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Influence of Surface Area, Water Level and Adjacent Vegetation on Bat Use of Artificial Water Sources

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ABSTRACT.—Reliable natural water sources often are unavailable for bats in semi-arid regions such as the Texas Panhandle. Metal stock tanks commonly are used to supply water to livestock and are used by bats as a water source. It is unknown how surface area, water level and adjacent vegetation influence use of tanks by bats. Infrared video cameras and supplemental infrared lights were used to video tape bat behavior and use of stock tanks in Palo Duro Canyon State Park, Texas. Treatment tanks were set out in pairs approximately 80 m apart in a cross-over design to account for influence of location on use of tanks by bats. Treatments included three sizes of tanks (1.2 m, 1.8 m and 3.0 m in diameter), three levels of cover of adjacent vegetation (no vegetation, light vegetation and heavy vegetation) and two water levels (full and ½ full). The number of bats that passed over 3.0 m and 1.2 m tanks was similar; however, bats drank from large tanks more than small tanks. Passes were similar between the tanks surrounded by light vegetation and tanks with no vegetation, but bats drank more from tanks surrounded by light vegetation. Tanks surrounded by heavy vegetation experienced fewer passes and fewer drinks than tanks without vegetation. Water level had no effect on the number of passes by bats but ½ full tanks were used for drinking less frequently than full tanks. Our research indicates that size of tank, water level in tanks and characteristics of adjacent vegetation influence use of metal livestock tanks by bats. Use of larger tanks, keeping tanks full and managing vegetation around tanks increases use of tanks by bats.

INTRODUCTION

Bats rely on water sources for foraging, reproductive and basic physiological requirements. Water requirements vary depending on the environment. An individual resting bat inhabiting a low humidity region can experience daily evaporative water loss equivalent to 30% of its body mass (Webb and Speakman, 1995). Consequently, a large number of bat species inhabiting drier climates select diurnal roosting sites near water (Rabe *et al.*, 1998). Bats inhabiting wetter regions do not appear to select habitat based on proximity to water (Betts, 1998; Waldien *et al.*, 2000). In addition to environment, water requirements also may vary widely depending on reproductive status. Daily water flux values double in lactating big brown bats compared to pregnant individuals (Kurta *et al.*, 1990). Adams and Hayes (2008) observed lactating female fringed myotis drinking from water sources an average of 21.3 times per night, whereas non-reproductive females visited only 3.7 times per night.

Large bat colonies thrive throughout arid and semi-arid habitats of the southwestern United States despite their dependence on increasingly unreliable water sources in harsh environments. Climate change models predict increasing temperatures and decreased precipitation throughout much of the southern Great Plains will result in lower soil water content and extensive drought (Morgan *et al.*, 2008). These trends predicted for the southern Great Plains are further exacerbated by direct extraction of water sources. The greatest amount of water withdrawn from surface and groundwater sources in the Great Plains states occurs in Texas. In one of the drier regions of the state, the semi-arid Texas

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Panhandle, the natural surface water sources (playa lakes) are declining due to agriculture. The Llano Estacado lies above the Ogallala Aquifer, however water for crop irrigation can be pumped less expensively from playas than the aquifer (Haukos and Smith, 1992; Cunfer, 2005). Over 70% of playas greater than 4 ha have been modified by deepening pits to concentrate water into a smaller surface area (Haukos and Smith, 1992). The shallow depressions of the playas are filled by eroding top soil as well as deliberate filling to increase the amount of land that can be cultivated (Proctor, 1990).

