Herpetological Conservation and Biology 1(1):27-38
Submitted: 25 April 2006; Accepted: 16 August 2006;

SEXUAL DIFFERENCES IN THE ECOLOGY AND HABITAT SELECTION OF WESTERN TOADS (*BUFO BOREAS*) IN NORTHEASTERN OREGON

EVELYN L. BULL

Pacific Northwest Research Station
1401 Gekeler Lane
La Grande, OR 97850, USA
e-mail ebull@fs.fed.us

Abstract.*—Several species of toads (family Bufonidae), including the Western Toad (*Bufo boreas*) have declined in the western United States. Information on toad ecology and habitat use is essential to determine potential causes for population declines, as is the potential relationship between this information and disturbance events. Aspects of western toad survival, mortality, movements, habitat selection, and diet were investigated at five study areas in northeastern Oregon during summers of 2002-2005. Of 100 radio-tagged toads monitored for one summer during these years, 32% survived until September, 29% were killed by predators, 10% died of other causes, and 29% were missing or had lost transmitters. At four study areas sampled in 2005, 24% of 37 males and 44% of 32 females sampled during the breeding season, and three dead male toads found after the breeding season tested positive for *Batrachochytrium dendrobatidis*. Females traveled significantly farther than males, and the maximum distances traveled by female and male toads were 6230 m and 3870 m, respectively. Toads with transmitters selected habitats: (1) with little or no canopy; (2) on south-facing slopes; (3) near water; and (4) with high densities of potential refugia (e.g., burrows, rocks, logs). Males were more closely associated with water than females. Twenty-six toads overwintered in rodent burrows (38%), under large rocks (27%), under logs or root wads (19%), and under banks adjacent to streams or a lake (15%). Diet consisted of 82% ants (Formicidae), 13% beetles (Coleoptera), and <1% in 8 additional orders of insects with no differences detected between male and female toads. Disturbance events, such as wildfire, can influence refugia and prey of toads, and climatic conditions may influence a toad's susceptibility to *B. dendrobatidis.

Key Words.—*Bufo boreas*; diet; habitat selection; movements; northeastern Oregon; predation; Western Toad.

INTRODUCTION

The decline of many amphibians is causing concern worldwide and reasons for the declines are often unknown (Carey 1993). Populations of the Western Toad (*Bufo boreas*) have declined in many parts of their range including in the central Rocky Mountains (Carey 1993; Corn et al. 1997; Livo and Yeakley 1997), California Great Central Valley (Fisher and Shaffer 1996), northern Utah (Corn et al. 1997; Thompson et al. 2003), and the northern Great Basin (Wente et al. 2005). Due to their declining numbers, populations of the Western Toad have been listed as: (1) endangered by New Mexico and Colorado; (2) Native Species Status 1 by the Wyoming Game and Fish Department; (3) a "Sensitive Species" by the U.S. Forest Service; and (4) a candidate species for federal listing under the Endangered Species Act (Loeffler 2001; Jones et al. 2005).

Some toad declines have been associated with fungal and bacterial infections. In Colorado, declines in Western Toads were attributed to *Batrachochytrium dendrobatidis* (B.d.)(Daszak et al. 1999; Green and Muths 2005; Scherer et al. 2005) and the bacteria *Aeromonas hydrophila* (Carey 1993). Other species of toads in the West have shown declines as well, with chytridiomycosis linked with die-offs of the Yosemite toad (*B. canorus*), Wyoming Toads (*B. hemiophrys baxteri*), and *B. californicus* (Kagarise Sherman and Morton 1993; Carey et al. 1999; Daszak et al. 1999; Green and Kagarise Sherman 2001; Carey et al. 2003; Muths et al. 2003). The fungus (*Saprolegnia ferax*) may have been responsible for egg mortality in a population of Western Toads in Oregon (Blaustein et al. 1994).

Disturbance events, such as fire and insect outbreaks, may affect Western Toads by impacting water quality and solar radiation, abundance of prey and predators, habitat quality in movement corridors, and terrestrial summer and winter refugia. Deliberate habitat alterations, such as fuel reductions, may cause toads to be more vulnerable to predation, starvation, disease, or desiccation during movements to these habitats. Little information is available on how disturbance events influence Western Toads in the northwest, although some information is available for other areas. For example, more *B. americanus* were trapped in burned than in unburned deciduous forests in Appalachian Mountains of eastern North American (Kirkland et al. 1996). Boreal Toads bred in shallow ponds in burned stands of Lodgepole Pine (*Pinus contorta*) in Glacier National Park and not in adjacent unburned areas (Pilliod et al. 2006).

Due to the population declines of Western Toads elsewhere, one objective of this study was to establish baseline data on demographics of populations in northeastern Oregon. Although this research is exploratory in nature, I am testing the hypotheses that female and male Western Toads do not differ in survival, mortality, movements, habitat use, and diet during the post-breeding period.

MATERIALS AND METHODS

***Study areas.*—**Toads (n = 472 females and 1297 males) were monitored from 2002 to 2005 at five areas on the Wallowa-Whitman National Forest in Baker, Wallowa, and Grant Counties in northeastern Oregon. Toads were monitored and radio-tagged at breeding sites in May or June at Fish Lake (Fish; 1992 m elevation), Twin Lake (Twin; 1944 m), Lilypad Lake (Lilypad; 2130 m), Crawfish Lake (Crawfish; 2094 m), and Balm Reservoir (Balm; 1368 m). The two reservoirs (Balm and Fish) are each about 35 ha in size and are used for crop irrigation 13-18 km downstream in the summer. Approximately 80% of the water was removed from each reservoir in August and September each year during our study. Lilypad, Crawfish, and Twin are lakes that range from 2.5 ha to 7.3 ha in size and whose water levels fluctuated by < 0.5 m during this study. All five bodies of water contained Rainbow (*Oncorhynchus mykiss*) or Brook Trout (*Salvelinus frontinalis*). Breeding sites were typically in shallow water on south-facing shores at four of the study areas, but were on the south-, east-, and north-facing shores at Balm. One breeding site was used at Crawfish, two at Twin, three at Lilypad, four at Fish, and six at Balm. Breeding sites with egg strings separated by >100 m were considered to be separate sites.

All study areas were in mountainous, forested terrain with undulating uplands and moderately or steeply walled drainages. Forests consisted primarily of Lodgepole Pine and Subalpine Fir (*Abies lasiocarpa*) at all study areas except Balm Reservoir, where Ponderosa Pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga menziesii*), Western Larch (*Larix occidentalis*) and Grand Fir (*A. grandis*) were present. Stand replacement fires (i.e., crown fire that kills the overstory trees) burned portions of the forests surrounding Fish, Twin and Crawfish between August 1994 and 1996. The burned stands were not logged and had high densities of standing dead trees and downed wood. Streams, springs, and seeps were common in all the study areas except Balm.

Daytime ambient temperatures in summer typically exceeded 24˚C, and winter low temperatures were typically freezing with an extreme of -15˚C in the study areas. Annual precipitation averaged 78 cm with about 60% falling as snow, depending on the elevation. At Fish and Twin, snow was on the ground from October until June each year with maximum depths of 3-6 m. At the other study areas, snow was on the ground from November until May with maximum depths of 1-3 m.

Study areas were selected based on the presence of at least 20 Western Toads at breeding sites and accessibility by vehicles during breeding activity. There were few water bodies to select from because high densities of Western Toads are uncommon in high elevation lakes in northeastern Oregon (Bull and Marx 2002). High densities of Western Toads have not been reported elsewhere in the Blue and Wallowa Mountains.

Population demography and telemetry.—To assess population dynamics, toads were captured with dip nets at breeding sites between early May and mid-June. I inserted a passive integrated transponder (PIT) tag for individual identification (Loeffler 2001), determined sex, snout-vent length (SVL) [measured to the nearest mm], and mass (to nearest g) for each toad. A toe was removed from a front limb of the smallest and largest male and female toad during breeding at each study area in 2005 to determine age using skeletochronology. Swab samples were taken from a limited number of toads in 2005 to test for the presence of B.d. Toad populations were monitored at Crawfish, Lilypad, and Balm each spring from 2003 to 2005 and at Fish in 2002, 2004, and 2005. Toads were monitored at Twin in 2002, but the breeding site was inaccessible during the other years.

