HOME RANGE AND HABITAT SELECTION OF CAVE-DWELLING NORTH AMERICAN PORCUPINES (*ERETHIZON DORSATUM*) IN CENTRAL TEXAS

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Abstract.–North American porcupines (*Erethizon dorsatum*) have expanded their range into central Texas and are now frequent users of caves as den sites. What remains unknown is how caves affect their home range, and their local habitat preferences. This information is important for management decisions on Joint Base San Antonio – Camp Bullis where novel and abundant porcupine scat in caves could jeopardize federally endangered cave-obligate arthropods by allowing for the invasion of less specialized terrestrial species. To better understand porcupine home range and habitat use at Camp Bullis, we trapped four porcupines at cave entrances and fitted them with GPS collars. The 95% home range averaged 71.3 ha for females and measured 420.6 ha for the male. The 50% core habitat averaged 55.4 ha for females and measured 7.4 ha for the male. Porcupines typically stayed near the den-cave trap site except when visiting more diverse mixed forest patches. At the landscape and point levels, individuals selected for forested cover and avoided open areas. At the home range level, individuals selected for bare ground and roads, which were likely used to get from the cave den site to feed at mixed forest patches. Typically solitary, individuals in this study tolerated sharing a cave. Because of the small sample size and single sampling location, this study represents a pilot study and additional research is needed to establish concrete conclusions. Should cave managers need to limit the cave use by porcupines, a cave gate, exclosure, or reduction of forested cover would make caves less desirable.

Keywords: *ecology, GPS collars, wildlife*

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North American porcupines (*Erethizon dorsatum*; hereafter porcupine) are an extremely adaptable species with populations found from Alaska to the southwest (Taylor 1935; Elbroch & Rinehart 2011; Coltrane & Sinnott 2013). Accordingly, porcupine home range and habitat use varies considerably across their range. In Nevada, porcupines had home ranges that averaged 15.3 ha for males and 8.2 ha for females and preferred riparian habitats with buffalo-berry (*Shepherdia argentea*) and willow (*Salix* sp.; Sweitzer 2003). In contrast, porcupines in Quebec had home ranges averaging 20.9 ha for males and 15.4 ha for females and selected for trembling aspen (*Populus tremuloides*) dominated deciduous and mixed forests (Morin et al. 2005).

The porcupine's adaptability has helped it expand its range south in the last 150 years and the species is now found in approximately 70% of Texas counties (Schmidly & Bradley 2016). A range map of the porcupine from 1866 suggests porcupines had just started to approach the Texas panhandle (Murray 1866), but the earliest written record of porcupines in Texas comes from the Biological Survey of Texas (Bailey 1905) where ranch hands in Alpine, Texas, near present day Big Bend National Park reported seeing the occasional porcupine beginning around 1901. Today, porcupines are still expanding their range in Texas. From 2004 to 2016, porcupine populations moved east along the Oklahoma border and south into the Rio Grande Valley and now inhabit all but the easternmost Texas counties (Schmidly 2004; Schmidly & Bradley 2016).

Generally, porcupines are known to use tree crevices, caves, and rocky outcrops as dens, though most available data is anecdotal and generally consists of observations made secondarily to other research questions (Dodge & Barnes 1975; Roze 1987; Griesemer et al. 1996; Morin et al. 2005; Roze 2009; Montalvo et al. 2017). Caves, in particular, also provide habitat for cave-obligate species adapted to the caves' oligotrophic conditions. These species rely on nutrients from external sources, particularly the scat of meso-mammals such as raccoons (*Procyon lotor*) or porcupines (Calder & Bleakney 1965; Peck

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1988; Elliott & Ashley 2005; Moseley et al. 2013). The caves in central Texas on Joint Base San Antonio – Camp Bullis (hereafter Camp Bullis) include three endangered arthropod species, Madla Cave meshweaver (*Cicurina madla*) and two ground beetles (*Rhadine exilis* and *R. infernalis*), that were historically associated with raccoon scat nutrient inputs (Reddell 1994; Veni et al. 2002). Porcupines were first recorded in Camp Bullis caves in 2003 (C. Thibodeaux, pers. comm.); consequently, porcupine scat represents a novel, and often abundant, nutrient source into the local caves environment. This is important because while small additions to a cave's nutrient input can help support cave-adapted species, an excess of nutrients may support their displacement through the introduction of less specialized, but more competitive or predatory terrestrial species into the cave environment (Veni et al. 2002; Gary 2009).