Although natural water sources in these regions are becoming increasingly scarce, over 265 million acres or 70% of grasslands in the Great Plains are grazed (Cunfer, 2005). Water tanks provided for the livestock that graze these lands may provide needed artificial sources of water for bats. Drinking by bats at these livestock water tanks has been well documented and tanks are frequently the locations chosen for population surveys of bats (Black, 1974; Perry *et al.*, 1997). Geluso (1978) suggested that constructed water sources influence local distribution of bats and may allow range expansion into areas with suitable roost sites. However, few studies have determined whether characteristics of artificial water sources influence use by bats. The influence of modifications to livestock tanks, such as cross fencing and metal or wooden support bars stretched across the tank, on drinking by bats was studied by Tuttle *et al.* (2006). Although bats did not avoid tanks with modifications, multiple passes were needed before bats were able to drink successfully. Tuttle *et al.* (2006) found that 38% of livestock tanks in Northern Arizona had some sort of modification. Our study focuses on the majority of livestock tanks that do not have modifications, considering instead how characteristics of livestock tanks themselves influences use by bats. We examined the influence of surface area, water level and adjacent vegetation on use of livestock tanks by videotaping bats at paired experimental livestock tanks in the Panhandle of Texas.

METHODS

Study site.—We studied use of livestock tanks by bats from Jun. through Aug. 2008 in Palo Duro Canyon State Park (Randall County) along the eastern escarpment of the Llano Estacado in the Texas Panhandle. Species of bats found in the park include *Tadarida brasiliensis, Eptesicus fuscus, Parastrellus hesperus, Antrozous pallidus, Corynorhinus townsendii, Myotis ciliolabrum, M. velifer, Lasiurus borealis, L. cinereus* and *Perimyotis subflavus* (R. Matlack, pers. obs.). Two galvanized steel livestock water tanks were positioned 80 m apart along a closed road surrounded by an open savannah of cottonwoods (*Populus deltoides*), mesquite (*Prosopis* sp.) and juniper (*Juniperus* sp.) approximately 100 m from the Prairie Dog Town Fork of the Red River. At this location the river is intermittent but water suitable for drinking by bats usually is present in pools when the river is not flowing.

Assessing activity of bats.—Canon night shot cameras with supplemental infrared lights recorded bat activity at each tank for 160 min/night following sunset for two nights. Cameras were positioned 3.3 m from each tank. Camera heights were adjusted to give an unobstructed view, allowing comparable detection of bat activity across treatments. Position of infrared lights were adjusted at dusk to ensure tanks were fully illuminated. A cross-over design (Dean and Voss, 1999), in which the treatments applied to each tank were switched between the two nights of the experiment, was used to account for location bias of tanks on use by bats.

Tank treatments.—The influence of tank size on use by bats was determined by using 3.0 m diameter (0.6 m height) and 1.2 m diameter (0.6 m height) galvanized livestock tanks. The influence of water level was assessed using two identical tanks (1.8 m diameter, 0.6 m height): one tank was filled to the rim and one was filled half-way (0.3 m) to the rim. Depth of water in a tank may influence use by bats by effectively reducing surface area because bats have to avoid the sides of the tank to reach the surface of the water (Tuttle *et al.*, 2006). The influence of light and heavy obstruction by vegetation was assessed by tying branches of salt cedar (*Tamarix* sp.) around the perimeter of tanks. Vegetation extended above the rim by 0.5 m to simulate conditions observed at some livestock tanks in ungrazed areas in the region. Light obstruction by vegetation was assessed on two identical tanks that were 3.0 m in diameter and heavy obstruction was assessed on two identical tanks that were 1.8 m in diameter. In each study, the perimeter of one tank was left open and salt cedar was spaced around the perimeter of the second tank. For the light obstruction study, gaps among the vegetation provided flyways for bats to travel through the vegetation to access the water's surface. For the heavy obstruction study, a continuous and dense application of vegetation around the perimeter formed a barrier without flyways through the vegetation.

All experimental treatments were established a minimum of 24 h before collecting data to ensure that bats had the opportunity to locate the tanks and respond to the current treatment rather than a carried-over response to treatments from a previous experiment (Tuttle *et al.*, 2006). Videotapes were observed using Pinnacle Studio Plus v. 9.4 software and the number of passes made by bats over each tank as well as the number of drinks from each tank by bats was recorded. Videos were analyzed by a single reviewer and were discarded if the quality of video from each of the experimental tanks was insufficient to allow detection of all bats.

