DEN SITE SELECTION OF RINGTAILS (*BASSARISCUS ASTUTUS*) IN WEST CENTRAL TEXAS

By

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ABSTRACT

Research was conducted to determine ringtails (*Bassariscus astutus*) den site preferences in west central Texas. From August 2008 - November 2009, 13 ringtails (8 females; 5 males) were captured and radio-collared in Tom Green and Irion Counties, Texas. Ringtails were found using owl nest boxes and natural dens at the study site. Two hundred and eighty-six dens were located, of which 105 were unique. Thirty-seven instances of den site co-occupancy by multiple ringtails were recorded. Data-loggers were used to characterize thermal profiles of known dens and controls from October 2008 – October 2009. Den selection for male and female ringtails revealed nest box preference more frequently in the winter (80%) followed by spring (77%), fall (67%), and summer (30%). Den types (nest boxes, below-ground dens, above-ground dens) selected were significantly different (χ^2=45.3, *df*=6, *P*<0.000). Seasonal den type selection was significant for female (χ^2=37.0, *df*=6, *P*<0.000) and male ringtails (χ^2=22.5, *df*=6, P<0.001).

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INTRODUCTION

The ringtail (*Bassariscus astutus*) is a small cat-sized mammal in the family Procyonidae, the carnivore family that includes the northern raccoon (*Procyon lotor*) and white-nosed coati (*Nasua narica*). The current distribution of ringtails in North America extends north from Mexico along the west coast into southwestern Oregon and eastwards into portions of Louisiana, Arkansas, Kansas, Oklahoma, Nevada, Colorado, Utah, and Texas (Hall 1981; Wozencraft 2005). Ringtails occur statewide in Texas, and are common in parts of the Edwards Plateau, Trans-Pecos, and Cross Timbers regions of Texas (Schmidly 2004).

The ringtail is the smallest procyonid with an average mass ranging from 0.8-1.1 kg and total lengths between 616-811 mm (Gehrt 2003). Their tails are nearly as long as their bodies and have seven to eight alternating white and dark rings (Gehrt 2003). Ringtails have short semi-retractable claws (Hall 1981) that, along with hind feet capable of rotating 180 degrees (Schmidly 2004), allow ringtails to quickly and skillfully ascend and descend from trees. Sensory hairs on their forelimbs aid ringtails in detection of prey (Toweill and Toweill 1978).

Ringtails are an important part of a functioning ecosystem, as they help to control populations of rodents, insects, and reptiles. They are not obligatory carnivores, as they eat fruits, thereby aiding in seed dispersion. Ringtails are prey species for larger predators, such as foxes, bobcats, coyotes, and raptorial birds (Poglayen-Neuwall and Toweill 1988).

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Many of the previous studies on ringtails have focused on dietary information (Ackerson and Harveson 2006; Alexander et al. 1994; Taylor 1954; Toweill and Teer 1977; Trapp 1978; Wood 1954). Information gathered from dietary studies varies geographically as well as seasonally. Alexander et al. (1994) found that in Oregon, plant material comprises 93% by volume of ringtail scat, although 66 percent of samples contained evidence of mammalian remains. In contrast, the study conducted by Toweill and Teer (1977) in the Edwards Plateau region of Texas found mammalian remains in only 14% of ringtail scat. Toweill and Teer (1977) found a high percentage (32%) of ringtail diet derived from arthropods including arachnids.

Movement and activity pattern studies have also been conducted on ringtails (Ackerson and Harveson 2006; Toweill 1976; Toweill and Teer 1980; Trapp 1978; Yarchin 1994). In the Edwards Plateau region, Toweill and Teer (1980) discovered that ringtails shift home ranges in accordance with the seasons; with females having more widely separated home ranges. Actual size of home ranges varied between the sexes, with males' home ranges averaging 43.4 ha compared to 20.3 ha for females during a five-month period (Toweill and Teer 1980).