Currently, resource managers in central Texas do not have sufficient information to make informed management decisions regarding porcupines, including knowing what draws porcupines to a particular habitat and how habitat attributes might affect the frequency of cave use. The goal of this study was to describe how North American porcupines incorporate caves into their habitat use in central Texas. Specifically, our objectives were to (1) calculate home ranges and overlap for North American porcupines that use caves with data from GPS collars, and (2) determine significant habitat features for these porcupines using habitat selection ratios.

MATERIALS & METHODS

We performed this study on Joint Base San Antonio - Camp Bullis (hereafter Camp Bullis) a 11,286 ha military installation just north of San Antonio (29.6833° N, 98.5667° W) at the junction of the Edwards Plateau, South Texas Plains, and Blackland Prairie ecoregions of Texas (Gould 1975). Typical vegetation includes pockets of mixed grass prairie, mowed landscapes, and dense stands of Ashe juniper

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(*Juniperus ashei*), plateau live oak (*Quercus fusiformis*), and Texas oak (*Q. buckleyi*). Camp Bullis has areas of both prairies and rolling hills with a limestone, karst geology that contains approximately 100 caves. For this study, we defined caves as naturally formed, humanly accessible cavities that were at least 5 m in depth and/or length where no dimension of the entrance exceeded the length or depth (Gary 2009).

We first monitored caves known to have frequent porcupine use with Cuddeback Attack IR Trail Cameras (Non Typical, Inc., Green Bay, WI). We checked cameras one hour before sunset using a laptop with a built-in SD card reader. When a photo showed a porcupine had entered a cave for daytime denning, we baited a large Tomahawk box trap (Tomahawk Live Trap LLC, Hazelhurst, WI) with apples and salt and placed it in the cave entrance. We checked traps the next day at sunrise. We weighed and immobilized trapped porcupines with Telazol® (Zoetis Services LLC, Parsippany, NJ) at a dosage of 9–11 mg/kg from a 100mg/ml solution (Hale et al. 1994). We determined their sex and fitted each with a GPS collar. We used two styles of collars: Telonics TGW-4200-2 GPS/SOB collars (Telonics, Inc., Mesa, AZ), which provided location data every 90 minutes and Lotek G2C 171C WGPS collars (Lotek Wireless Inc., Newarket, ON, Canada), which provided location data every two hours between 1800 and 0600, and every six hours between 0600 and 1800. We selected these collar configurations because they maximized the number of locations that could be collected while maintaining a battery-life of at least six months. Porcupines were then returned to the trap to recover and later released at the trap site before dark. We performed all procedures under Texas Parks and Wildlife Research Permit SPR-0914-168 and Texas A&M Institutional Animal Care and Use Committee (IACUC) permit 2014-0233.

We calculated kernel density estimator (KDE) 95% home range and 50% core utilization distribution isopleths using Home Range Tools for ArcGIS (Rodgers et al. 2007) after removing points known or suspected to be in error. We performed calculations using a fixed-kernel estimator and least-squares cross-validation to estimate the smoothing parameter.

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We found the areas of KDE overlap using the ArcMap 10.3 (ESRI, Inc., Redlands, CA) intersect tool and calculated overlap indices with the formula:

$$OI = [(n1 + n2) / (N1 + N2)] \times 100.$$

The variables n1 and n2 correspond to the number of adjacent individual porcupines' locations within the overlap polygon, and N1 and N2 correspond to the total number of locations for the two porcupines used in the calculation of the home range overlap (Chamberlain & Leopold 2002; Brunjes et al. 2009; Kelley et al. 2011; Montalvo et al. 2014). We did not include overlap indices with a value of zero.

