffers while they remain within the main riparian area. Boreal Toads at this site are most at risk of direct impacts from vegetation and fuel reduction treatments if toads leave the breeding area in spring and immediately move into upland habitat (as other studies have shown female toads often do), and from late August through spring when toads in general are most likely to be using upland habitat away from the main riparian corridor. Thus, we provide the following recommendations:

- Maintain adequate buffers around all water features (perennial and intermittent ponds, creeks, seeps, springs, etc.) to minimize disturbance to important toad upland habitat. Pre-treatment field surveys to map the location of water features, particularly those not depicted in GIS layers, could significantly reduce impacts to Boreal Toads (Goates et al. 2007).

- Conduct pre-treatment surveys to identify and protect likely Boreal Toad hibernacula. Since most hibernation sites occur in uplands away from breeding ponds (Bull 2006, Browne and Paszkowski 2010; Barrile et al. 2018), and hibernation sites are often communal (Campbell 1970; Browne and Paszkowski 2010; Barrile et al. 2018), protecting hibernacula is critical to the persistence of Boreal Toads. In addition to water features, important upland habitat for overwintering Boreal Toads identified by this and similar studies include slash piles and other accumulations of woody debris, large decaying logs, overturned root balls, burrows, cavities and tunnels under rocks, logs, and trees, and red squirrel (*Tamiasciurus hudsonicus*) middens (Bull 2006; Browne and Paszkowski 2010; Barrile et al. 2018).

- Evaluate the effectiveness of different size buffers to adequately protect toad populations. The actual size of buffers around water sources and other important habitat features needed to adequately protect critical habitat is not fully understood and likely varies by site and sex. Throughout the active season, no radio-tagged toads in our study were relocated farther than 150 m (492 ft) from a water feature; however, our data come primarily from male toads. Because female toads in similar studies travel significantly farther from breeding sites and from water sources (Bartelt et al. 2004; Bull 2006; Goates et al. 2007; Browne and Paszkowski 2014), and because each female likely only breeds once every three years (Muths et al. 2010), female survival and abundance is critical to population persistence. The maximum distance of a hibernation site from a stream in western Wyoming was 309 m (mean = 101 m; Barrile et al. 2018) but greater distances have been documented in other studies (Bull 2006; Browne and Paszkowski 2010).

- Consider both constructing and burning slash piles during winter when toads are already using other hibernacula or keep piles small to reduce the need for burning. Old slash piles were used by both marked and unmarked toads during this study and slash piles were noted as important habitat to toads in another study. Thus, construction of slash piles could benefit toads, but caution is needed to ensure that piles are not burned when toads might be occupying them.

- Prevent the spread of Bd. Because Bd occurs at this study site and streams around Ryan Park, caution should be taken to prevent the spread of Bd from Ryan Park to other watersheds. Furthermore, because different strains of Bd can affect amphibian populations differently (Blaustein et al. 2018; O'Hanlon et al. 2018), resource management crews should minimize the risk of bringing new strains of Bd to Ryan Park. We recommend that crews follow protocols to disinfect boots and equipment both before and after working in Ryan Park. Protocols include disinfecting all equipment that contacts water with a 10% bleach solution, fungicide, or a commercially available quaternary ammonia compound disinfectant, or allowing clothing and equipment to dry thoroughly before moving between waterbodies. Crews can refer to the Medicine Bow Forest Plan or consult regional biologists for specific protocols.

ACKNOWLEDGEMENTS

This study would not have been possible without the support of the landowners surrounding this unique population of Boreal Toads. We thank the many landowners for allowing us to traverse their willows, ponds, creeks, and meadows throughout the summer to ensure that we could check on the health and status of radio-tagged toads. We also thank USFS technicians Ben Gressler, Carolyn Buesch, Theresa Demaree, and Ben Walton and WGFD employees and volunteers Asila Bergman, Amanda Bevan, James Erdmann, and Anne Yen who helped to track toads throughout the summer. Special thanks to University of Wyoming graduate student Gabe Barrile for teaching us how to attach transmitters to toads.

LITERATURE CITED

Barrile, G., A. Chalfoun, and A. Walters. 2018. Boreal Toad habitat selection and survival in relation to grazing intensity and disease prevalence. Interim report to the Wyoming Game and Fish Department. Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming, Laramie, Wyoming.

Bartelt, P.E., C.R. Peterson, and R.W. Klaver. 2004. Sexual differences in the post-breeding movements and habitats selected by Western Toads (*Bufo boreas*) in southeastern Idaho. Herpetologica 60:455-467.

Blaustein, A.R., J. Urbina, P.W. Snyder, E. Reynolds, T. Dang, J.T. Hoverman, B. Han, D.H. Olson, C. Searle, and N.M. Hambalek. 2018. Effects of emerging infectious diseases on amphibians: A review of experimental studies. Diversity 81:doi:10.3390/d10030081.

Browne, C.L. and C.A. Paszkowski. 2010. Hibernation sites of Western Toads (*Anaxyrus boreas*): Characterization and management implications. Herpetological Conservation and Biology 5:49-63.