Current knowledge of den site selection of ringtails in Texas suggests that ringtails do not construct dens or den together with the exception of young occupying natal dens (Schmidly 2004). Ringtail den site characteristics have been described as "very informal" by Taylor (1954), as dens appear to occur at any convenient place, but ringtails are often found denning in rock crevices, brush piles, and hollow trees and logs (Schmidly 2004). Naylor and Wilson (1956) reported finding a female ringtail with two kittens in California utilizing a wood duck nest box. Incidental reports from local ranchers also indicate that ringtails inhabit attics throughout different parts of the year.

Access to potable water sources may account for a disproportionate number of ringtails along riparian habitats (Richards 1976). Toweill and Teer (1980) believed this tie to water is in response to food availability and not due to any physiological water requirement. Richards (1976) also found that when stressed for water, the ringtail can produce the most concentrated urine of any carnivore.

A previous student began a study on the Knickerbocker and Tweedy ranches, in Tom Green and Irion Counties, Texas, under the guidance of Dr. Terry Maxwell (Professor, Department of Biology, Angelo State University). One hundred nest boxes were mounted to trees in presumed screech owl habitat at the study site. The nest boxes were designed to monitor and record nesting in two sympatric owl species: the western screech owl (*Megascops kennicottii*) and the eastern screech owl (*Megascops asio*). The nest boxes have a hinged top with a single circular entrance 7.7 cm in diameter. Over the course of that study, owls were rarely encountered; instead, researchers discovered ringtails frequenting the nest boxes.

Previous researches at Angelo State University have demonstrated that nest boxes provide a valuable tool to analyze den site selection for ringtails. Furthermore, the varied habitats in which the boxes were placed have provided important information on ringtail habitat.

Nest boxes have proven useful in understanding the ecology of other mammals. A ten-year study by Lindenmayer et al. (2009) in Australia showed the value of nest boxes for arboreal marsupials. They found nest boxes were used 58% of the time in young forest, 20 years after clearfell logging, compared to 4% usage in older growth forest (68 years post 1939 wildfires). Another study (Stuewer 1948) in Michigan constructed nest boxes for raccoons (*Procyon lotor*), and found average nest box usage of 80% for two consecutive years (1946 - 47). Stuewer (1948) reported that the raccoon population increased greatly from 1940 to 1947, which likely led to the increase in usage over time, especially as vacant natural hollows were occupied.

Objectives

The major objective in this study was to determine if ringtails exhibit seasonal shifts in den site selection in west central Texas, and to examine habitat associations in den site selections. The specific objectives were to assess (1) differences between male and female selection of dens, (2) differences in den selection across the seasons, (3) habitat associations for den use patterns in ringtails, (4) thermal profiles of monitored ringtail dens, and (5) to determine the ecological function(s) of the den (predator avoidance, proximity to food sources, or protection from the elements).

MATERIALS AND METHODS

Study Area

This research was conducted on 2 adjacent ranches, the Knickerbocker and Tweedy ranches, located near Knickerbocker, in Tom Green and Irion Counties, Texas. Combined, the ranches encompass 3,200 ha. The study site has both riparian (Fig. 1), and upland habitat (Fig. 2). The riparian habitat is dominated by pecan (*Carya illinoinensis*) along Dove Creek. Along both sides of Dove Creek on the Knickerbocker

Fig. 1. General appearance of riparian habitat along Dove Creek dominated by pecan (*Carya illinoinensis*) on the study site located near Knickerbocker in Tom Green and Irion Counties, Texas. A nest box used by ringtails (*Bassariscus astutus*) is visible in the upper left of the photograph.

Fig. 2. General appearance of upland habitat showing mixed grasses and mesquite (*Prosopis glanulosa*) on the study site located near Knickerbocker in Tom Green and Irion Counties, Texas.

ranch lays irrigated farmland. In recent years, the creek and river's banks were fenced off to preserve the riparian stream corridor. The upland habitat is dominated by mesquite (*Prosopis glandulosa*), Texas live oak (*Quercus fusiformis*), red-berry juniper (*Juniperus pinchotti*), and prickly pear (*Opuntia spp*.) rangeland. This research project was conducted from September 2008 to November 2009.