One hundred toads were also radio-tagged (models BD-2G and BD2, Holohil Systems Ltd., Carp, Ontario, Canada) at the five study areas. Radio-tagged toads were monitored in Fish and Twin in 2002, Crawfish and Lilypad in 2003, and Balm in 2003-04. Transmitters weighed 1.8 g, performed for 5 months, and had a range of 50-500 m depending on the disposition of the toad (above or below ground). Transmitters were attached to males and females without eggs with a 3-mm wide satin ribbon fitted around the waist or with a thin satin ribbon (2 mm) around the upper arm for toads with narrow hips or gravid females (in 2002 only) (Bull 2000). Ribbons were both glued and stitched to the transmitter with carpet thread through the tunnel that was embedded in the acrylic at the anterior end of the transmitters.

An alternative temporary attachment technique using absorbable suture material was developed for: (1) gravid females; (2) toads that developed abrasions from the satin ribbon around the waist or arm; and (3) all toads still carrying transmitters in September each year. This attachment did not restrict oviposition, allowed abrasions to heal, and, importantly, allowed the transmitter to fall off when the sutures dissolved. This was critical for toads with radios on into the winter because waistbands can cause serious injury (cuts > 0.5 cm deep, pers. obs.) if not removed. These transmitters were attached by stitching the transmitter to the dorsal surface of the toad, adjacent to and on either side of the spinal column between the shoulder blades and urostyle, with absorbable suture material (i.e., polydioxanone monofilament synthetic absorbable suture; size: 3/0 and 2/0). The suture material was sewn through the skin only of the toad either with a sewing needle or by putting a 20 gauge hollow needle (2.5 cm long) through the skin of the toad and passing the suture material through the needle. A horizontal stitch 8-10 mm in length was used and the suture material was knotted with three square knots to provide a good anchor for the transmitter. One person could attach the transmitter without sedating the toad in less than 10 minutes. It is unknown if this transmitter attachment technique affected the behavior and movements of the toads.

Radio-tagged toads were located with a portable receiver (Telonics TR-4, Mesa, Arizona, USA) and H-type directional antenna each week from capture until the transmitter failed or came off, the toad was preyed upon or died, the signal could not be detected, or until late November when snow and cold conditions inhibited toad movement. Toads were located between 0900 and 1700, and the location was confirmed visually 49% of the time. During this study, toads were typically in refugia during the day, so the time of day that each toad was located was not randomized.

In order to estimate longevity and age at sexual maturity, age estimates were determined using skeletochronology (Matson's Laboratory LLC, Milltown, Montana USA); the lines of arrested growth in transverse sections taken from the mid-diaphysis phalanges of arbitrarily selected toads were counted (Guarino et al. 1995). The relationship between estimated age, SVL, and mass for females and males was determined using Pearson's correlation coefficient.

Survival, mortality, and chytridiomycosis.—The fate of toads was classified as alive, preyed upon, dead with no evidence of predation, missing, transmitter off, or other. When only the transmitter and band were found on the ground, it was unknown if the toad had been killed by a predator or if the transmitter had come off. If the tunnel was broken on the transmitter or there were tooth marks, it was attributed to predation because it is unlikely the toad would be strong enough to break the tunnel in the acrylic. Toads located in the same underground burrow for a month were excavated to determine their condition.

Predation was attributed to avian species when the transmitter was in a tree or the toad remains were accompanied by white excrement. Avian or mammalian predators were assigned responsibility when remains included the bones of the head and portions of the back, only the skin turned inside out, or the legs of the toad had been consumed with the skin turned inside out (Olson 1989; Corn 1993; Kagarise Sherman and Morton 1993).

When a signal could not be detected, the toad was classified as missing, and we searched within a 4-km radius of the last known location driving all roads to detect a signal. In 2002, missing toads were located with a fixed wing airplane, but funding restrictions limited this to the first year. All missing toads were located when aerial searches were used, even though ground searches failed to locate them. Missing toads could have moved outside the range of detection, been carried away by a predator, the transmitter could have quit due to a mechanical failure or due to damage from a predator.

Assays for B.d. employed swab samples of the first 10 male and 10 female toads captured (if available) at the breeding site in each study area in 2005 using techniques described by Livo (2004). Samples were sent to Pisces Molecular (Boulder, Colorado, USA) where a polymerase chain reaction (PCR) assay (Annis et al. 2004) was used to determine the presence of B.d. In 2004, five dead radio-tagged toads with no evidence of predation or injury were sent to the National Wildlife Health Center in Madison, Wisconsin for necropsies, as well as bacterial and fungal cultures (U.S. Geological Survey 2004).

Movements.—To investigate movement distances and potential routes, I recorded global positioning system (GPS) coordinates for each toad location. For each toad that was monitored for at least 7 weeks, I calculated the maximum distance traveled and straight line direction from the breeding site where all toads were captured. Seven weeks was selected as the minimum time period because toads reached their summer habitat within 7 weeks in 2002 and 2003. I determined that summer habitat had been reached when movements within a week did not exceed 150 m. The rate of movement (reported in m/day) was determined by dividing the distance traveled by the number of days between when the toad left the breeding site and arrived at the summer habitat. This measurement was an approximation because toads were located once or twice a week during breeding, and the exact day that toads left the breeding site was not known. The maximum distances traveled and rate of movement were compared between males and females using *t*-tests. The maximum distances traveled by toads in burned and green forests were also compared using *t*-tests at Fish and Twin where extensive burns occurred.

Habitat use and availability.—To assess these aspects of toad ecology, habitat characteristics of the location where radio-tagged toads were found were recorded each week in 2002 and 2003. Each time a toad was located, I determined its habitat (in water or terrestrial location) and recorded the type of shelter used (i.e., none, self-excavated depression, burrow, rock, log, root wad, bark, or stump). Outside of the breeding season, toads were typically underground or under cover during the day and were not disturbed. Landscape characteristics were recorded visually in approximately 1-ha circular area around the toad. The presence of an opening (area without woody vegetation) at least 15 m in diameter within 10 m of the toad was noted. Vegetation type was classified as open forest (< 30% canopy closure), closed forest (30% canopy closure or more), riparian, burn, scab flat, or rock slope. Structural stage was classified as no trees, stem initiation, stem exclusion, young multi-stage, or old multi-stage (Oliver and Larson 1990). Harvest activity (Balm only) was classified as none, partial cut, or clear-cut. Fire activity was classified as none, understory burn, or overstory burn. Slope gradient and aspect were recorded, as well as the distance to water, green forest, and/or burned forest, if applicable.

Micro-habitat characteristics were recorded in a 0.005-ha circular plot (4-m radius) with the toad as the center point. Canopy closure (using GRS densitometer) was determined by averaging five readings at plot center and 1 m away in four cardinal directions. The number of live and dead stems < 20 cm and 20 cm dbh (diameter at breast height) and larger were counted. Ground cover was estimated as the percent of bare ground, water, rock, forbs, shrubs, grass, and logs in each plot. The number of burrows and shelters that were large enough to accommodate a toad (an opening > 5 cm in diameter) were counted in each plot.

Twenty-six over-wintering sites were identified in October and November when toads ceased moving and snow covered the ground. Habitat characteristics were recorded as described for summer habitat. The depth of toads in burrows underground was measured with a rigid tape measure and flashlight. Toads in over-wintering sites in fall 2003 and 2004 were located again in December and January to verify that they had not made any additional moves since the previous location in November.

To assess potential habitat selection by toads, available terrestrial habitat was measured in the five study areas at randomly selected points within a calculated radius of each breeding site. The radius of the circle that contained the random points was determined by taking the mean of the farthest distance each radio-tagged toad traveled from the breeding site in each study area. I used the mean rather than the maximum distance because the greatest distance was traveled by large females, and it was unknown if the smaller males were capable of traveling this distance. Only toads monitored for at least 7 weeks were included in calculating the mean. The maximum dispersal distance and number of random points were determined at the end of September during the year toads were monitored. Available habitat was assessed at Fish and Twin in September 2002 and at Balm, Crawfish, and Lilypad in July 2004. Conditions of most habitat variables measured did not change appreciably between July and September except ground cover. I recorded percent ground cover by vegetation type because the plant species composition would be consistent over time even though the height of grasses, forbs, and shrubs would likely change. The number of random points approximately equaled the number of toad locations during 2002-03 at terrestrial sites in each study area. I generated random points with a uniform distribution within the circle using ArcView (ESRI Inc., Redlands, California, USA) and the Animal Movement version 1.1. extension for ArcView (Hooge, P.N., and B. Eichenlaub. 1997. Alaska Biological Science Center, United States Geological Survey, Anchorage, Alaska, USA.).

