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USE OF BREEDING SITES BY ARID-LAND TOADS IN RANGELANDS: LANDSCAPE-LEVEL FACTORS

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Abstract—We examined spatial extent of habitat that anaxyrids responded to in an arid environment. We used surveys of vocalizations and searches to identify toads after rainfall events to examine whether the spatial arrangement and proximity of earthen tanks could influence breeding populations of *Anaxyrus cognatus* and *A. debilis.* These species responded to the landscape complement of breeding sites inside a buffer of 5 km, a much larger distance than most studies have addressed.

Resumen—Examinamos el grado espacial al que los anaxyridos responden al hábitat en un ambiente árido. Se muestrearon las vocalizaciones e hicimos búsquedas para identificar sapos después de lluvias para examinar si el patrón espacial y la proximidad de los tanques de agua de fondo de tierra pueden influir en las poblaciones reproductoras de *Anaxyrus cognatus* y *A. debilis.* Estas especies respondieron a la escala del paisaje dentro de una franja de 5 km de los sitios de reproducción, una distancia mucho mayor que la mayoría de los estudios ha enfocado.

In arid lands, ephemeral sources of water (desert playas and earthen tanks) offer breeding sites for amphibians. Rainfall in these areas is patchy and may fill only a small proportion of the potential breeding sites in a given year. We currently do not understand how arid-land amphibians select breeding sites. In these landscapes, amphibians may migrate to the closest filled depression rather than miss breeding; consequently using a cluster of ponds as breeding habitat as opposed to being philopatric to a single pond (Fortuna et al., 2006).

Researchers studying networks of wetlands suggest that network systems, nodes connected by links, describe the dynamics of amphibian populations in stochastic environments (Fortuna et al., 2006). We hypothesize that if this model is correct, more amphibians will be present in areas with more tanks or nodes. Additionally, researchers often assume that amphibians move <1 km, which may underestimate actual distances moved (Bradford et al., 2003; Smith and Green, 2005). Hence, if arid-land amphibians are more vagile than traditionally expected, we should detect a response to density of tanks at buffers >1 km. Our objectives were to examine whether spatial arrangement and proximity of potential breeding sites could influence density of breeding populations of arid-land toads and to assess the scale at which these toads respond to their environment.

Amphibians in this system of ephemeral wetlands breed and lay their eggs en masse within 1–3 days of a large rainfall event (Sullivan, 1989). Complete development occurs within 2–7 weeks, depending on species and ambient temperatures (Degenhardt et al., 1996). Toads common in this area are the Great Plains toad (*Anaxyrus cognatus*) and the green toad (*Anaxyrus debilis*; Graves and Krupa, 2005; Painter, 2005). The red-spotted toad (*Anaxyrus punctatus*) also is present in areas with talus slopes (Sullivan, 2005), but we did not sample these areas.

We conducted this research in Chihuahuan Desert grasslands and shrublands of south-central New Mexico in an area of ca. 95,500-ha (elevation, ca.1,200–1,500 m). We used earthen livestock-watering tanks as experimental units to evaluate the arrangement of sources of water to toads. Earthen tanks are manmade depressions that catch and hold water for livestock. We identified focal earthen tanks and playas from 7.5-min maps (1:24,000 scale), including additional tanks identified by ranchers or biologists from the Bureau of Land Management. Several tanks were excluded because clay based roads were impassable when wet.

Tanks fill with water when it rains, but not all tanks fill every year. Most rains occur during early July-late August. The study area received 41.0 mm of rain in 2006 (72% July–September) and 26.8 mm in 2007 (41% July–September; Jornada Basin Long Term Ecological Research site, Doña Ana County, New Mexico). We surveyed 46 tanks, 23 had water in 2006, 31 had water in 2007, 12 had water in both years, and 4 did not contain water during our sampling period. Totals for rainfall were the average of 34 rain gauges. Both years were above long-term averages from the same gauges in the Jornada Basin (24.8 mm).