Capture and Den Site Use

Initial capturing protocol involved checking nest boxes for ringtail occupancy, as well as placement of Tomahawk live traps in presumed ringtail habitats. Tomahawk live trapping methods proved ineffective, and all capturing efforts focused on nest boxes. All captures of ringtails were from nest boxes, as they served as permanently mounted 'traps'. Nest boxes measured approximately 38 x 22 x 19 cm with a 7.7 cm entrance hole. In this study, boxes were checked for ringtail occupancy by opening the hinged top of the box. The boxes were all mounted at heights between 3-5 m above the ground on pecan and live oak trees. All boxes had geo-referenced locations determined with a handheld global position system (Appendix I). Thirty nest boxes were checked monthly, with 15 located in riparian and 15 in upland habitats (Fig. 3). There were additional nest boxes that were not monitored for this study. Minor repair was made to boxes to ensure utility by ringtails throughout the study.

All methods for trapping, anesthetizing, and handling of animals followed the guidelines set forth by the Animal Care and Use Committee of the American Society of Mammalogists (Gannon et al. 2007). When a new individual ringtail was found,

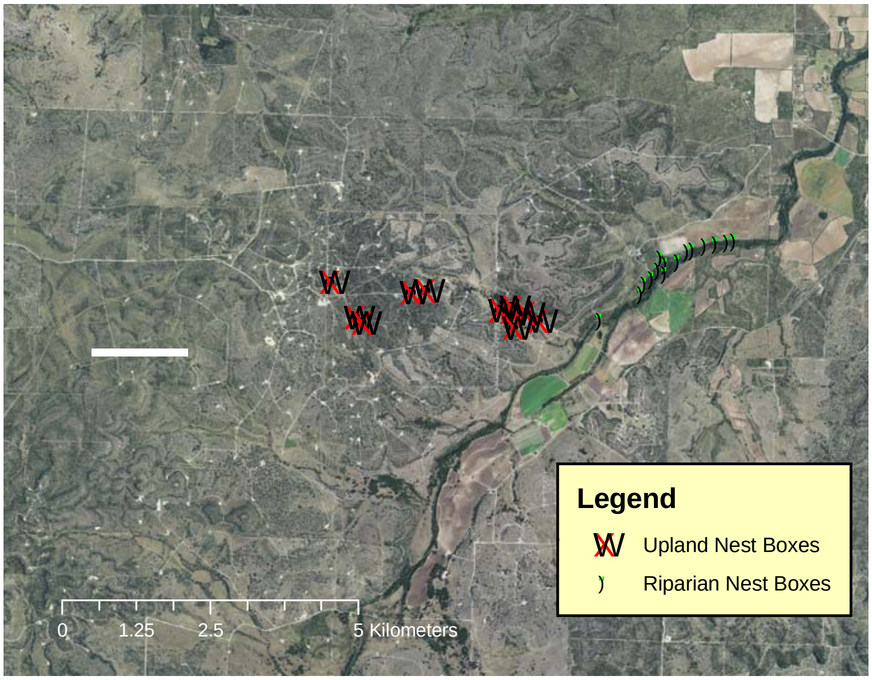

Fig 3. Geo-referenced map showing the locations of monitored nest boxes on the study area, Tom Green and Irion Counties, Texas.

it was held in place for sedation with the aid of a push stick made of medium gauge wire mesh affixed to a ½ m long wooden stick. Captured ringtails were anesthetized intramuscularly, in their hind limb, using a 2:1:1 ratio of ketamine hydrochloride (10mg/kg), xylazine (5mg/kg), and acepromazine (1mg/kg) (Edwards et al. 1998). External measurements, mass, and gender were recorded for each capture. Each ringtail was then fitted with a radio-collar that weighed 24 g, and featured both an activity monitor and mortality sensor (Telemetry Solutions, Concord, CA). All ringtails had uniquely numbered ear tags (National Band and Tag Company, Newport, Kentucky) affixed, as well as passive integrated transponders (Avid Identification Systems Inc., Norco California) to accurately determine recaptures if they lost the radio-collar. Furthermore, a small piece of ear tissue was taken from each individual for possible genetic work in future studies.

