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BREEDING FREQUENCY OF WESTERN TOADS (*BUFO BOREAS*) IN NORTHEASTERN OREGON

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***Abstract.*—Many species of toads (family Bufonidae), including the Western Toad (*Bufo boreas*), are declining in the western United States. The ability of this species to recover from declines depends, in part, on its reproductive success. This study examined the breeding frequency in both sexes of *B. boreas* in northeastern Oregon compared to that observed in other populations. We recaptured 0-8.7% (n = 844) of adult female toads that were tagged between 2002 and 2007. Twenty-one females oviposited during two consecutive years, and two females laid eggs in three consecutive years. We recaptured 4.7-34.6% (n = 2208) of adult male toads in a subsequent year. We captured 165 males in two consecutive years, 37 males in three years, and 14 males in four years.**

Key Words.—Boreal Toad; *Bufo boreas*; fecundity; northeastern Oregon; oviposition; Western Toad

INTRODUCTION

Western Toads (*Bufo [Anaxyrus] boreas*; Fig. 1) are widely distributed throughout the western United States. This species has several subspecies, including *B. b. boreas*, and *B. b. halophilus* (Crother et al. 2001). Populations of *B. boreas* have declined in size or have been extirpated throughout the mountains of Colorado since the early 1970s (Carey 1993; Livo and Yeakley 1997; Muths et al. 2003). This toad also has declined in the Central Valley of California (Fisher and Shaffer 1996), northern Utah (Corn et al. 1997; Thompson et al. 2003), and the northern Great Basin (Wente et al. 2005). *B. boreas* is listed as "endangered" in Colorado (Goettl, J.P., and the Boreal Toad Recovery Team. 1997. Boreal Toad (*Bufo boreas boreas*) (Southern Rocky Mountain population) recovery plan. Colorado Division of Wildlife, unpublished report, Denver, Colorado, USA.) and New Mexico (New Mexico Department of Game and Fish. 1990. Amended listing of endangered wildlife in New Mexico. State Game Commission Regulations No. 682). It is also a "species of special concern" in Wyoming (Keinath and Bennett. 2000. Distribution and status of the boreal toad [*Bufo boreas boreas*] in Wyoming. U.S. Fish and Wildlife Service Report) and a "sensitive species" in Utah (Utah Division of Wildlife Resources. 1998. Western Toad. Inventory of sensitive vertebrate and invertebrate species: a progress report).

FIGURE 1. Western Toads (*Bufo [Anaxyrus] boreas*) are widely distributed throughout the western United States. Photograph by Dave S. Wyland.

Population declines of *B. boreas* in Colorado are closely linked to outbreaks of chytridiomycosis (Carey et al. 1999; Muths et al. 2003), a skin disease caused by a chytrid fungal pathogen *(Batrachochytrium dendrobatidis).* This pathogen is associated with population declines and extinctions of a wide variety of amphibians throughout the world in what has been termed, "the most spectacular loss of vertebrate biodiversity due to disease in recorded history" (Skerratt et al. 2007). Captive *B. boreas* are highly susceptible to this pathogen (Carey et al. 2006). Currently, no methods exist to remove *B. dendrobatidis* from infected habitats or for preventing it from spreading to other regions or populations.

Several factors could potentially affect the ability of populations to persist during an outbreak of this pathogen and recover from this disease. These include: (1) improved host resistance; (2) maintenance of population viability in the face of reduced genetic variation in small, relict populations; and (3) the ability to breed successfully despite population declines.

A number of factors influence reproductive capacity. These include age-at-first-breeding, frequency of breeding, adult longevity, and offspring survivorship.

FIGURE 2. Study sites for *Bufo boreas* reproduction were at Fish Lake, Baker Co., Oregon , California, USA (1992 m elevation). The lake is 35 ha during the spring breeding season, but irrigation use reduces its volume by about 50-80% in August and September. Photograph by Dave S. Wyland.

The environments in which these toads breed profoundly affects these life-history parameters (see discussion in McCallum and McCallum 2005).