Browne, C.L. and C.A. Paszkowski. 2014. The influence of habitat composition, season, and gender on habitat selection by Western Toads (*Anaxyrus boreas*). Herpetological Conservation and Biology 9:417-427.

Browne, C.L. and C.A. Paszkowski. 2018. Microhabitat selection by Western Toads (*Anaxyrus boreas*). Herpetological Conservation and Biology 13:317-330.

Bull, E.L. 2006. Sexual differences in the ecology and habitat selection of Western Toads (*Bufo boreas*) in northeastern Oregon. Herpetological Conservation and Biology 1:27-38.

Burow, A.L., A.L. Herrick, A.C. Geffre, and P.E. Bartelt. 2012. A fully adjustable transmitter belt for ranids and bufonids. Herpetological Review 43:66-68.

Campbell, J.B. 1970. Hibernacula of a population of *Bufo boreas* in the Colorado front range. Herpetologica 26:278-282.

Goates, M.C., K.A. Hatch, and D.L. Eggett. 2007. The need to ground truth 30.5 m buffers: A case study of the boreal toad (*Bufo boreas*). Biological Conservation 138:474-483.

Goebel, A.M., T.A. Ranker, P.S. Corn, and R.G. Olmstead. 2009. Mitochondrial DNA evolution in the *Anaxyrus boreas* species group. Molecular Phylogenetics and Evolution 50:209-225.

Hof, C., M.B. Araújo, W. Jetz, and C. Rahbek. 2011. Additive threats from pathogens, climate and land-use change for global amphibian diversity. Nature 480:516-519.

Kinney, V.C., J.L. Heemeyer, A.P. Pessier, and M.J. Lannoo. 2011. Seasonal pattern of *Batrachochytrium dendrobatidis* infection and mortality in *Lithobates areolatus*: Affirmation of Vredenburg's "10,000 Zoospore Rule". PLoS ONE 6:e16708. doi:10.1371/journal.pone.0016708

Lips, K.R. 2016. Overview of chytrid emergence and impacts on amphibians. Philosophical Transactions of the Royal Society B 371:20150465. http://dx.doi.org/10.1098/rstb.2015.0465

McGee, M. and D. Keinath. 2004. Species assessment for Boreal Toad (*Bufo boreas boreas*) in Wyoming. Prepared for the Bureau of Land Management Wyoming State Office by the Wyoming Natural Diversity Database, Laramie, Wyoming.

Muths, E., R.D. Scherer, and B.A. Lambert. 2010. Unbiased survival estimates and evidence for skipped breeding opportunities in females. Methods in Ecology and Evolution 1:123-130.

O'Hanlon et al. 2018. Recent Asian origin of chytrid fungi causing global amphibian declines. Science 360:621-627.

Pimm, S.L, C.N. Jenkins, R. Abell, T.M. Brooks, J.L. Gittleman, L.N. Joppa, P.H. Raven, C.M. Roberts, and J.O. Sexton. 2014. The biodiversity of species and their rates of extinction, distribution, and protection. Science 344:1246752. DOI: 10.1126/science.1246752.

Pullen, K.D., A.M. Best, and J.L. Ware. 2010. Amphibian pathogen *Batrachochytrium dendrobatidis* prevalence is correlated with season and not urbanization in central Virginia. Diseases of Aquatic Organisms 91:9-16.

R Core Team. 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Scheele et al. 2019. Amphibian fungal panzootic causes catastrophic and ongoing loss of biodiversity. Science 363:1459-1463.

Schmetterling, D.A. and M.K. Young. 2008. Summer movements of Boreal Toads (*Bufo boreas boreas*) in two western Montana basins. Journal of Herpetology 42:111-123.

Skerratt, L.F, L. Berger, R. Speare, S. Cashins, K.R. McDonald, A.D. Phillott, H.B Hines, and N. Kenyon. 2007. Spread of chytridiomycosis has caused the rapid global decline and extinction of frogs. EcoHealth 4:125–134.

Stuart, S.N., J.S. Chanson, N.A. Cox, B.E. Young, A.S.L. Rodrigues, D.L. Fischman, and R.W. Waller. 2004. Status and Trends of Amphibian Declines and Extinctions Worldwide. Science 306:1783-1786.

USDA Forest Service. 2003. Medicine Bow National Forest Revised Land and Resource Management Plan. 1-29 and 1-44 pp.

USDA Forest Service. 2018. Decision memo, Ryan Park farm bill categorical exclusion. USDA Forest Service, Brush Creek/Hayden Ranger District, Medicine Bow – Routt National Forests and Thunder Basin National Grassland, Carbon County, Wyoming. 12pp.

U.S. Fish and Wildlife Service (USFWS). 2017. Species Status Assessment report for the eastern population of the Boreal Toad, Anaxyrus boreas boreas. Western Colorado Ecological Services Field Office, Grand Junction, Colorado. 145pp.

WGFD. 1993. Annual Fisheries Progress Report on the 1992 Work Schedule. Wyoming Game and Fish Department, Fish Division. Cheyenne, Wyoming.