Thermal Profiles

Temperature was recorded throughout this study to determine its role in den site selection by ringtails. The Thermochron iButton (Maxim Integrated Products, Dallas, Texas) is a small watch-battery-sized (3.3 g) data-logging device used to record both temperature and time. The iButton has a built in real-time clock that is accurate to within ± 2 minutes per month, and records temperature to within ± 1 C° (40 C° to 85 C°). Data-loggers were set to record and store temperature readings every hour, which allowed up to 85 days of readings (maximum 2048 individual readings). The devices were pulled from dens monthly for data retrieval via the 1-Wire and 1-Wire Viewer (Maxim Integrated Products, Dallas, Texas). Temperature data was imported into

Microsoft Excel. Placement of the data-loggers was dependent on the type of den under examination. For dens in nest boxes, data-loggers were placed in plastic Ziploc bags and affixed to a nylon monofilament line for ease of retrieval. For natural den sites, the thermal sensors were similarly packaged and placed into the furthest recesses of the den. Twelve nest boxes (6 riparian, 6 upland) had single data-loggers placed on the floor of the boxes to record body heat generated from presumed ringtails inside of the nest box. Two thermal devices were placed approximately 1 m above nest boxes in both riparian and upland habitats, and served as environmental controls, and to document thermal differences between the inside and outside of nest boxes through an entire year. Two additional thermal sensors were placed in randomly located cactus patches that never served as ringtail den sites. Five iButtons were also placed inside of natural dens that had been utilized by ringtails, which included: two below-ground burrow dens, one rock outcropping, one pecan snag 4 m high, and a woodpile burrow system. Data were collected for one year, with mean monthly temperatures generated for each monitored site.

Den Site Selection and Habitat Analysis

Any site where the animal remained inactive during daylight hours was considered as a den. Den sites were located via homing and locations recorded in latitude and longitude coordinates with a handheld GPS unit (Garmin, Olathe, Kansas). Den sites were classified as nest boxes, above-ground dens (natural tree snags and log piles), and below-ground (rock outcroppings and burrow systems). Den characteristics were later recorded when the ringtail had vacated. Monthly information on presence/absence of scat on top of the boxes was recorded and boxes with scat were cleared when found.

Habitat analyses were similar to those of Doty and Dowler (2006) in that examination of vegetative and environmental factors surrounding den sites were limited to a 20 m diameter circle. Line transects of 10 m radiating from the center of each den plot were conducted along primary cardinal directions. Habitat variables were recorded using the line transects method, and included: percent grass, shrub, forb, rock, cactus, bare ground, water, and woody debris. Also from the line transects, estimates of canopy cover were recorded with a handheld densitometer (Geographic Resource Solutions, Arcata, CA). Canopy cover was estimated as 0, 25, 50, 75 or 100%, with recordings taken at the center (den site opening) and at intervals of five meters. All observations at five and ten meters were then averaged together to arrive at a single canopy estimate for five and ten meters, respectively. Dimensions, depth and number of openings for belowground dens were estimated when feasible using a video burrow probe (Sandpiper Technologies, Manteca, California). Nest box dens had the same vegetative and habitat information collected, using the line transect method described above, with the addition of factors including: species of tree, diameter of nest box tree at breast height (DBH), and cardinal direction of box opening. Four quadrants were produced from the line transects habitat analysis method, and the following parameters recorded: number of large pecans and oaks (>50 cm DBH), number of small pecans and oaks (<50 cm DBH), and number of other tree species.

A principal component analysis (PCA) was conducted on habitat variables to normalize and reduce the dimensionality of the data. A multivariate analysis of variance (MANOVA) was then used on the component scores to evaluate differences in den habitats and selection throughout the seasons. A discriminant function analysis (DFA) was conducted on the 6 informative PCA factor scores in order to categorize den types. Pearson's chi-square test was used to interpret seasonal denning habitats for male and female ringtails. All statistical analyses were conducted using SYSTAT 12 (SPSS Inc.).