We conducted surveys of vocalizations of amphibians and used headlamps and flashlights to conduct visual-encounter surveys during 2200-0200 h in areas that received rain that day or the previous day during July and August 2006 and 2007. We surveyed each site until all species of amphibians were detected or the end of August, whichever came first. We quantified abundance categories of calling toads as follows: 0, no individual detected; 1, individuals could be counted (there was space between calls); 2, calls of individuals could be distinguished but there was some overlapping of calls; 3, full chorus (calls were constant, continuous, and overlapping; Weir and Mossman, 2005). We observed amplexing pairs in the earthen tanks; thus, demonstrating that our index of calling males was related to reproductive activity.

For sites with water, we calculated the Euclidian nearest-neighbor distance (m) to any other livestock-watering tank or playa (Environmental Systems Research Institute, 2002). We used 1:24,000 digital-raster maps (United States Geological Survey) to estimate the topographic nearest-neighbor distance to other breeding sites within the same drainage by following contours. We calculated density of livestock-watering tanks or playas within 0.5, 1, 3, and 5 km of focal tanks. We used univariate logistic regression to analyze presence-absence data in relation to these isolation metrics for tanks that contained water during the breeding season, and polytomous logistic regression to analyze abundance categories in relation to spatial attributes as described above (SPSS, 1997).

Average nearest-neighbor distance was 1,440 m straight-line distance and 1,610 m along drainages. In 2006 and 2007, presence and abundance categories of *A. cognatus* were related positively to density of potential breeding sites within 5 km ($\chi^2 > 5.2$, $P < 0.04$; Fig. 1). Presence and abundance categories of *A. debilis* were related positively to density of potential breeding sites within both 3 and 5 km in 2007 ($\chi^2 > 5.5$, $P < 0.04$); we did not detect a relationship with spatial attributes in 2006 (Fig. 1). Isolation by distance did not correctly categorize as many breeding sites in terms of abundance or presence for either species, although they were significantly related to presence of both *A. cognatus* and *A. debilis* in 2007 ($P < 0.02$). In all instances, the Hosmer-Lemeshow (bivariate) or Pearson (multivariate) goodness-of-fit tests did not indicate lack of fit by the model ($P > 0.10$).

We did not detect a relationship between presence or abundance categories for *A. debilis* in 2006 and the landscape-level predictors, possibly