Bufo boreas occur at elevations from sea level in Alaska (Tim Shields, pers. comm.) to over 3600 m in the Colorado Rockies (Livo and Yeakley 1997). This wide distribution across a large variety of habitats creates considerable variation in environmental factors that control *B. boreas* life-history characteristics. Among these life-history attributes, energy reserves available for breeding, maintenance, and growth are very important (McCallum and Trauth 2007). The long hibernation period of this species, 6-9 months, leaves only a short, summer growing season for refueling energy reserves. In northeastern Oregon, differential behavior between the sexes exposes them to different risks, where males are more closely associated with water (and chytridiomycosis), and females travel longer distances but select habitats where exposure to solar radiation is maximized (Bull 2006). In the southern end of their range in Colorado, where *B. boreas* occur at the high altitudes (2400-3600 m), cold summer nights and short growing seasons combine to slow growth rates (sexual maturity is reached in 4-7 years). Female *B. boreas* seldom breed annually and their clutch size in Colorado averages 6661 eggs (range of 3239-10,872; Carey et al. 2005). Northern populations of *B. boreas* occur at lower altitudes than do populations occurring further to the south. However, relatively little information is available on life-history characteristics of high latitude species. Therefore, we studied how the breeding frequency of male and female *B. boreas* in northeastern Oregon compared to that of other populations. How frequently each female oviposits may influence the overall reproductive success of a population.

MATERIALS AND METHODS

We monitored *B. boreas* at four breeding sites on the Wallowa-Whitman National Forest in northeastern Oregon. These sites were in mountainous, forested terrain with undulating uplands and moderately or steeply walled drainages (Fig. 2). These study sites were at Fish Lake (Fish; 1992 m elevation); Lilypad Lake

TABLE 1. Number of male and female *B. boreas* PIT tagged and recaptured at four breeding sites in northeastern Oregon, USA. Toads were captured in 2003 through 2007, except at Fish Lake, where they were captured in 2002 and 2004-2007.

Site/sex	No.	% recap.	2 yrs	3 yrs	4 yrs	2 of 3 yrs	2 of 4 yrs	3 of 4 yrs	2 of 5 yrs	3 of 5 yrs	4 of 5 yrs
Females											
Balm	668	8.7	17	2		29	6	2	1	1	
Fish	163	8.6	2			11	1				
Crawfish	5										
Lilypad	8										
Total	844		19	2		40	7	2	1	1	
Males											
Balm	1290	4.7	37	1		19	2	1			
Fish	836	28.3	119	35	15	35	13	20			
Lilypad	52	34.6	9			3		4		1	1
Crawfish	30	33.3	4	2		2		1			1
Total	2208		170	38	15	59	15	26		1	2

(Lilypad; 2130 m); Crawfish Lake (Crawfish; 2094 m); and Balm Creek Reservoir (Balm; 1368 m). All study sites were in Baker County except Crawfish, which is in Grant County. The two reservoirs (Balm and Fish) are each about 35 ha during the spring breeding season, but use for irrigation reduces their volumes by about 50-80% in August and September. Lilypad (2.5 ha) and Crawfish (7.3 ha) water levels fluctuated about 0.5 m between high and low extremes during this study. Streams, springs, and seeps are common in the general vicinity of all the breeding sites except Balm Creek Reservoir.

Mean daily maximum and minimum temperatures were recorded with dataloggers (Onset Computer Corporation, Cape Cod, Massachusetts, USA) near the breeding sites from early June through mid-September 2007 were 25.3 ± 0.7ºC and 9.2 ± 0.3ºC at Balm, 19.5 ± 0.6ºC and 7.4 ± 0.4ºC at Fish, and 17.7 ± 0.5ºC and 5.2 ± 0.3ºC at a site at the same elevation as Crawfish. Frost can occur any month of the year. Two distinct periods of precipitation occur, the first as snow in October or November and the second as rain during March-May. Moisture within the growing season results from highly variable convection storms. Cornucopia, Oregon (351852; 45º00'N, 117º12'W) is the weather station closest to Balm Creek Reservoir and Fish Lake, and it has recorded an average of 106 cm precipitation and 500 cm of snowfall (1949-1972). Rock Creek, Oregon (357250; 44º55'N, 118º04'W) is the station closest to Lilypad Lake and Crawfish Lake and has recorded an average of 52 cm precipitation and 231 cm of snowfall with continuous records since 1948.

We selected areas for use in this study if ≥ 20 *B. boreas* were present at one or more oviposition sites and if we could access the site by vehicle. High densities of *B. boreas* are uncommon at high elevation (1800-2972 m) lakes in northeastern Oregon (Bull and Marx 2002). We monitored breeding populations at Crawfish, Lilypad, and Balm from 2003 - 2007, and at Fish in 2002 and 2004 - 2007. Timing of breeding varied at each site each year, although the earliest and latest date toads were captured between 2003 and 2007 were: 23 April - 21 May at Balm, 29 May-5 July at Fish, 20 May-4 June at Crawfish, and 25 May-24 June at Lilypad. Oviposition sites were typically in shallow water on south-facing shores but were on the south-, east-, and west-facing shores at Balm. Egg strings occurred at one oviposition site at Crawfish, three at Lilypad, four at Fish, and five at Balm. We considered sites with egg strings separated by >100 m as separate sites