RESULTS

Capture and Den Site Use

The Tomahawk live trapping methods proved ineffective in the beginning of this project, as only non-target species such as northern raccoon (*Procyon lotor*) and Virginia opossum (*Didelphis virginiana*) were caught. Total trap nights for Tomahawk live trapping were not calculated, as this was abandoned very early in the study. Beginning in October of 2008 all capturing efforts focused on nest boxes. Thirty nest boxes were checked for ringtail occupancy from November 2008 – November 2009, for a total of 390 times. Thirteen ringtails were captured from riparian (6) and upland (7) nest boxes. Eight females and 5 male ringtails were radio-collared beginning September 2008, with the last ringtail collared in late February of 2009. Radio-tracking of individuals ended in August 2009. Overall capture success was 3.3%, which is based on total number of captures (13) out of 390 nest box monitoring events. Capture success (3.3%) does not include the number of times a previously captured ringtail was found using a particular nest box. Capture success was similar to ringtail studies that used live traps.

For the 13 radio-tracked individual ringtails, 286 total den sites were located (Table 1). The initial capture of ringtails from nest boxes varied by habitat. Six ringtails (F1, F2, F7, M1, M2, and M4) were captured in riparian habitat nest boxes. The remaining 7 ringtails (F3, F4, F5, F6, F8, M3, and M5) were captured in upland habitat nest boxes. Two ringtails (F2 and M2) were captured together and radio-collared in a riparian nest box (Fig. 4). Ringtail F3 was radio-collared while sharing a nest box (45W) with 3 other ringtails. The other three ringtails in box 45W were not radio-collared, because anesthetic could not be safely administered.

Nest boxes were used a total of 69% (197 of 286) and natural dens used 31% (89 of 286) of the time by both sexes during the entire sampling period (Table 1). Ringtails F5, F6, and M4 were tracked to nest boxes 100% of the time. Other ringtails used nest boxes less frequently, such as F2 and F8, whose box usage was 51 and 27%, respectively.

Repeat use of a particular nest box was around 36%. All ringtails during this study revisited previously utilized nest boxes. For example, female F5 after initially making use of box 41W was found on 5 separate occasions to return to the same box over a 5-month period; of these box visits, 2 separate times F5 was co-occupying that nest box with F6 and later with M3. The highest percent of reuse was by F4, who repeated use of previous nest boxes nearly 56% in a 7-month period.

Table 1. Summary of data on number of den sites utilized per individual ringtail (with 1 or more den locations). Percentages of total den sites that consisted of nest boxes, repeat nest box usage, and co-occupancy of den sites between individuals during entire study period (F=Female, M=Male).

Bassariscus astutus ID	# total den sites	% nest box usage	% repeat usage of nest box	% shared dens
F1	11	90.9 (10)	36.4 (4)	0
F2	35	51.4 (18)	22.9 (8)	20 (7)
F3	11	63.6 (7)	36.4 (4)	9.09 (1)
F4	18	94.4(17)	55.5 (10)	11.1 (2)
F5	11	100 (11)	72.7 (8)	72.7 (8)
F6	20	100 (20)	55.0 (11)	20 (4)
F7	28	60.7 (17)	28.6 (8)	0
F8	26	26.9 (7)	7.7 (2)	0
M1	36	80.5 (29)	50.0 (18)	5.5 (2)
M2	36	63.8 (23)	30.5 (11)	13.8 (5)
M3	30	56.6 (17)	33.3 (10)	20 (6)
M4	7	100 (7)	28.6 (2)	28.6 (2)
M5	17	82.3 (14)	35.3 (6)	0
Total	286	68.9 (197)	35.7 (102)	12.9 (37)

Fig. 4. Photograph of ringtails F2 and M2 captured on 05 September 2008 in riparian nest box on Knickerbocker Ranch.

Ringtails were also found at higher than expected frequency to be sharing or co-occupying nest boxes. Thirty-seven instances of co-occupancy of nest boxes were documented throughout this study, which is close to 13% of all denning events combined (37 of 286). Not all ringtails were found sharing nest boxes. F1, F7, F8, and M5 were never documented sharing dens. The remaining ringtails exhibited generally low percentages of den sharing. The ringtail with the highest percent of co-occupancy of a nest box was F5, which shared nest boxes in 8 of her 11 total dens located (73%). Females utilized nest boxes 68% of the time, and below and above-ground natural dens were selected 16% of the time. Overall, males selected nest boxes 71% of the time, followed by below-ground dens 21%, and above-ground dens 8% (Fig. 5). Males also shifted den use in the summer, favoring below-ground burrows (58%), with nest box usage falling to around 30% (Fig. 6). Females continued exhibiting preference for nest boxes until the summer months (June - August), when they shifted to above-ground dens (54%) such as naturally occurring tree cavities (Fig. 7). Both sexes used nest boxes at higher percentages during the winter months (December - February) as male and female usage was at 87 and 83%, respectively (Figs. 6, 7).

