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EGG MASS DEPOSITION BY ARIZONA TOADS, *BUFO MICROSCAPHUS*, ALONG A NARROW CANYON STREAM

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Key words: *Bufo microscaphus*, *dispersion*, *breeding site selection*.

Declining amphibian populations in the arid southwestern United States have prompted increased efforts to understand the reproductive behavior of desert anurans, particularly those species in restricted habitats (Sullivan 1989, Corn 1994). The Arizona toad, *Bufo microscaphus*, is confined in southwestern Utah to tributaries of the Virgin River drainage (Price and Sullivan 1988). Like most desert anurans, *B. microscaphus* is an explosive breeder (Wells 1977, Sullivan 1992); however, unlike many other toads, which deposit their eggs in still ponds and lakes, it prefers to lay eggs in the flowing water of a perennial or semi-permanent stream. Water quality and breeding behavior are influenced by many physical and biological variables so that choice of a nesting site may not be simply by chance. The questions we consider here are: Do mating pairs select a particular portion of the habitat to deposit their eggs, and, if so, what factors might explain site selection?

We observed egg deposition by Arizona toads in Oak Creek, Zion National Park, between 26 April and 9 May 1998. Oak Creek is a narrow (1–3 m in width), shallow, intermittent stream (<0.5 m in depth at its deepest point). In many places stream banks rise 3–4 m above the flow. The streambed consists of various mixtures of sandy soil and rock, and stream bank vegetation ranges from sparse shrubs and grasses to thick shrubs and trees with large, branching canopies. Egg masses were counted along a 1750-m transect marked every 50 m with labeled surveyor's tape. The transect began near the parking lot of the visitors center and research complex (section 1) and continued upstream (to section 36); we did

not survey the entire stream prior to setting up the transect but merely chose a portion that was convenient for frequent visitation and nocturnal sampling. We also assumed the stream flow was perennial throughout the sampling area.

Blair (1955) reported a female typically deposits about 4500 eggs. We observed these in long, gelatinous strings that were usually found in irregular masses in pools and other parts of the stream where flow is minimal. Each egg mass was marked with a numbered flag and its section recorded. Between 1010 and 1330 h on 26 April 1999, the 1st day egg masses were found in the creek, the following measurements were taken at the beginning of each of 36 sections in the transect: temperature (°C) and percent of dissolved oxygen (DO measured with a YSI model 55), pH (taken with a pHep 3, Hanna Instruments), water depth (cm) in the middle of the egg mass, number of streamside pools (>1 m in diameter and 4 cm in depth), distance (m) to the nearest tree, and percent canopy covering the stream channel estimated by simply viewing 5 areas per section and averaging percentages for each section. The choice of these independent variables was based on factors known to affect both development of embryos and larvae and the energetics of finding mates (Wells 1977, Rome et al. 1992, Shoemaker et al. 1992). From April to August 1999, we also surveyed the entire transect on 7 evenings, marking (by toe clipping) the number of adult and juvenile toads seen in each section.

Twenty-one egg masses were deposited in 11 contiguous sections (24–34) of the transect; obviously, masses were not distributed randomly

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along the stream (mean number of egg masses per section = 0.58, Poisson $\chi^2 = 76.7$, $df = 35$, $P < 0.001$) but were concentrated in particular sections (variance to mean ratio = 2.19, Moristia's index of dispersion = 3.089; Brower and Zar 1984). Although in previous years adults were seen all along the stream transect (Breck Bartholomew and Mary Hunnicutt personal communication), most were found in the same areas as the egg masses (numbers of adults in sections 24–34, mean = 18.5, range = 6–33, vs. those in sections 1–23, 35–36, mean = 4.0, range = 0–16; Mann-Whitney test, 2-tailed $P < 0.001$). During the breeding period in April, we saw toads only in sections 24–34, the area of egg mass deposition; in June and July adults were found in sections 1–34. A summer flood followed by stream drying in sections 1–12 seemed to further restrict toads to upstream sections of the transect.