We calculated second- (landscape), third- (home range), and fourth-order (point locations) resource selection ratios (Johnson 1980). We calculated second-order selection ratios by comparing the proportion of locations in each mapped variable to their proportion in the study area. We calculated third-order selection ratios by dividing the proportion of each mapped variable in each 95% KDE home range estimate by the proportion in the study area. We calculated fourth-order selection ratios by comparing the proportion of locations in each mapped variable to those present in their individual 95% KDE home range estimate. Selection ratios equal to 1.0 indicated resource use proportional to availability, ratios >1.0 indicated preference, and ratios <1.0 indicated avoidance (Manly et al. 2002).

We calculated selection ratios for mapped variables created using ArcMap's supervised classification. This map assigned portions of the study site to one of three land cover variables: forested vegetation, herbaceous vegetation, and bare ground. Forested vegetation included dense mottes of shrubs and trees with heavy canopy cover; herbaceous vegetation included areas dominated by grass and forb species with minimal canopy cover; and bare ground included paved and non-paved roads, rock, buildings, gravel, and other areas lacking vegetation.

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RESULTS

We trapped and tracked four adult porcupines for this study. Only four individuals were used for this study because we were focused on obtaining an initial understanding of how caves are incorporated into an individual's habitat use. We trapped one female (PorcA) and one male (PorcB) near Well Done Cave and followed them from the end of July 2015 through November 2015 (Table 1; Fig. 1). We trapped two females (PorcC and PorcD) at Peace Pipe Cave and followed them from August 2016 through January 2017 (Table 1; Fig. 2). The average number of GPS points collected for each of the four porcupines was 500.3 (*SD* = 137.9; Table 1). Porcupine GPS locations often clumped into distinct clusters. Clusters A–D and F–L were closed canopy, mixed forested areas with tall, mature oaks (*Quercus* spp.). Cluster E was a grassland with scattered mottes that included a diverse assemblage of trees and shrubs (Figs. 1, 2).

We calculated PorcA 95% home range KDE at 103.6 ha and 50% core KDE at 10.6 ha (Table 1). Both the home range and core KDE were centralized around Well Done Cave where this porcupine was trapped, although a number of points were also collected around 'cluster A' (Fig. 1). We calculated PorcB 95% home range KDE at 420.6 ha and 50% core KDE at 7.4 ha (Table 1). In particular, the core KDE included points collected around 'cluster B', 'cluster C', and 'cluster D'. The home range KDE further included points collected around 'cluster E', 'cluster F', and original cave trap site (Well Done Cave; Fig. 1). We calculated the overlap index for PorcA and PorcB at 42.44% although they only spent 5 out of 100 days within 100 m of each other. The porcupines' simultaneous use of neighboring habitat all occurred around Well Done Cave where both were trapped and collared.

We calculated PorcC 95% home range KDE at 46.4 ha and 50% core KDE at 4.0 ha (Table 1). The core KDE centered on the cave trap site (Peace Pipe Cave) and approximates a 100 m buffer around the cave entrance. The home range KDE further included points collected around 'cluster G', 'cluster H', 'cluster I', and 'cluster J'. We calculated

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Table 1. Individual porcupine data including sex, dates of location data collection, number of GPS locations (n), 95% KDE home range estimate (ha), and 50% KDE core estimate (ha) at Camp Bullis, Texas, USA, 2015–2017.

	Sex	Dates	n	95% KDE	50% KDE
PorcA	F	07/28/2015 – 11/11/2015	314	103.6	10.6
PorcB	M	07/24/2015 – 11/23/2015	645	420.6	7.39
PorcC	F	08/10/2016 – 01/11/2017	538	46.35	4.04
PorcD	F	08/10/2016 – 01/03/2017	504	64.0	40.8