Available habitats and habitat at toad locations were compared using a multivariate analysis of variance (MANOVA) for continuous variables (percent slope; percent canopy closure; distance to a burned forest, green forest, and water; number of stems < 20 cm and ≥ 20 cm dbh; percent ground cover) and Mann-Whitney *U* tests for categorical variables (slope aspect, vegetation type, structural stage, presence of an opening, harvest activity, fire activity, number of burrows, and shelters). If MANOVA results were significant, separate ANOVAs were used to examine individual habitat variables. The number of burrows and shelters were treated as categorical variables because these variables are skewed to low numbers and are not normally distributed. Only toad locations at terrestrial sites were used for comparisons with available habitat. The same statistical comparisons were used to determine if habitat use differed by sex.

Diet.—An adequate source of prey may reflect the quality of habitat, so diet samples were collected from radio-tagged toads each week to determine what they ingested. Diet samples were obtained in all study areas when toads were accessible from 21 May through 24 September 2002 and 2003, which corresponds to the time that toads are active (pers. obs.). Diet samples were also collected opportunistically when toads without radios were encountered.

A diet sample was obtained by stomach flushing with a plastic flexible catheter (2 mm wide, 56 cm long) inserted through the mouth and esophagus of the toad with the opposite end attached to a 65-cc syringe filled with water (Legler and Sullivan 1979; Whitaker et al. 1983). Stomach flushing is expected to have limited adverse impact on the population, and it allows re-sampling of the same individual. The use of stomach flushing (rather than dissection) may introduce bias toward smaller size classes, with larger items becoming stuck in the esophagus, although palpating the stomach after flushing reduced this bias. Diet samples were preserved in vials of 75% ethanol and returned to the lab for identification. After the diet sample was removed by flushing, the stomach was palpated to ensure that the stomach was empty. After stomach flushing, crickets (*Gryllus* sp.) were fed to each toad to replace the sample taken. Prey items were identified at least to order, and placed in body-length size classes (1-4.5, 5-9.5, 10-14.5, and 15 mm and larger; Bull 2003). Biomass (in mg) was determined after oven-drying each sample for 24 h at 40˚C. Prey types and availability at these locations are unknown.

Dietary composition was defined as the percentage of items of a particular prey type out of the total number of prey items. The diet composition, number and size of prey items, and biomass were compared by month (three time periods: May-June, July, August-September), study area, and sex using a MANOVA. Diet composition was compared for orders, families, and genera that comprised > 5% of the prey items. Pearson's correlation coefficient was used to assess correlation between biomass and number of prey items. Probability levels of < 0.05 were considered significant for all statistical comparisons.

RESULTS

Population demographics.—A total of 1,769 toads were PIT-tagged between 2002 and 2005. The highest number of toads and the highest ratio of females to males occurred at Balm (Table 1). Data on mature toads captured at each breeding site are shown in Table 1. Of 14 female toads I aged using skeletochronology, the youngest and oldest at a breeding site were 1.9 and 10.8 years, respectively. Of 20 male toads, the youngest and oldest at a breeding site were 1.9 and 7.7 years, respectively. There was a correlation in male toads between age and SVL ($r = 0.47$, $P = 0.04$) and between age and body mass ($r = 0.52$, $P = 0.02$); there was no correlation in females between age and these variables. Females lost 20-44% of their body weight after depositing eggs (n = 5).

The recapture rate (percentage of toads recaptured in successive or alternate years) was 2-37% and varied by study area (Table 1). During 2003-2005, two females were gravid in consecutive years at Balm.

Survival.—Of 100 radio-tagged toads in five study areas, 32% survived until September of the year they were monitored, at least 30% were preyed upon, and chytridiomycosis was the likely cause of death in at least 6% (Table 2). Fifteen of 46 females (33%) and 31% of 54 males survived until September. Only the transmitter was recovered in 13 cases; thus it was not possible to verify if the toad had been consumed by a predator. It was unlikely that transmitters slipped off, although not impossible. The fate of an additional 16 toads was unknown because their signals could not be detected, and their radios were not recovered.

Predation.—At least 26% of radio-tagged males and 33% of females were killed by predators. Of the 13 males killed, 38% were killed at the breeding site, while only 25% of the 16 females

TABLE 1. Recapture rate and mean (range) measurements of SVL (snout-vent length), mass, and maximum movements within 6 months of male and female Western Toads PIT-tagged in five study areas in northeastern Oregon, 2002-2005.

	STUDY AREA				
Characteristic	**Balm**	**Twin**	**Fish**	**Crawfish**	**Lilypad**
Females					
SVL	104 (73-126)	119(115-123)	102(86-130)	101(95-107)	93(91-96)
Mass	117(44-234)	130(120-141)	105(56-185)	102(94-110)	71(60-79)
n	383	2	80	3	4
Males					
SVL	95(63-125)	93(79-103)	90(69-110)	87(80-94)	83(38-94)
Mass	72(28-145)	64(40-84)	64(32-112)	57(46-74)	53(38-85)
n	722	14	513	18	30
Female:male ratio	0.53	0.14	0.16	0.16	0.13
Recapture rate					
Females	2%[a]	-	3%[b]	-	-
Males	3%	-	34%	12%	37%
Distance (m) traveled					
Females	2823(180-6230)	2270(2110-2430)	2067(260-3560)	1670	-
n	17	2	7	1	0
Males	1390(350-3870)	530 (220-1130)	1248(390-2180)	537(340-730)	700(360-930)
n	9	4	6	3	6
Years monitored	2003-05	2002	2002, 2004-05	2003-05	2003-05

[a]Represents two females that were gravid in two consecutive years, and two females that were gravid in 2003 and in 2005.
[b]Represents one female that was gravid in 2002 and in 2005.

were killed at the breeding site; all others were killed away from the breeding site. The highest predation rate (37% of tagged toads) occurred at Balm Reservoir where avian species were presumed responsible for at least 74% of the predation (Table 2). I was unable to distinguish between avian and mammalian predation at Lilypad Lake and Fish Lake. No predation was detected at Crawfish and Twin.

Eight radio-tagged and 21 unmarked toads were found skinned along the shore of Balm Reservoir in 2004. These deaths were attributed to raven predation based on observations of ravens, presence of white excrement, and the absence of mammal tracks. Six transmitters were found in trees at Balm Reservoir. Two transmitters were located in an active Red-tailed Hawk (*Buteo jamaicensis*) nest, three were in trees about 100, 250, and 450 m from the nest, and I observed a red-tailed hawk capture a toad at the shoreline and carry it to the nest. Therefore, the six transmitters found in trees in 2004 were attributed to red-tailed hawk predation. Osprey (*Pandion haliaetus*) also frequented the reservoir and could have been responsible for some of the transmitters in trees. Two radio-tagged toads were found in Common Garter Snakes (*Thamnophis sirtalis*). The predator of 7 toads could not be determined conclusively. In these cases, only a small piece of the toad remained with the transmitter or the transmitter was found with a broken tunnel.

Batrachochytrium dendrobatidis.—In 2005, 24% of 37 tested males and 44% of 32 tested females returned positive results for B.d. at the four study sites sampled. A higher incidence of B.d. was detected in females than in males at three of four study sites. Advanced B.d. infection was found in three male toads found dead at terrestrial sites at Balm Reservoir 1-3 weeks after leaving the breeding site, and a mild chytrid infection was detected in one live toad at Lilypad Lake (U.S. Geological Survey 2004). Mortality due to chytridiomycosis may have been underestimated given that an additional five dead radio-tagged toads showed no evidence of predation but tissue samples submitted for histology determination of infection were too desiccated to determine fungal infection (U.S. Geological Survey 2004).