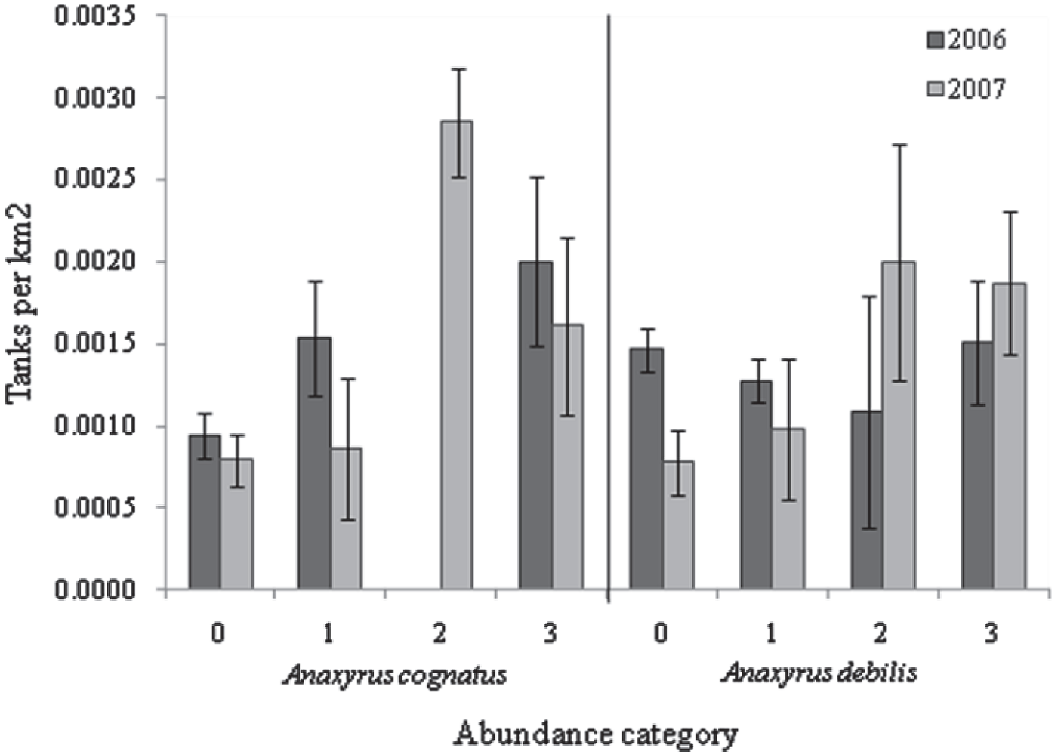

Fig. 1—Average density of potential breeding sites within a 5-km radius of the breeding site in relation to abundance category of calling *Anaxyrus cognatus* and *A. debilis* (see text for description of categories). Both filled and empty earthen tanks are included in calculations of density. Error bars represent ±*SE*.

due to one-half as much rain in 2005 (24.5 mm). We speculate that this could lead to fewer tanks filling, lower reproduction, and fewer individuals at tanks in 2006.

We determined that *A. cognatus and A. debilis* responded to landscape-scale attributes relating to potential breeding sites; furthermore, scales at which they responded were larger than the scale at which many studies of amphibians have been conducted (Smith and Green, 2005). These species responded to the density of other sites ≤5 km regardless of whether or not individual tanks held water. This suggests that arid-land toads use a variety of potential breeding sites and are not philopatric to a single wetland; thus, areas with more tanks or playas may provide better habitat for individuals. Rainfall is patchy in arid systems and tanks adjacent to each other may not both fill with water during the rainy season. Hence, it likely reduces fitness for individuals to be highly tied to particular breeding locations.

Isolation from other potential breeding sites is a critical metric when assessing the metapopulation or patch dynamics of a system, as it is a predictor of the rate of colonization and rescue effect from neighboring patches. Isolation for populations of amphibians often is measured using nearest-neighbor distances and often is assessed only ≤1 km (Laan and Verboom, 1990; Findlay and Houlahan, 1997; Gibbs, 1998; Joly et al., 2001). These measures ignore the landscape complement of alternative patches, focusing only on distance to closest suitable habitat. In systems where availability of water at a given site is unpredictable, animals should exploit any chance for breeding within their tolerance of movement, as suggested by our results. This indicates density, an area-based metric, is a better measure of isolation than the distance-based metrics (Tischendorf et al., 2003) in our study.

Factors other than density of potential breeding sites are important in selection of breeding habitat, although we did not include them in our analysis. This is expected; landscape and patch characteristics are important in selection of breeding sites (Mazerolle and Villard, 1999; Van Buskirk, 2005; Denoël and Lehmann, 2006). We were unable to include breeding sites, such as roadsides or small depressions that held water for 1–2 weeks. Hence our measures of isolation may not be absolute. Additionally, few tanks were closer than 0.5 km, so we may have missed fine-scale associations.

Many populations of amphibians in the arid southwestern United States have been threatened by invasions of exotics such as crayfish *Procambarus clarkii*) and bullfrogs (*Rana catesbeiana*; Kats and Ferrer, 2003). Ephemeral livestock-watering tanks provide habitat that supports amphibians adapted to temporary systems, but likely will not support invasive exotics that are dependent on more permanent sources of water. However, more research needs to be conducted on the environment that earthen livestock-watering tanks provide for breeding by amphibians and for development of their embryos and tadpoles. These habitats could act as population sinks if adults are unable to discriminate between suitable and unsuitable conditions for development of young. Furthermore, increasing breeding sites also can increase gene flow, potentially homogenizing historically isolated populations by reducing genetic diversity among populations (Jungels et al., 2010).

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