Thermal Profiles

Data-loggers recorded temperature as a function of time for one year October 2008 – October 2009, for an approximate total of 201,480 individual hourly temperatures. Initial programming and placement was limited to 4 previously located ringtail dens in nest boxes starting in October of 2008. Two burrows dens located in late October of 2008 had devices placed and began recording data for the month of

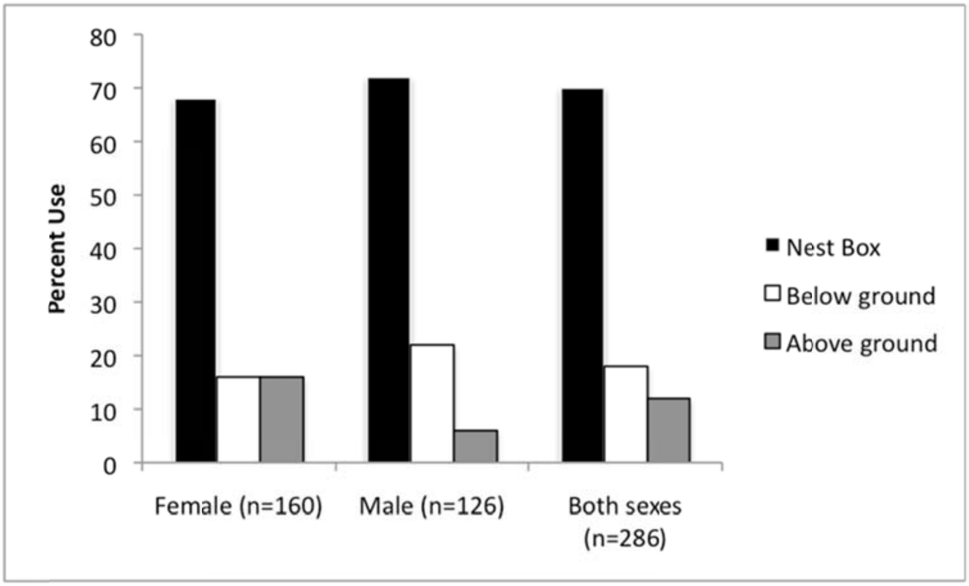

Fig. 5. Total den sites selected for male and female *Bassariscus astutus*, Tom Green and Irion Counties, Texas, 2008 - 2009.