Movements.—The majority of Western Toads in these study areas left the breeding ponds and traveled in a relatively straight line from the breeding site to an area where they remained for the rest of the summer (Fig. 1, 2); only toads monitored for at least 7 weeks are included in this section on movements. SVL and mass of male and female toads were not significantly correlated with the distance each toad traveled. The maximum distance traveled by a toad was 6230 m. Females traveled significantly farther (mean = 2543 m, SE = 267.9, *n* = 27) than males (mean = 997 m, SE = 151.4, *n* = 28) from the breeding sites for those toads monitored at least 7 weeks ($t = -5.07$, df = 53, $P < 0.01$; Table 1). Twenty-four

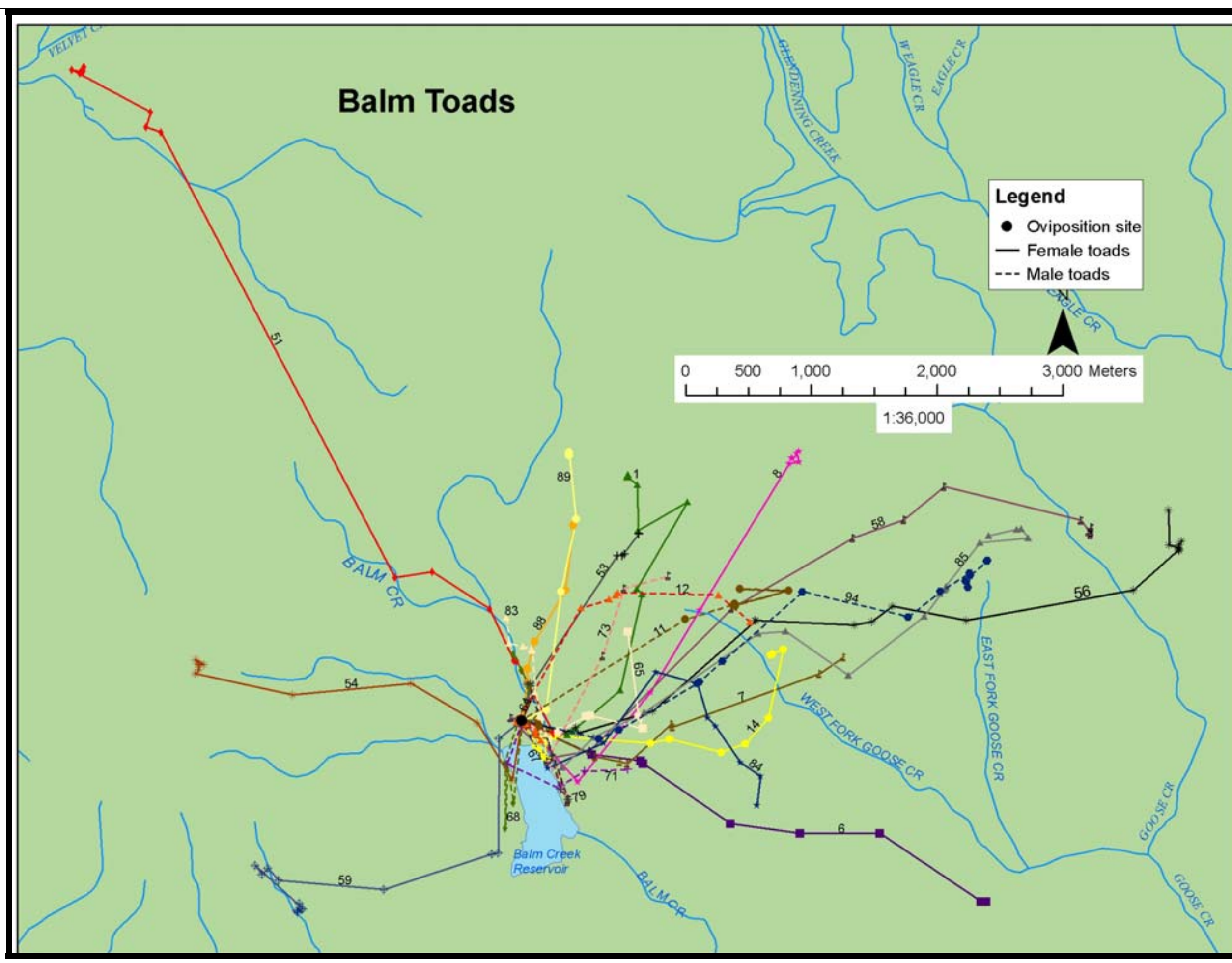

FIGURE 1. Locations of toads monitored more than 7 weeks at Balm study area in northeastern Oregon from 2003-2004. Numbered lines correlate to individual toads and their travel routes.

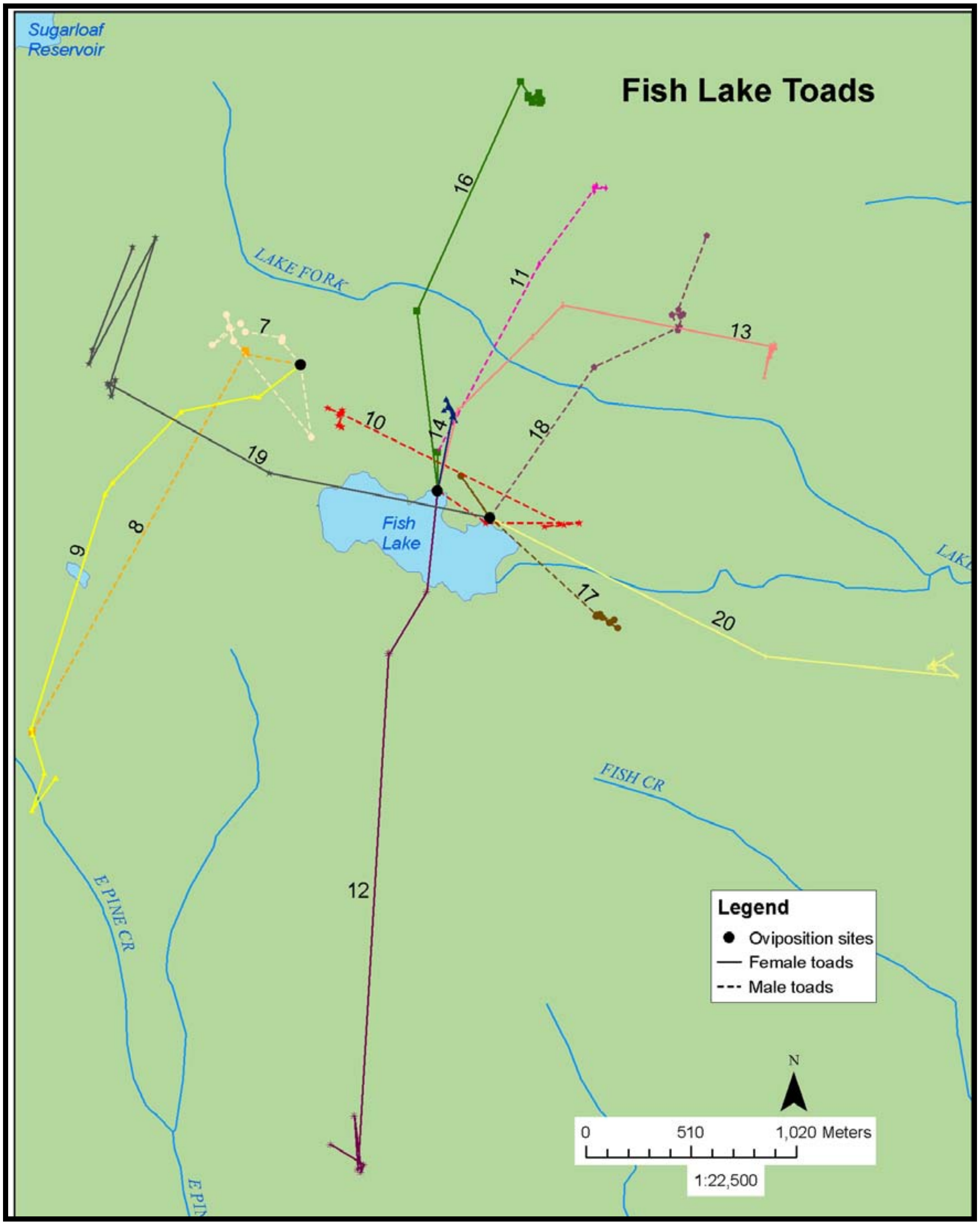

FIGURE 2. Locations of toads monitored more than 7 weeks at Fish study area in northeastern Oregon from 2003-2004. Numbered lines correlate to individual toads and their travel routes.

of 27 females moved more than 1600 m from the breeding site, and three females moved only 180, 260, and 930 m away. Only 8 of 28 males monitored at least 7 weeks traveled more than 1000 m from the breeding site. Toads in Balm tended to travel the farthest distances, although sample sizes were inadequate to compare among study areas (Table 1).

Females typically left the breeding site 1 or 2 days after egg laying, while males remained at the breeding site for 1 to 4 weeks and often traveled between different breeding sites at the pond or lake. The number of days for toads to reach summer habitat largely depended on the distance traveled per day, but the rate of movement (m/day) to the summer habitat was not statistically different between males and females. The slowest rate of travel for male and female toads was 17 m/day and the fastest was 241 m/day. The shortest number of days to reach summer habitat was 16 days (1080 m movement at 67.5 m/day), and the longest was 83 days (5400 m movement at 66.1 m/day). Some toads crossed rugged terrain to reach summer habitat; two females traveled 2.4 km down steep cliffs to the Imnaha River which was 530 m lower in elevation. Two toads climbed 200 m in elevation up rock

TABLE 2. Fates of 100 radio-tagged Western Toads (percentage of toads) monitored between the breeding season (May or June) and 1 September of 1 year (2002, 2003, or 2004).