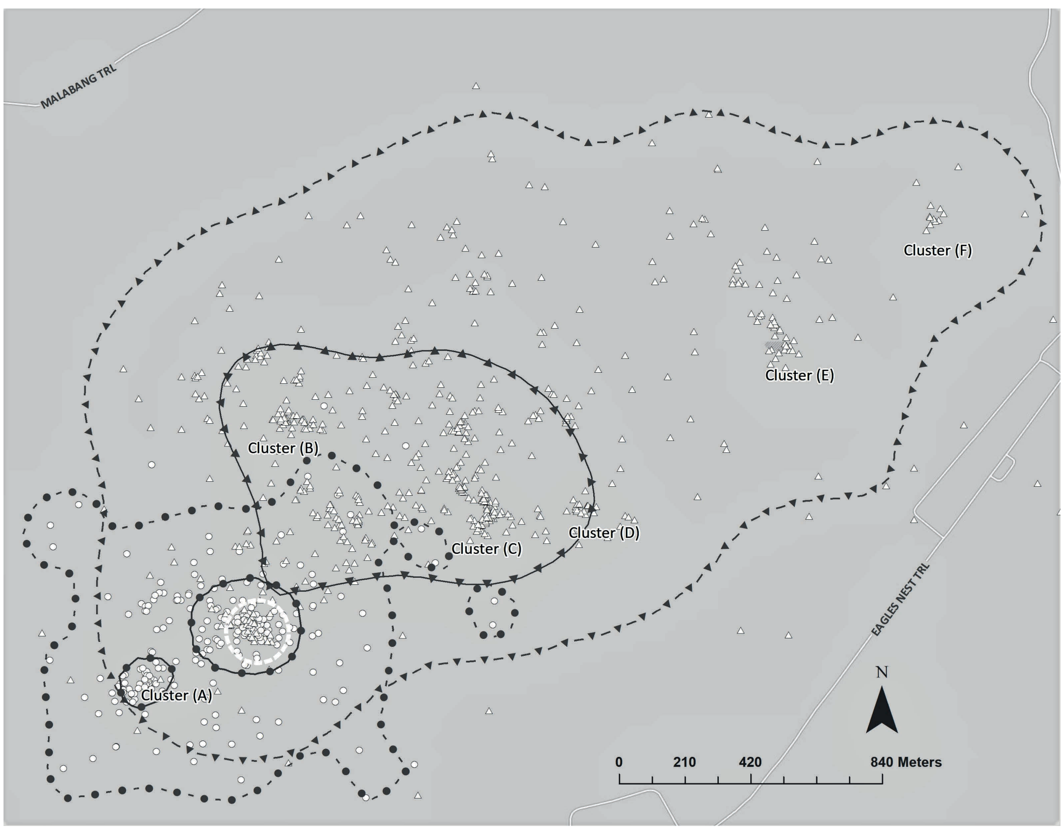

Figure 1. Ninety-five percent KDE home range (circle dotted line), 50% KDE core estimates (circle solid line), and individual locations (gray circles) for PorcA; 95% KDE home range (triangle dotted line), 50% KDE core estimates (triangle solid line), and individual locations (gray triangles) for PorcB; and 100m buffer around Well Done Cave (thick, white dashed lined) at Camp Bullis, Texas, USA, 2015.

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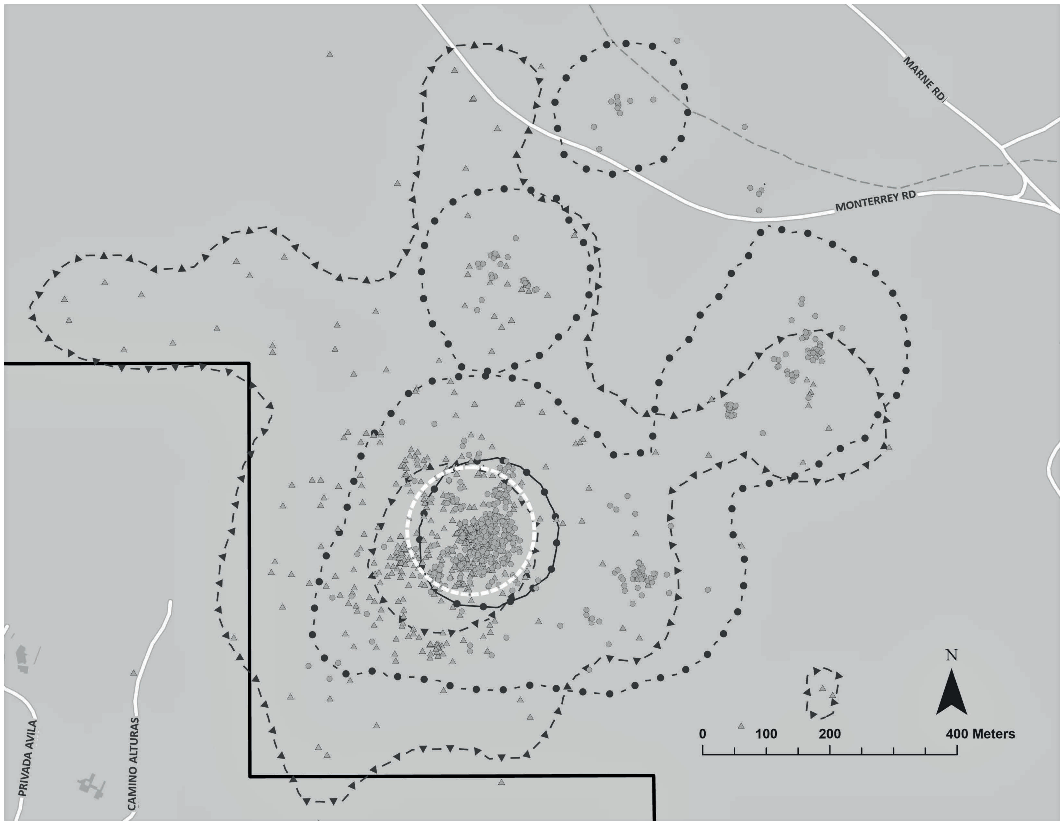

