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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 Colorado Division of Wildlife, unpublished report, Denver, Colorado, USA.)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.

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 ± 0.7°C and 9.2 ± 0.3°C at Balm, 19.5 ± 0.6°C and 7.4 ± 0.4°C at Fish, and 17.7 ± 0.5°C and 5.2 ± 0.3°C 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; 45°00'N, 117°12'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; 44°55'N, 118°04'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

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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