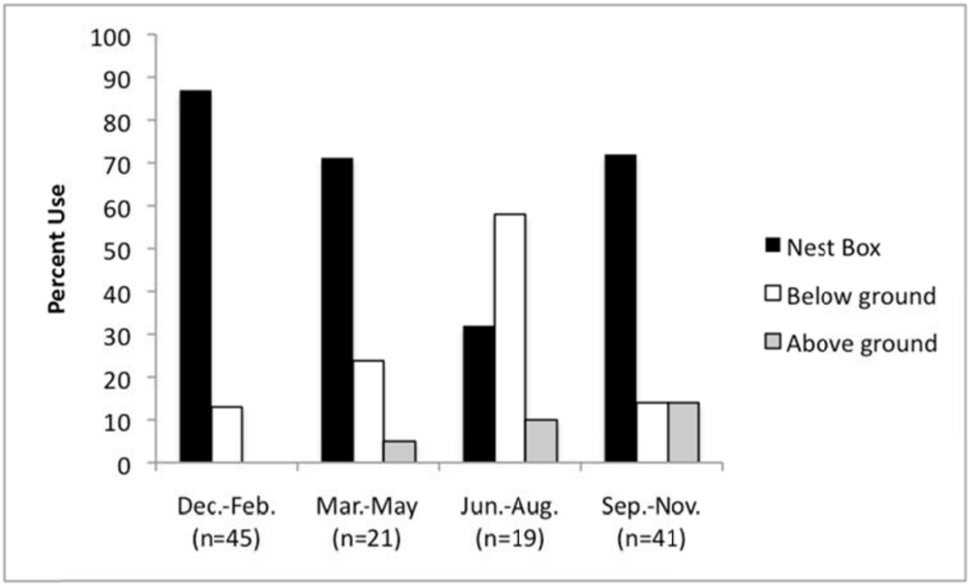

Fig. 6. Male *Bassariscus astutus* den site selection by season, beginning December 2008 - November 2009, Tom Green and Irion Counties, Texas.

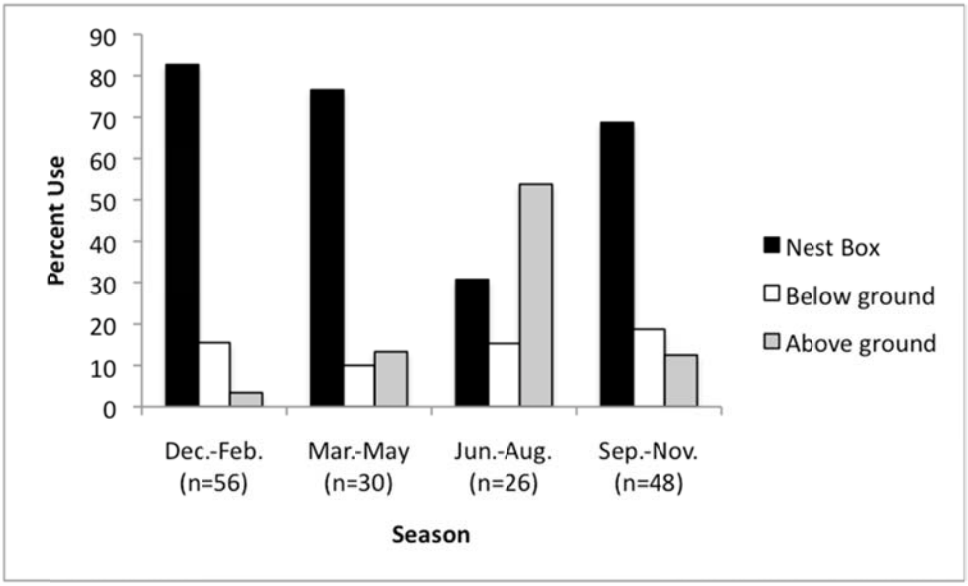

Fig. 7. Female *Bassariscus astutus* den site selection by season, beginning December 2008 - November 2009, Tom Green and Irion Counties, Texas.

November, raising the total number of data-loggers to 6. By December 2008, all 23 thermal data-loggers had been placed in upland and riparian nest boxes, as well as the environmental controls, cactus patches, and natural dens. Average monthly temperatures of nest boxes were compared to ambient (control) and natural den sites in this study from December 2008 – October 2009 (Appendix II, III, IV). Monthly averages temperatures were used to minimize the number of data points that could be visually interpreted, and serve as approximations of thermal site profiles. A single nest box from each habitat was randomly selected for analysis, in addition to a frequented burrow system and a cactus patch (Fig. 8). Nest boxes in both riparian and upland habitats proved to have very similar thermal profiles. Burrow systems provided more stable year-round thermal profiles, and were not subjected to the extreme temperatures seen in the summer months. Cactus patches proved thermally unstable, and exhibited the highest and lowest average monthly temperatures of any sampled site.

Because radio-tracking could confirm occupancy of a nest box with a thermal data-logger, thermal profiles could be used to determine duration of stay by a ringtail. One such account was from the upland nest box 43W, which on January 18, 2009 was identified as occupied by radio tracking one ringtail (Fig. 9). This thermal profile shows the ringtail to have entered the den around 1030 hrs and exited the box sometime close to 1630 hrs. The temperature profile inside the nest box rose at a greater rate than ambient conditions, and allowed the ability to determine duration of stay of about 6 hours.