Figure 2. Ninety-five percent KDE home range (circle dotted line), 50% KDE core estimates (circle solid line), and individual locations (gray circles) for PorcC; 95% KDE home range (triangle dotted line), 50% KDE core estimates (triangle solid line), and individual locations (gray triangles) for PorcD; and 100m buffer around Peace Pipe Cave (thick, white dashed line) at Camp Bullis, Texas, USA, 2016–2017.

PorcD 95% home range KDE at 64.0 ha and 50% core KDE at 5.4 ha (Table 1; Fig. 2). The core KDE also centered on the cave trap site (Peace Pipe Cave) and approximates a 100 m buffer around the cave entrance. The home range KDE included points collected around ‘cluster G’, ‘cluster I’, and ‘cluster K’ (Fig. 2). We calculated the overlap index for PorcC and PorcD at 92.7% with these two porcupines having spent 69 out of 147 days within 100 m of each other. Almost all of the porcupines’ simultaneous use of neighboring habitat occurred around Peace Pipe Cave where both were trapped and collared.

ArcMap’s supervised classification procedure classified Camp Bullis as 57% forested cover, 31% herbaceous vegetation cover, and

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Table 2. Individual porcupine multi-level, habitat selection ratios for woody vegetation (W), herbaceous vegetation (H), and bare ground, road, or buildings (BG) cover types at Camp Bullis, Texas, USA, 2015-2017.

	2^{nd} Order (Landscape)	3^{rd} Order (Home Range)	4^{th} Order (Point)
PorcA			
W	1.26	1.06	1.22
H	0.74	0.86	0.88
BG	0.53	1.20	0.45
PorcB			
W	1.20	0.98	1.27
H	0.76	0.98	0.80
BG	0.57	1.20	0.49
PorcC			
W	1.09	0.72	1.52
H	0.86	2.55	0.34
BG	0.38	1.37	0.28
PorcD			
W	1.11	0.70	1.63
H	0.74	3.80	0.20
BG	0.25	1.21	0.21

12% bare ground cover. Our calculations for porcupine selection ratios showed that at the landscape scale (second-order), PorcA and PorcB both selected for forested cover and selected against bare ground and herbaceous cover. PorcC and PorcD also selected against herbaceous cover and bare ground but used forested cover proportionally to what was available (Table 2). At the home range scale (third-order), PorcA, PorcB, PorcC, and PorcD all selected for bare ground. PorcC and PorcD also selected for herbaceous cover and selected against forested cover (Table 2). At the point scale (fourth-order), PorcA, PorcB, PorcC, and PorcD all selected for forested cover and selected against bare ground and herbaceous cover (Table 2).