	STUDY AREA					
	Balm	**Twin**	**Fish**	**Crawfish**	**Lilypad**	**Total (%)**
Alive	16%	83%	79%	20%	38%	32
Total predation	37%	0	21%	0	23%	29
Avian/mammalian	33%	0	21%	0	23%	27
Snake	3%	0	0	0	0	2
Radio off or redation[a]	16%	0	0	40%	8%	13
Dead, not predation[b]	11%	17%	0	0	0	8
Missing[c]	16%	0	0	40%	31%	16
Other[d]	3%	0	0	0	0	2
No. radio-tagged toads	62	6	14	5	13	100
Year of monitoring	**2003-04**	**2002**	**2002**	**2003**	**2003**	

[a]Toads may have slipped their transmitters or been consumed by a predator.
[b]Three of these toads were confirmed as having died of *B. dendrobatidis* and another five were too desiccated to determine fungal infection.
[c]Missing toads could have moved out of the range of detection or been carried off by a predator or the transmitter may have quit from mechanical problems.
[d]One toad was run over on a gravel road, and one toad died after it became entangled in vegetation.

hillsides with 60 percent slopes. Many toads followed small drainages with temporary runoff water or streams for a portion of their movements (Fig. 1, 2).

No male (N = 13) or female (N = 13) toads returned to their respective breeding sites during the summer, although four males at Fish and Twin moved 20-550 m to within 50 m of the breeding site by October 2002. Distance of males from the breeding site in November varied by study area; males at Lilypad and Crawfish were 240-920 m (n = 5) from the breeding site and males at Balm were 2028 and 3870 m (n = 2) from the breeding site.

A comparison of movements of toads in the two study areas with extensive amounts of burned forests (Fish and Twin) showed that females (n = 6) in burned forests traveled shorter distances (mean = 1807 m, SE = 328.5) than females (n=3) in green forests (mean = 2723 m, SE = 433.2). At the same two study areas, males (n = 8) in burns traveled a mean of 826 m (SE = 206.7) and males (n = 2) in green forests traveled 1500 m (SE = 961.7); these values were not significantly different (females: t = -1.64, df = 558, P = 0.14; males: t = -1.32, df = 509, P = 0.22).

Habitat selection.—After breeding, toads were primarily terrestrial (81% of the locations on land, 19% in the water away from breeding sites). Of the terrestrial locations, 81% of the toads were in refugia and 19% were on the surface. Refugia used by toads included: rocks (31%); burrows (18%) (Fig. 3); logs (17%); self-excavated depressions (8%); and stumps, root wads, or bark (6%).

In all five study areas combined, toads used vegetation types, burn activities, harvest activities, and percent slope in proportion to their occurrence (162 toad locations at Fish, 66 at Twin, 113 at Lilypad, 129 at Balm, 57 at Crawfish). In the three study areas where a portion had been burned by wildfires in the last 10 years, 56% of the toad locations and 58% of the random plots were in burned forests. Toads did not use certain habitat characteristics at random (F = 46.64, df = 975, P < 0.01; Table 3). In all study areas, toads selected south-facing slopes and avoided north-facing slopes compared to random plots (Table 3). Areas with no trees and seedlings were used more and older stands used less than expected based on availability (Z = -2.63, P < 0.001). Toads occurred in openings > 15 m in diameter 62% of the time and in forests 38%, yet only 39% of the random plots occurred in openings and 61% in forests (Z = -7.33, P < 0.01). In the 4-m radius plots, toads typically selected locations that had more open forest canopy and were closer to burrows used for refugia than occurred at random plots (Table 3). The ground cover at toad locations had more rocks (Fig. 4), more water, more forbs, fewer logs, and less bare ground compared to random plots (Table 3). Toad locations were also closer to water compared to random plots; the type of water at toad locations included streams (69%), permanent standing water (22%; e.g., ponds, springs), and temporary water (9%).

Differences in the use of habitat between sexes were observed (F = 6.81, df = 481, P < 0.01) with males more closely associated with water. Twenty-six percent of radio-tagged males were at aquatic locations, whereas only 5% of the locations of radio-tagged females were aquatic. Overall, locations of radio-tagged males were significantly closer to water (F = 8.42, P < 0.01), had a higher percentage of water in the 4-m radius plots (F = 19.38, P < 0.01), and were farther from burrows (F = 4.31, P = 0.04) than locations of radio-tagged females. More locations of radio-tagged females were found: (1) in openings (Z = -3.91, P < 0.01); (2) on south and west slopes (Z = -3.01, P < 0.01); and (3) at locations with more open canopy (F = 11.97, P < 0.01), fewer trees < 20 cm dbh. (F = 4.31, P = 0.04), more bare ground (F = 19.51, P < 0.01), more forb cover (F = 9.81, P < 0.01), and less shrub cover (F = 5.48, P = 0.02) compared to males. These observations suggest that females selected sites that received more solar radiation.

The mean distance of hibernacula from breeding sites was 1968 m (range = 180-6230 m, N = 26). Toads arrived at over-wintering areas between 16 September and 10 November. Toad movements were monitored until October or late November depending on the study area, although snow covered the ground in all areas before we terminated monitoring. I found that some toads moved up to 2 m underground or between locations even in November after snow covered the ground. No movements among hibernacula were detected between late December and January with 1-2 m of snow on the ground (n = 5, Balm and Lilypad).

FIGURE 3. Western Toads (*Bufo boreas*) frequently used rodent burrows for thermoregulation and protection from predators.

TABLE 3. Mean values of micro-habitat variables recorded at locations of 100 radio-tagged Western Toads after toads left the breeding sites in five study areas, 2002-2003. An overall multivariate analysis of variance reflected significant differences between habitat at 527 toad locations and 501 random plots. Number in parentheses is the standard error.

Variable	Toad	Random	F value	*P* value
Canopy closure (%)	25 (1.25)	42 (1.50)	65.34	< 0.01
Distance to water (m)	46 (3.70)	133 (5.79)	154.24	< 0.01
Distance to burrow (cm)	29 (4.57)	372 (28.07)	146.32	< 0.01
Distance to green forest (m)	68 (6.74)	92 (10.6)	3.88	0.05
Stems < 20 cm dbh	5.4 (0.42)	8.4 (0.54)	22.47	< 0.01
Stems ≥ 20 cm dbh	0.5 (0.04)	1.5 (0.8)	128.66	< 0.01
Ground cover (%)				
Bare ground	23 (0.92)	32 (2.86)	7.83	< 0.01
Grass	117 (0.73)	16 (0.78)	0.59	0.44
Forbs	20 (0.68)	15 (0.64)	16.18	< 0.01
Shrubs	12 (1.00)	12 (0.76)	0.52	0.47
Rock	18 (0.98)	15 (0.94)	8.30	< 0.01
Log	9 (0.48)	12 (0.44)	12.39	< 0.01
Water	7 (0.52)	1 (0.25)	79.59	< 0.01
Slope aspect (%)			Z = -3.59	< 0.01
North	19%	32%		
East	31%	26%		
South	33%	22%		
West	17%	20%		
No. burrows in 4-m radius	1.6 (0.13)	0.9 (0.09)	*Z* = -7.14	< 0.01
No. shelters in 4-m radius	3.5 (0.27)	1.9 (0.16)	*Z* = -7.97	< 0.01

Toads over-wintered underground in rodent burrows and under large rocks, logs or root wads, and banks adjacent to streams or a lake (Table 4). Standing water or streams were observed within 1 m of the hibernacula at 7 of 26 over-wintering sites. Six of the 10 over-wintering sites in burrows had been excavated by Red Squirrels (*Tamiasciurus hudsonicus*) based on the presence of middens and cone scales at the burrows. The remaining four over-wintering sites in burrows were likely excavated by red squirrels or ground squirrels (*Spermophilus* spp.). None of the toads were known to hibernate communally.