We captured toads with dip nets at breeding sites and recorded each individual present at each breeding site. We determined sex and then PIT (passive integrated transponders; Biomark, Boise, Idaho 83709) tagged each toad. We measured snout-vent length (SVL) to the nearest mm and mass to the nearest g for each toad. A toe was removed from the front limb of a total of 25 females at these study areas in 2005 (Bull 2006) and 2006 to determine age using skeletochronology. All females captured at breeding sites were gravid or had deposited eggs within 1-2 days; radio-tagged females at these sites typically left the breeding site one or two days after egg laying (Bull 2006). We visited one site each day and continued visiting an area until breeding activity appeared to cease. We calculated a sex ratio at breeding sites where females and males were captured.

RESULTS

We captured 844 female toads at the four sites. Of these, 72 (8.5%) returned to the breeding site at least once in five years. We found 58 of these toads at Balm. Of returning females, 21 returned in the second year and two toads returned to the breeding site in three consecutive years. Toads returned for two consecutive years at Balm and Fish. All those returning three consecutive years occurred at Balm. Forty-one females skipped a year between breeding bouts, and eight

TABLE 2. Sex ratio (male:female) of *B. boreas* captured at four breeding sites from 2003 to 2007 in northeastern Oregon, USA.

	Year				
Site	2003	2004	2005	2006	2007
Balm Reservoir		2.2	2.0	2.1	1.6
Fish Lake		10.1	5.8	5.3	7.1
Crawfish Lake			8.0	6.0	
Lilypad Lake	5.3			7.0	17.0

skipped 2-3 years (Table 1). At Crawfish and Lilypad, we captured only 13 females, none of which were recaptured.

Females breeding in consecutive years were significantly smaller (SVL: mean = 103.0 mm, SE = 1.89, n = 19) than females breeding in alternate years (SVL: mean = 107.7 mm, SE = 1.13, n = 38; t = 2.27, df = 55, P = 0.03). Non-recaptured females (SVL: mean = 105.4 mm, SE = 0.39, n = 579) had SVLs intermediate to those breeding in consecutive (t = 1.08, df = 596, P = 0.28) or alternate years (t = -1.52, df = 615, P = 0.13.

We recaptured 14.8% (326/2208) of PIT-tagged male toads in a second year at the breeding sites. Of the 326 recaptured males, we recaptured 198 in two consecutive years, 39 in three consecutive years, and 15 in four consecutive years (Table 1). In addition, we recaptured 74 toads in non-consecutive years. The proportion of recaptured males ranged from 4.7% (60/1290) at Balm to 34.6% (18/52) at Lilypad.

Across all breeding sites, males were more frequently present than females. There were 1.6-2.2 males for every female toad at Balm, 5.3-10.1 males per female at Fish, and 6.0-8.0 males per female at Crawfish, and 5.3-17.0 males per female at Lilypad (Table 2).

DISCUSSION

Many *Bufo* spp. females breeding at low altitudes lay eggs annually; in contrast, many high altitude amphibians lay eggs at least every two years (Carey et al. 2005). We believe we captured almost all of the toads at the breeding sites based on field observations and recaptures of those toads already marked (Table 3). However, we could have missed toads that: (1) were present at the breeding sites only at night; (2) arrived after the breeding activity was over; or (3) arrived on days we were visiting active breeding sites in one of the other study sites. This study documents that a small percentage (2.5%) of female *B. boreas* from northeastern Oregon oviposit in two and three consecutive years at an elevation of 1368 m; whereas they do not oviposit > 2 consecutive years at an elevation of 1992 m.

Females breeding in consecutive years were most common at Balm, the study area with the lowest elevation, the longest growing season, and warmest temperatures. Our findings are similar to observations in central Oregon (Olson 1992) where 5.2% (88/1700) of female *B. boreas* that occurred at elevations from 1220-2000 m returned for a second breeding season, 20% (18/88) oviposited in consecutive years, and the rest skipped at least one year.

Morphological evidence, a low recapture rate of females, and a skewed sex ratio to males suggested that female *B. boreas* rarely, if ever, breed two years in a row in the West Elk Mountains in Colorado, USA (elevation = 2990 m; Carey et al. 2005).

Lowland species of *Bufo* may breed annually because

TABLE 3. Number of unmarked (i.e., no PIT tag) male and female *B. boreas* captured at each of four study areas, and the number that had been captured in one or more previous years (i.e., PIT tagged) in northeastern Oregon, USA from 2002-2007.