Discussion

Our study further demonstrates the potential variability of porcupine home range and habitat use across their range. Across their range, North American porcupine populations have an average home range of 25 ha

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for females and 78 ha for males (Elbroch & Rinehart 2011). All of the females in this study had home range estimates that were larger than this average, one being four times as large, with the male's home range estimate being more than five times as large. One other study of porcupines in northern Texas also found their home ranges to be larger than average (67.9 ha for females, 203.7 ha for males; Montgomery 2010). For our study site, this may be because much of Camp Bullis is a patchwork of closed canopy forest and open grassland. Open grasslands are a known high-risk area for predation (Sweitzer & Berger 1992; Sweitzer 1996) and porcupines may have circumvented these risky patches by expanding their home ranges into fringe forested patches. Our GPS data show that all four porcupines appeared to avoid open canopy vegetation in favor of closed canopy habitats.

Additionally, our data demonstrate the importance of caves as porcupine den sites on Camp Bullis. All of our female porcupines' core habitats, in particular, centered on caves. Additionally, these porcupines did not appear to rotate den sites as seen in other populations (Roze 1987; Morin et al. 2005; Roze 2009). Our porcupine population's use of various habitat 'clusters' also indicates some resource is likely not being met in the cave or its immediate surroundings. Many of the cave entrances at Camp Bullis are situated within mottes dominated by Ashe juniper, while cluster habitats typically were composed of more diverse vegetation that often included large, mature oak trees (*Quercus* spp.). Given the porcupines' documented use of more mature and diverse vegetation (Morin et al. 2005; Coltrane & Sinnott 2013) and acorns for food (Griesemer et al. 1998; Ilse & Hellgren 2007; Roze 2009), we suspect these clusters are important feeding microhabitats.

Porcupines in this study, especially PorcC and PorcD, showed a large amount of home range overlap, suggesting that this study site's population is not markedly territorial, especially female-to-female. Additionally, the cave used by PorcA and PorcB, in particular, was known to be concurrently used by a minimum of three porcupines. Interestingly, New York populations showed territoriality among females (Roze 2009) while Nevada populations showed territoriality among males. In Nevada, female home range overlap averaged only

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20% (Sweitzer 2003), much lower than our female-female home range overlap calculation of 92.7%. This Camp Bullis porcupine population may be suspected as an outlier, but we believe that this overlap calculation only further demonstrates the importance of caves, in that a typically solitary species (Morin et al. 2005; Roze 2009) would tolerate such an intense degree of interaction for this resource.

The porcupines in this study selected for both landscapes and individual locations with ample herbaceous and woody vegetation cover and little bare ground or roads. Their home ranges, in contrast, contained more regions of bare ground or roads. We suspect bare ground and roads were crucial at the home range scale because they were used as corridors between cave den sites and cluster feeding sites. Other habitat studies have also shown porcupines selecting for diverse forest cover and selecting against grasslands with more open canopy cover (Morin et al. 2005; Mally 2008; Montgomery 2010; Coltrane & Sinnott 2013) but only the porcupines of this study selected for bare ground at any hierarchical level.

In this study, the porcupine population had large home ranges where individuals demonstrated the importance of both closed and open canopy cover. Our data also demonstrated the importance of caves as a fixed den site around which all females centered their core habitat. The results of this study are pertinent to porcupine management on Camp Bullis where their recent cave use could jeopardize federally endangered cave-obligate arthropods. Because the oligotrophic cave environments on Camp Bullis were historically supported mainly by the nutrient inputs provided by raccoon scat (Reddell 1994;Veni et al. 2002), scat left by porcupines represents a novel and often abundant source of additional nutrients. These additional nutrients could eventually threaten cave-obligate species by supporting less specialized, but more competitive or predatory terrestrial species in the cave environment (Gary 2009). Should managers need to limit porcupine cave use, a previous study indicates that installation of an entrance gate (Montalvo et al. 2017) or similar exclosure will reduce their visitation to a cave. Our data suggest that reduction or replacement of forested habitat around cave openings would make the habitat less

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desirable to porcupines. All of these management techniques should be carefully studied beforehand as both the practicality and potential effects to the cave ecosystem are unknown. Similarly, because of the small sample size, expanded studies are needed to identify overall trends for Texas porcupines, including populations which are isolated from caves.

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