Statistics.—Chi-square goodness of fit test was used to compare the observed and expected frequency of passes and drinking by bats between experimental treatments. To determine expected frequencies, the number of passes and drinks observed over two nights at both tanks were combined, giving a total number of passes and a total number of drinks per experiment. Expected frequencies were one half of these total numbers, reflecting the null hypothesis of no difference between treatments in the number of passes or the number of drinks by bats. A permutation test was used when expected frequencies for a treatment were five or fewer.

RESULTS

Our initial test to ensure no location bias sufficiently accounted for the influence of location on bat use of livestock tanks. The number of passes and drinks from two identical tanks were equivalent when the cross-over design accounted for the location bias (passes: $X^2 = 2.82$, $P = 0.1016$ and drinks: $X^2 = 0.13$, $P = 0.415$). Consequently this method was used for each subsequent paired experiment. When evaluating the influence of tank size, the number of passes over the two different sized tanks was equivalent ($X^2 = 0.04$, $P = 0.8415$; Fig. 1A). However, bats drank more frequently from the 3.0 m than the 1.2 m livestock tank ($X^2 = 30$, $P < 0.0001$; Fig. 1A) and drinking was never observed at the 1.2 m tank. The number of passes by bats over full and ½ full tanks was similar ($X^2 = 0.02$, $P = 1.0$; Fig. 1B) but bats drank more often from full than ½ full tanks (Permutation test, $P = 0.0158$). The number of passes by bats over lightly and unobstructed tanks was similar ($X^2 = 2.03$, $P = 0.1703$), however drinking occurred more frequently at lightly obstructed tanks ($X^2 = 9.94$, $P = 0.0036$; Fig. 1C). Significantly fewer passes by bats were observed over the heavily obstructed tank compared with the unobstructed tank ($X^2 = 7.64$, $P = 0.0057$) and bats were never observed drinking at heavily obstructed tanks (Permutation test, $P = 0.061$; Fig. 1D).

DISCUSSION

Since the 1940s, supplemental water sources have been provided specifically for use by wildlife in dry environments of the southwestern United States. These wildlife water development projects operated by federal and state agencies frequently are incorporated into