Diet.—In 2002 and 2003, 91 diet samples were collected at the five study areas (N = 33 males and 16 females). One sample was collected from each of 27 toads, 2 or 3 samples from each of 19 toads, and 4-7 samples from each of 3 toads over a 4 month period. More than 90% of the samples were collected from toads captured on land versus in water. The mean size of sampled toads was 104 (SE = 2.7) mm SVL and 99 g mass (SE = 5.9) for females and 89 (SE = 1.3) mm SVL and 63 g mass (SE = 2.8) for males. The mean number of prey items per sample was 20.3 (SE = 3.1, range of 1 to 228) with a total of 1844 prey items identified (Table 5). There were no significant differences between sexes, among time periods, or among study areas in the number or size of prey items, diet composition, or total flushed biomass.

Prey items found in diet samples indicate that the Western Toad consumes primarily ants and ground beetles at these study areas with no differences between the sexes. Toads concentrated on terrestrial arthropods that were < 15 mm in size and seemed to take advantage of arthropods that were ground-dwelling and colonial. Very few aerial or aquatic arthropods were found in the diet samples. Toads appeared to use areas with a high density of ants but were also opportunistic and ate passing invertebrates within the size range that they could handle. More prey items (mean = 30.5, SE = 8.50, n = 31) were found in diet samples collected in burned forests compared in green forests (mean = 15.0, SE = 1.55, n = 60), although these were not statistically different (t = 1.79, df = 32, P = 0.08).

Ants (Formicidae) (82%) and beetles (Coleoptera) (13%) represented 95% of the prey items identified in the samples (Table 5). Eight additional orders of insects and two classes of arthropods each comprised < 1% of the diet, and arachnids comprised 2.2% of the samples. Twelve individual prey items were larval forms, and six of these might have been aquatic forms. Of the prey items that could be measured, 24% were 1-4.5 mm in body length, 47% were 5-9.5 mm, 26% were 10-14.5, and 3% were 15 mm or larger. Mean biomass of diet samples was 12.5 (SE = 1.6) mg with a range of 0.1 to 79.4 mg. Biomass of the diet sample was correlated with number of prey items (r = 0.66, P < 0.01), which suggests that toads foraged on many small prey items versus a few large ones.

DISCUSSION

Population demographics.—Large declines in the numbers of Western Toads at these breeding sites were not detected during this study. I marked the most toads at the two reservoirs (1105 individuals at Balm and 593 at Fish) in spite of these sites experiencing high fluctuations in water levels compared to the three lakes with constant water levels. Differences between males and females were detected in predation rate, presence of B.d., movements, and habitat use during this study. No differences were detected in diet and overall survival between females (33%) and males (31%). The behavioral differences in movements and habitat use between the sexes likely influenced their vulnerability to predation. Too little is known regarding the transmission and effects of *B. dendrobatidis* on the Western Toad in these study areas to determine how their behavior influences this mortality factor or how B.d. influences behavior in Western Toads.

Females had a higher rate of mortality overall, but predation at the breeding sites was higher for males probably because males spend more time at the breeding sites than females. Most predation occurred during the post-breeding period at terrestrial locations. Numerous other studies have documented predators of adult Western Toads, although only Olson (1989) and Corn (1993) calculated a predation rate of > 60% and > 20% at breeding aggregations in Oregon and Colorado, respectively.

More females than males tested positive for B.d. through PCR at Fish, Crawfish, and Balm; no toads were tested at Twin and only one male was tested (positive) at Lilpad. The only dead animals found that tested positive for B.d. via PCR analysis were radio-tagged males from Balm. It is unknown if B.d. causes mortality at the other study areas, although Balm, at the lowest elevation, has the warmest and driest conditions of the five study areas which may have influenced the toad’s susceptibility to the fungus (Carey et al. 1993). The effect of climate on B.d. in amphibians is unclear although temperature and precipitation have

TABLE 4. Characteristics of 26 over-wintering sites of Western Toads in five study areas in northeastern Oregon, 2002-2004.

	STUDY AREA					
Variable	**Balm**	**Twin**	**Fish**	**Crawfish**	**Lilypad**	**Total**
Elevation (m)	1368	1944	1992	2094	2130	
No. toads	7	5	9	1	4	26
Males (%)	29%	60%	33%	100%	100%	50%
Mean distance to site from breeding site (m) (range)	4063 (2028-6230)	982 (180-2220)	1694 (50-3440)	540	510 (240-920)	1968 (50-6230)
Type of site						
Burrow	86%	20%	22%	0%	25%	38%
Rock	0%	20%	56%	0%	25%	27%
Log/roots	14%	20%	22%	0%	25%	19%
Bank	0%	40%	0%	100%	25%	15%

been implicated in the infection with and impact of B.d. on amphibians (Daszak et al. 2003; Woodhams and Alford 2005; Pounds et al. 2006). Carey et al. (2006) reported that air temperature between 12°C and 23°C had no significant effect on survival time of *B. boreas* toadlets infected with B.d. Additional research is needed to determine the extent of mortality caused by B.d. in Western Toads and the influence of local weather.

Movements.—Telemetry enabled me to monitor movements of individual toads for an entire active season. Although the majority of the movement data was collected using waistbands on toads, the benefits of the alternative temporary transmitter attachment outweighed the difficulties. Stitching transmitters to toads with dissolvable suture material allowed me to monitor toad movements to hibernacula where the transmitters eventually fell off with no apparent lasting harm to the toads. I recaptured 5 toads 6 months or 1.5 years after they went into hibernation with transmitters sewn through the skin and could detect no obvious injury (pers. obs.).

Sixty-seven percent of 27 females moved > 2000 m from the breeding site while only 14% of the males moved > 2000 m. Potential reasons for these "long distance" movements include reducing the risk of predation, finding food sources, reducing competition for prey, colonization of other breeding sites, or finding warmer microclimates to allow activity later in the season. The period of activity at high elevation study areas was slightly over 3 months; finding a location with any thermal advantage and abundant prey to extend the active season would be presumably advantageous. Another factor that likely facilitates "long distance" travel may be water availability. The use of streams as travel routes has been documented in western Montana (Adams et al. 2005). The longer distances traveled by females may be related to their larger size and greater capacity to store and carry water in their lymph sacs and bladder (Bartelt et al. 2004).

Males that traveled a short distance (< 500 m) in the summer or moved back toward the breeding site in the fall, as occurred at Fish, Crawfish and Lilypad, could easily return to the breeding site in the spring. These three study areas were also the ones with the highest recapture rate of male toads. In contrast, toads that over-winter more than 2000 m from the breeding site may be unable to return in time to breed the next spring. Breeding occurs within days after the ice melts on the lakes, and in spring snow and freezing temperatures are likely to impede movement and extend travel time. The distances toads traveled from the breeding sites in this study exceeded the distances reported in other studies. In southeastern Idaho, male toads traveled an average of 581 m and females a mean of 1105 m from the breeding site (Bartelt et al. 2004). In Colorado, Muths (2003) reported the maximum distance traveled from the breeding pond in one season was 2324 m for a female and 972 m for a male. Also in Colorado, two female toads traveled maximum distances of 5756 m and 6485 m during a summer (Carey et al. 2005). The ratio of female to male mean maximum distances traveled was 2.4

Table 5. Number of prey items identified to order, family, or genus found in 91 Western Toad diet samples in northeastern Oregon, 2002-2003. Numbers of diet samples with each prey item are listed. Families with fewer than three representatives are not listed separately. Percent of prey items are listed by order only.

Class/Order/Family	Prey items (*N*)	Samples with prey item (*N*)	% by order
Insecta		91	
Hymenoptera (ants, bees, and wasps)		83	81.9
Formicidae (ants)	439	45	
Formica (Formica ants)	625	48	-
Camponotus (carpenter ants)	429	49	-
Vespidae (wasps)	7	6	
Other	11	7	-
Coleoptera (beetles)		57	12.6
Carabidae (ground beetles)	67	23	-
Staphylinidae (rove beetles)	23	8	-
Curculionidae (snout beetles)	13	11	-
Scarabaeidae (scarab beetles)	6	3	-
Other (>6 families)	124	39	-
Diptera (flies) (>1 family)	16	10	0.9
Orthoptera (grasshoppers)	8	6	0.4
Lepidoptera (butterflies and moths)	7	6	0.4
Heteroptera (true bugs) (>2 families)	8	6	0.2
Trichoptera (caddisflies)	6	4	0.3
Dermaptera (earwigs)	5	1	0.3
Homoptera (hoppers, aphids)	1	1	0.1
Plecoptera (stoneflies)	1	1	0.1
Arachinida (arachnids)		30	2.2
Araneae (spiders)	25	23	-
Opiliones (harvestmen)	11	9	-
Acari (mites and ticks)	5	2	-
Chilopoda (centipedes)	4	3	0.2
Diplopoda (millipedes)	3	1	0.2

FIGURE 4. Western Toads used the rocky habitat in the foreground for summer habitat and the wet meadow for breeding in the spring. The adjacent landscape had been burned by a wildfire.

in Colorado (Muths 2003), 1.9 in Idaho (Bartelt et al. 2004), and 2.6 in this study.