	Year					
Study area	2002	2003	2004	2005	2006	2007
Balm Reservoir						
No. of new males marked	0	75	266	386	297	257
No. of males previously marked	0	0	6	12	29	16
No. of new females marked	0	73	121	199	137	128
No. of females previously marked	0	0	1	3	19	40
Fish Lake						
No. of new males marked	10	0	353	153	147	159
No. of males previously marked	0	0	0	75	118	131
No. of new females marked	9	0	35	38	45	33
No. of females previously marked	0	0	0	1	5	8
Crawfish Lake						
No. of new males marked	0	4	1	13	8	3
No. of males previously marked	0	0	0	3	4	8
No. of new females marked	0	1	0	2	2	0
No. of females previously marked	0	0	0	0	0	0
Lilypad Lake						
No. of new males marked	0	16	12	1	13	7
No. of males previously marked	0	0	7	0	8	10
No. of new females marked	0	3	1	0	3	1
No. of females previously marked	0	0	0	0	0	0

they can begin refueling their reserves for reproduction immediately after oviposition. Females enter hibernation with a full complement of mature eggs and are ready to breed immediately upon exiting their hibernacula (Jorgensen et al. 1979). In contrast, the oocytes of *B. boreas* females in the Colorado Rockies remain undeveloped for at least a year after breeding (Carey et al. 2005). Clutch sizes of these toads are comparable to similar sized, lowland *Bufo* (Carey et al. 2005). The shortened foraging season experienced by females at high altitudes and/or high latitudes may stimulate a trade-off system for resource between frequency of oviposition and clutch or egg size. It may take multiple summers to accumulate the nutrients required to produce large clutches of large eggs. These females could presumably breed every year if they laid smaller clutches with smaller eggs. Because offspring survival to metamorphosis is reduced by predation, desiccation, and other factors (Livo 1999), females that oviposit every 2-3 years may maximize their reproductive output by maximizing the amount of resources dedicated per clutch or egg.

Future studies will further target this hypothesis by comparing clutch and egg sizes of small females that breed annually to those of large females that skip years. Snout-vent length of females from these study areas was positively correlated with age (based on skeletochronology; $r = 0.48$, n = 25, $P = 0.015$ [*see* Bull 2006]), suggesting that females that breed in consecutive years are younger than those that breed every other year. Although individual populations in the Rocky Mountains of Colorado demonstrated no significant relationship between clutch size and female size, the relationship was significant when the data from three Colorado populations were combined (Carey et al. 2005).

Males invest fewer resources per gamete than females (Charnov 1982), so male breeding frequency should be a valid comparison with that of females. Therefore, males may have limited energetic limitation to breed every year but may experience other costs such as increased predation risk. In central Oregon, recaptures comprised 15-77% of the male-captures at three sites over a 10-year period (Olson 1992). One study in Colorado suggested that at least 10% of male *B. boreas* skipped a breeding season, although this varied among years, and weather appeared to influence this behavior (Muths et al. 2006).

We might explain the male-biased sex ratio observed in this study as an artifact of the larger number of males than females that appeared to return to the breeding site each year. At three sites in the Oregon Cascade Mountains, the sex ratios of breeding adults were male-biased (male/female range: 1.5-2.6; Olson et al. 1986.). Samollow (1980) also reported a sex ratio that was skewed towards males in the Oregon Cascades. Muths (2005) reported that the number of males at breeding sites in Colorado can sometimes out-number females by 20:1. Differential survivorship of males and females is an area that requires further research.

Females laying eggs and males visiting the breeding sites in consecutive years may increase the reproductive potential of *B. boreas*. We could not determine the number of eggs produced by females in this study. It is possible that breeding every year may result in lower fecundity or smaller eggs. However, given the erratic nature of these habitats (i.e., reservoirs may be drawn down early or winter conditions may set in early), brood survivorship in any one year is problematic. Therefore, breeding each year, despite reduced egg numbers, may provide a higher probability of long-term reproductive success.

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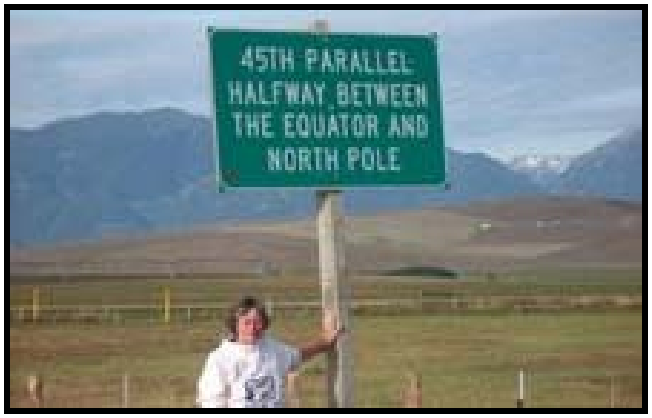

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