Number of pools and water temperature best explained number of egg masses per section (multiple regression, number of egg masses = $7.08 + 0.60$ [number of pools] + 0.38 [water temperature], $R^2 = 0.74$, $P < 0.001$). Number of egg masses per section was negatively and significantly correlated with percent canopy (Pearson product-moment correlation = -0.40 , $P < 0.01$, $N = 36$). Significant intercorrelation among independent variables was negative for canopy cover and distance (-0.44 , $P < 0.01$) to the nearest tree, number of pools (-0.34 , $P < 0.05$), and temperature (-0.75 , $P < 0.001$). Water temperature and both distance to the nearest tree (0.41 , $P < 0.01$) and number of pools (0.34 , $P < 0.05$) were positively correlated. Depth of stream (mean = 7.7 cm, $s = 3.3$ cm) and pH (mean = 7.3, $s = 0.10$) were relatively constant along the stream.

If *B. microscaphus* in Oak Creek chose sections for laying eggs, those 11 sites were characterized by an abundance of pools (mean = 6.3, $s = 2.7$, range 2–10). Twenty-five sections without egg masses had less than half the average number of pools per section (mean = 3.1, $s = 1.6$, range = 0–6). Pools have less flow than the stream, so breeding male toads may more easily detect movement by an approaching female (Sullivan 1992). Egg masses also have little chance of being washed downstream (except during flash flooding) when laid in a pool. Pools may be more numerous in sections with egg masses because trees and their roots

are farther from the stream (mean = 5.0 m, $s = 3.7$ m, range = 2–15 m) than they are in sections without egg masses (mean = 4.2 m, $s = 3.8$ m, range = 1–20 m). Without tree roots to hold the soil, erosion and subsequent meandering of the stream course can occur. Sections of the stream with egg masses were warmer (mean = 16.5°C , $s = 0.5^\circ\text{C}$, range = $15.7^\circ\text{--}17.1^\circ\text{C}$) than sections without egg masses (mean = 12.3°C , $s = 2.2^\circ\text{C}$, range = $9.6^\circ\text{--}16.7^\circ\text{C}$). They also had less tree canopy cover (mean = 8.2%, $s = 9.8\%$, range = 0–20%) than those sections without eggs (mean = 52.8%, $s = 36.9\%$, range = 0–95%). Warmer temperature shortens development time to metamorphosis in anuran embryos (e.g., Noland and Ultsch 1981); however, finding that eggs are preferentially laid in warmer pools may be irrelevant. If water temperature influences site selection and mating takes place at night, then variation in temperature among stream sections would be expected at night; these measurements were not taken. Toads preferred to lay eggs in open-canopy pools with photosynthetic algae that raised dissolved oxygen levels, in contrast to ponds with closed canopies and heavy leaf litter, the decomposition of which consumed oxygen (Werner and Glennemeier 1999). A similar relationship probably does not explain selection of breeding sites along our stream zone. We found no significant correlation between number of egg masses and dissolved oxygen in the stream. Actually, average dissolved oxygen concentration at egg mass sites in pools (mean = 65.8, $s = 10.3$, $N = 22$) was lower than for those measurements in the adjacent stream (mean = 77.3, $s = 1.8$, $N = 11$; Mann-Whitney test, 2-tailed $P < 0.001$).

Other breeding species and the presence of predators may affect nesting site selection (e.g., Petranka et al. 1994, Skelly 1996). We observed both red-spotted toads, *Bufo punctatus*, and canyon treefrogs, *Hyla arenicolor*, breeding in the same sections as *B. microscaphus*. In addition, we noted the presence of predatory insect larvae in many pools. Understanding the extent to which interspecific competition or predation affects site selection, as well as the determination of causal relationships between nest site selection and other potentially explanatory variables, must await either comparative (natural) studies among populations in similar habitats or experimental manipulations of variables.

It is entirely possible that we may have overlooked factors critical to the final site for egg deposition that are not represented in our limited choice of physical and biological variables. The deposition of eggs may simply be a function of where females emerge from hibernacula in response to calling males that wander up and down the stream, or to subtle aspects of stream bank terraces, either of which may have little relationship to male or female choice, and for which we took no measurements (S. Sweet personal communication).

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