Habitat selection.—Habitat that allows behavioral thermoregulation, water absorption, prey, over-wintering sites, and protection from predators is essential for toad survival. Toads appeared to be seeking habitat that included areas: (1) with open forest canopies or openings in the landscape with no trees; (2) with south-facing slopes; (3) close to water; and (4) with a high density of burrows, rocks, or logs that could be used for cover. The difference in habitat conditions selected by sexes suggested that water was more important to males, perhaps because of their smaller size and less capacity to store water (Bartelt et al. 2004). The selection of more open locations enabled toads to maintain a higher body temperature, which likely facilitated growth if ground dwelling prey were available (Lilywhite et al. 1973; Bartelt et al. 2004). These conditions are likely advantageous for replenishing body reserves after laying selection of more open locations enabled toads to maintain a higher body temperature, which likely facilitated growth if ground dwelling prey were available (Lilywhite et al. 1973; Bartelt et al. 2004).

Refugia may contribute to thermal regulation, moisture retention, and protection from predators (Schwarzkopf and Alford 1996). These habitat characteristics were not common in these study areas, and they became scarcer over the summer when intermittent streams and seeps dried. In this study, a second radio-tagged toad or an unmarked toad was found frequently within 20 m of the target animal. Because Western Toads are solitary beyond the breeding season (Loeffler 2001), this observation suggests that these particular habitats are being sought out. Multiple animals were found at certain locations, even at great distances from the breeding sites (Fig. 1, 2).

The majority (70%) of hibernacula I found did not have water nearby, which is in contrast to Campbell's (1970a) finding that hibernacula need a continuous flow of ground water beneath the chamber to prevent toads from freezing. Loeffler (2001) cited unpublished data that indicated boreal toads hibernated below the frost line in ground squirrel burrows, which was similar to 38% of the hibernacula I detected (Table 4). In California, Western Toads remained underground in gopher or ground squirrel holes during the day and throughout the freezing part of the night in March at 2025 m elevation (Mullally 1952). The portions of the hibernacula that were accessible to me were damp and likely did not freeze due to deep snow cover and their depth underground (Bull and Carter 1996).

Diet.—Diet samples suggest that Western Toads consume primarily ants and ground beetles at these study areas with no difference between the sexes. The tendency of toads to be underground during the day resulted in a limited number of diet samples; however, the sample size in this study is larger than other studies reporting diet, most of which involved dissections of toad stomachs (Burger and Bragg 1947; Campbell 1970b; Miller 1978). Three other studies reported the same predominance of ants that we detected. In Colorado, toads ate mostly ants, beetles, and spiders, although representatives from 43 invertebrate families were found in 33 stomachs (Campbell 1970b). Miller (1978) found 75% Hymenoptera, 23% Coleoptera, 3% Arachnida, and <1% Diptera, Lepidoptera, Orthoptera, and Diplopoda in seven toad stomachs in Montana. Moths, grasshoppers, ants, deer flies, mosquitoes and beetles (Staphylinidae, *Dytiscus*) were found in 15 toad stomachs in Colorado (Burger and Bragg 1947).

Disturbance.—The effects of disturbance events on toads are largely unknown. Although the sample size is limited, habitat alteration due to wildfires at Fish, Twin, and Crayfish did not appear to be detrimental to toads. Habitats with stand replacement fires (that were not logged) were used by toads in proportion to their occurrence. In addition, toads traveled shorter distances in burned forests than in green forests. This observation suggests that suitable habitat conditions and food were found closer to the breeding site than in green forests or that travel is considerably more hazardous. Changes in vegetation following wildfires could influence toads through thermoregulation and water conservation, predation, and prey or burrow availability.

Fuel reductions are being implemented across the western United States to reduce the risk and severity of wildfires. Fuel reductions are designed to reduce the amount of coarse woody debris in treated stands (Bull et al. 2005) and may impact toads negatively in areas where logs and other woody material are used for refugia. Removing large amounts of woody debris, clear-cutting or other harvest activities may greatly limit toad movements and habitat use, particularly during dry weather (Bartelt et al. 2004). The removal of coarse woody debris from the forest floor also reduces the amount of nesting substrate for some species of *Camponotus* and *Formica* ants (Torgersen and Bull 1995), which are prey for the Western Toad. Additionally, the effects of these fuel reduction treatments on squirrel species (that create burrows used by toads) and on populations of ants and ground beetles (prey for Western Toads) are unknown. Research is needed to determine if the changes in vegetation following wildfires in different habitats are beneficial or detrimental to toads.

Large declines in numbers of breeding toads were not detected over the course of this study even though B.d. was present in all study areas. The study area where three male toads died with B.d. infections severe enough to have caused mortality, also had the lowest recapture rate of males (3%). Additional research is needed to determine if this low recapture rate of male toads is due to mortality by B.d. or other causes. Predation in some of the study areas may be high enough to cause declines over time, depending on the rate of recruitment at these sites. It is unclear whether the risk of predation associated with breeding sites may be responsible for the extensive movements I detected or if other factors are contributing. Other factors that might influence movements by toads include habitat quality, length of active season, prey availability or the need to find over-wintering sites that minimize the risk of freezing or desiccation. With the continued die-off of Western Toads in the Rocky Mountains, it is important to continue monitoring populations of Western Toads in other portions of their range to detect changes in their survival and recruitment. It is critical to assess basic natural history parameters as well as such acute issues as B.d. to provide a complete picture of Western Toad demographics. Information included in the present study will be helpful in determining the health and general life history patterns of other toad populations.

Acknowledgments.—A. Clark assisted with field work and identification of prey items. R Beckwith identified a portion of the prey items. J. Shepherd analyzed the data. D. Green (USGS National Wildlife Health Center) conducted necropsies on toads. U. Kelley provided information on suturing materials and techniques. J. Hayes, C. Pearl, M. Snook, and B. Wales reviewed a previous version of this manuscript. Funding was provided by the Pacific Northwest Research Station and U.S. Fish and Wildlife Service. Toads were handled under Oregon Permit Numbers 57-02, 47-03, 21-04, and 37-05.

LITERATURE CITED

Adams, S.A., D.A. Schmetterling, and M.K. Young. 2005. Instream movements by Boreal Toads. Herpetological Review 36:27-33.

Annis, S.L., F.P. Satoor, H. Ziel, P. Daszak, and J.E. Longcore. 2004. A DNA-based assay identifies *Batrachochytrium dendrobatidis* in amphibians. Journal of Wildlife Diseases 40:420-428.

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., D.G. Hokit, R.K. O'Hara, and R.A. Holt. 1994. Pathogenic fungus contributes to amphibian losses in the Pacific Northwest. Biological Conservation 67:251-254.

Bull, E.L. 2000. Comparison of two radio transmitter attachments on Columbia Spotted Frogs (*Rana luteiventris*). Herpetological Review 31:26-28.

_____. 2003. Diet and prey availability of Columbia Spotted Frogs in northeastern Oregon. Northwest Science 77:349-356.

_____, and B.E. Carter. 1996. Winter observations of Tailed Frogs in northeastern Oregon. Northwestern Naturalist 77:45-47.

_____, and D.B. Marx. 2002. Influence of fish and habitat on amphibian communities in high elevation lakes in northeastern Oregon. Northwest Science 76:240-248.

_____, A.A. Clark, and J.F. Shepherd. 2005. Short-term fuel reduction on Pileated Woodpeckers in northeastern Oregon. Research Paper PNW-RP-564. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon, USA.

Burger, W.L., Jr., and A.N. Bragg. 1947. Notes on *Bufo boreas* (B. and G.) from the gothic region of Colorado. Proceedings of the Oklahoma Academy of Science 27:61-65.

Campbell, J.B. 1970a. Hibernacula of a population of *Bufo boreas boreas* in the Colorado Front Range. Herpetologica 25:278-282.

_____. 1970b. Food habits of the Boreal Toad, *Bufo boreas boreas*, in the Colorado Front Range. Journal of Herpetology 4:83-85.

Carey, C. 1993. Hypothesis concerning the causes of the disappearance of Boreal Toads from the mountains of Colorado. Conservation Biology 7:355-362.