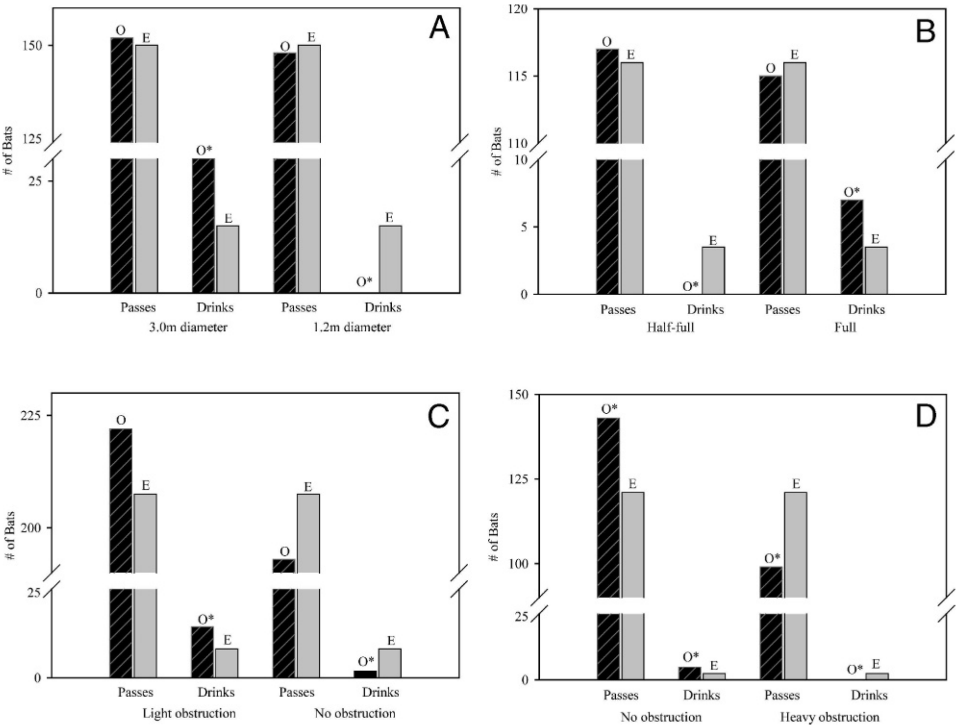

FIG. 1.—Number of observed (O) and expected (E) passes and drinks by bats from 3.0 m and 1.8 m diameter livestock tanks (A), 1.8 m diameter livestock tanks with two different water levels (full or ½ full; (B), 3.0 m diameter livestock tanks with perimeters unobstructed or lightly obstructed by vegetation (C), and 1.8 m diameter livestock tanks with perimeters unobstructed or heavily obstructed by vegetation (D) in Palo Duro Canyon State Park, Randall County, Texas. Bat behavior was examined by video taping bats at each tank with supplemental infrared lights during June and July 2008. Asterisks indicate significant differences ($\alpha = 0.05$)

landscapes where they are used by many species of bats (Rosenstock *et al.*, 2004). However, with fewer than 6000 of these developments scattered throughout 11 states (Rosenstock *et al.*, 1999), these artificial water sources provided specifically for wildlife are vastly outnumbered by those with a primarily anthropocentric purpose, such as livestock tanks.

Understanding basic drinking behavior of bats is essential in order to manage artificial water sources for bats inhabiting regions that lack reliable natural sources of water. The Llano Estacado of the Texas Panhandle has the highest density of playa lakes in the world (Bolen *et al.*, 1989), but these natural water sources are declining due to climate change and direct irrigation. With over 94% of Texas under private ownership, much of which is used for grazing, the artificial water resources on these private lands may play an important role in conserving bat populations. Considering the extensive distribution of livestock tanks throughout the Texas Panhandle and much of the Western United States, as well as the hydrological changes that have occurred since human settlement, these artificial water sources may be of substantial value to bats. Our experimental design allowed us to directly compare the value of different artificial water sources actually available for use by bats inhabiting these landscapes.

While a number of previous studies have documented certain trends in drinking behavior of bats, few have directly compared the value of the various artificial water sources found abundantly in the landscape. The results of our study have clear management implications. To increase use of tanks by bats, land owners should use tanks that are as large as feasible. Regardless of the surface area of a tank, the water level should be maintained to the rim in order to maximize the effective surface area.

We studied vegetation surrounding the perimeter of tanks because we observed vegetation growing around some tanks in the region. When tanks are not actively used by livestock, water may overflow and promote vegetation growth around the perimeter of the tank. A small amount of vegetation surrounding the rim appears to promote use by bats. A potential reason for these results is that the vegetation causes steel livestock tanks to blend in with the surrounding environment and resemble more natural water sources. A small amount of vegetation also may provide improved conditions for flying or foraging by providing a wind barrier as well as protection from predators. A heavy barrier of vegetation appeared to hinder bats from identifying the tank as a source of water. The majority of echolocation signals may have reflected against vegetation rather than water, making the water source essentially invisible to bats. Consequently, unused livestock tanks should be managed to prevent dense vegetation from obstructing the perimeter of the tank to maintain their value for bats. However, we expect the impact of heavy vegetation on use of tanks by bats to decrease with increasing diameter of tanks.

Increasing the attractiveness of artificial water sources may have negative consequences for some native wildlife. Most desert species drink water when it is available but do not actively seek water sources. Individuals rarely die from dehydration and water availability alone does not tend to be sufficient in preventing population decline (Broyles, 1995). However, unlike most mammals inhabiting dry climates, bats are strongly attracted to water sources. Bat population sizes and ranges likely have expanded due to artificial water sources. Little evidence supports concerns that artificial water sources may increase predation and competition, facilitate disease transmission, or cause direct mortalities via drowning or injury (Rosenstock *et al.*, 1999; Andrew *et al.*, 2001). Livestock tanks are a common feature of arid regions and are used for drinking by bats. Our findings suggest that use of larger tanks, keeping tanks full and managing vegetation around tanks increases use by bats. Therefore, existing or planned livestock tanks can easily and inexpensively be managed for use by bats.

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