_____, N. Cohen, and L. Rollins-Smith. 1999. Amphibian declines: an immunological perspective. Developmental and Comparative Immunology 23:459-72.

_____, D.F. Bradford, H., K, Brunner, J.P. Collins, E.W. Davidson, J.E. Longcore, M. Ouellet, A.P. Pessier, and D.M. Schock. 2003. Biotic factors in amphibian declines. Pp. 153-208 *In* G. Linder, S.K. Krest, and D.W. Sparling (Eds.), Amphibian Decline: An Integrated Analysis of Multiple Stressor Effects. Society of Environmental Toxicology and Chemistry, Pensacola, Florida, USA.

_____, J.E. Bruzgul, L.J. Livo, M.L. Walling, K.A. Kuehl, B.F. Dixon, A. P. Pessier, R.A. Alford, and K.B. Rogers. 2006. Experimental exposures of Boreal Toads (*Bufo boreas*) to a pathogenic chytrid fungus (*Batrachochytrium dendrobatidis*). EcoHealth 3:5-21.

_____, C. Carey, P.S. Corn, M.S. Jones, L.J. Livo, E. Muths, and C.W. Loeffler. 2005. Factors limiting the recovery of Boreal Toads (*Bufo b. boreas*) Pp. 222-236 *In* M. Lannoo (Ed.). Amphibian Declines: The Conservation Status of United States Species. University of California Press, Berkeley, California, USA.

Corn, P.S. 1993. *Bufo boreas* (Boreal Toad). Predation. Herpetological Review 24:57.

_____, M.L. Jennings, and E. Muths. 1997. Survey and assessment of amphibian populations in Rocky Mountain National Park. Northwestern Naturalist 78:34-55.

Daszak, P., L. Berger, A.A. Cunningham, A.D. Hyatt, D.E. Green, and R. Speare. 1999. Emerging infectious diseases and amphibian population declines. Emerging Infectious Diseases 180:. .

Daszak, P., A.A. Cunningham, and A.D. Hyatt. 2003. Infectious disease and amphibian population declines. Diversity and Distributions 9:141-150.

Fisher, R.N., and H.B. Shaffer. 1996. The decline of amphibians in California's Great Central Valley. Conservation Biology 10:1387-1397.

Green, D.E., and E. Muths. 2005. Health evaluation of amphibians in and near Rocky Mountain National Park (Colorado, USA). Alytes 22:109-129.

Green, D.E, and C.K. Kagarise Sherman. 2001. Diagnostic histological findings in Yosemite Toads (*Bufo canorus*) from a die-off in the 1970s. Journal of Herpetology 35:92-103.

Guarino, F.M., F. Angelini, and M. Cammarota. 1995. A skeletochronological analysis of three syntopic amphibian species from southern Italy. Amphibia-Reptilia 16:297-302.

Jones, L.L.C., W.P. Leonard, and D.H. Olson (Eds.). 2005. Amphibians of the Pacific Northwest. Seattle Audubon Society, Seattle, Washington, USA.

Kagarise Sherman, C.K., and M.L. Morton. 1993. Population declines of Yosemite Toads in the eastern Sierra Nevada of California. Journal of Herpetology 27:186-198.

Kirkland, G.L., Jr., H.W. Snoddy, and T.L. Amsler. 1996. Impact of fire on small mammals and amphibians in a central Appalachian deciduous forest. American Midland Naturalist 135: 253-260.

Legler, J.M., and L.J. Sullivan. 1979. The application of stomach-flushing to lizards and anurans. Herpetologica 35: 107-110.

Lilywhite, H.B., P. Licht, and P. Chelgren. 1973. The role of behavioral thermoregulation in the growth energetics of the toad *Bufo boreas*. Ecology 54:375-383.

Livo, L.J. 2004. Methods for obtaining *Batrachochytrium dendrobatidis* (BD) samples for PCR testing. Pp. 64-68 *In* Rogers, K.B. (Ed.). Boreal Toad Research Report. Colorado Department of Natural Resources, Division of Wildlife, Denver, Colorado, USA.

Livo, L.J., and D. Yeakley. 1997. Comparison of current with historical elevational range in the Boreal Toad. Herpetological Review 28:143-144.

Loeffler, C. (Ed.). 2001. Conservation plan and agreement for the management and recovery of the southern Rocky Mountain population of the Boreal Toad (*Bufo boreas boreas*). Boreal Toad Recovery Team, Colorado Department of Natural Resources, Division of Wildlife. 76 p.

Mullally, D.P. 1952. Habits and minimum temperatures of the toad *Bufo boreas halophilus*. Copeia 1952:274-276.

Miller, J.D. 1978. Observations on the diets of *Rana pretiosa*, *Rana pipiens*, and *Bufo boreas* from western Montana. Northwest Science 52:243-249.

Muths, E. 2003. Home range and movements of Boreal Toads in undisturbed habitat. Copeia 2003:160-165.

Muths, E., P.S. Corn, A.P. Pessier, and D.E. Green. 2003. Evidence for disease-related amphibian decline in Colorado. Biological Conservation 110:357-365.

Oliver, C.D., and B.C. Larson. 1990. Forest stand dynamics. McGraw-Hill, Inc., New York, New York, USA.

Olson, D.H. 1989. Predation on breeding Western Toads (*Bufo boreas*). Copeia 1989:391-397.

Pilliod, S.D., E.L. Bull, B. Wales, and J.L. Hayes. 2006. Wildlife and Invertebrate Response to Fuel Reduction Treatments in Dry Coniferous Forests of the Western United States: A Synthesis. General Technical Report RMRS-GTR-173. USDA Forest Service, Rocky Mountain Research Station, Fort Collins, Colorado, USA. 34 p.

Pounds, J.A., M.R. Bustamante, L.A. Coloma, J.A. Consuegra, M.P.L. Fogden, P.N. Foster, E. La Marca, K.L. Masters, A. merino-Viteri, R. Puschendorf, S.R. Ron, G.A. Sanchez-Azofeifa, C.J. Still, and B.E. Young. 2006. Widespread amphibian extinctions from epidemic disease driven by global warming. Nature 439:161-167.

Scherer, R.D, E. Muths, B.R. Noon, and P.S. Corn. 2005. An evaluation of weather and disease as causes of decline in two populations of Boreal Toads. Ecological Applications 15:2150-2160.

Schwarzkopf, L., and R.A. Alford. 1996. Desiccation and shelter-site use in a tropical amphibian: comparing toads with physical models. Functional Ecology 10:193-200.

Thompson, P., B. Hadolski, and P. Chase. 2003. Boreal Toad (*Bufo boreas boreas*) and Spotted Frog (*Rana luteiventris*) distributional surveys and monitoring in northern Utah, 2002. Utah Division of Wildlife Resources, Salt Lake City, Utah, USA. Publication Number 03-02.

Torgersen, T.R., and E.L. Bull. 1995. Down logs as habitat for forest-dwelling ants-the primary prey of Pileated Woodpeckers in northeastern Oregon. Northwest Science 69:294-303.

U.S. Geological Survey, National Wildlife Health Center. 2004. Diagnostic Service Case Report No. 19112. Madison, Wisconsin, USA. 3 p.

Wente, W.H., M.J. Adams, and C.A. Pearl. 2005. Evidence of decline for *Bufo boreas* and *Rana luteiventris* in and around the northern Great Basin, western USA. Alytes 22: 95-108.

Whitaker, J.O., Jr., S.P. Cross, Jr., J.M. Skovlin, and C. Maser. 1983. Food habits of the Spotted Frog (*Rana pretiosa*) from managed sites in Grant County, Oregon. Northwest Science 57:147-154.

Woodhams, D.C., and R.A. Alford. 2005. Ecology of chytridiomycosis in rainforest stream for assemblages of tropical Queensland. Conservation Biology 19:1449-1459.

Woodhams, D.C., R.A. Alford, and G. Marantelli. 2003. Emerging disease of amphibians cured by elevated body temperature. Diseases of Aquatic Organisms 55:65-67.

EVELYN L. BULL is a Research Wildlife Biologist with the Pacific Northwest Research Station, U.S.D.A. Forest Service. She received her B.S. in Zoology at University of Wisconsin at Madison, her M.S. in Fisheries and Wildlife at Oregon State University at Corvallis, and her Ph.D. in Wildlife Ecology at University of Idaho at Moscow. Her research focuses on the effects of natural and human disturbances on Western Toads and Columbia Spotted Frogs and on old-growth dependent species, including Pileated Woodpeckers and other cavity nesting birds, Great Gray Owls, Vaux's Swifts, and American Martens.