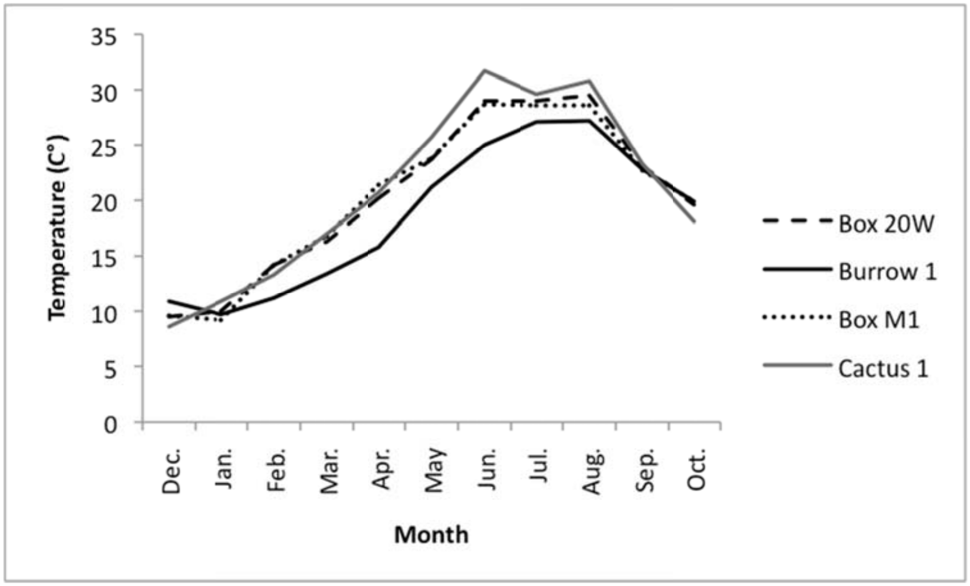

Fig. 8. Average monthly thermal profiles from December 2008 - October 2009, recorded inside an upland nest box (20W), a riparian nest box (M1), a burrow system, and a cactus patch, Tom Green and Irion Counties, Texas.

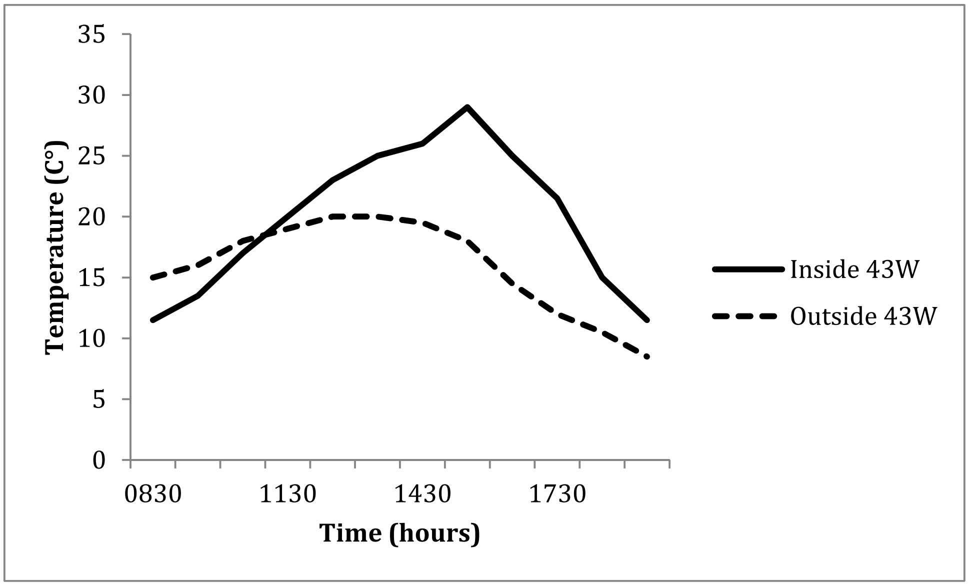

Fig. 9. Thermal profile inside upland nest box 43W, occupied by single *Bassariscus astutus*, compared to profile outside of the box, 18 January 2009, Tom Green and Irion Counties, Texas.

Den Site Selection and Habitat Analysis

Den site analysis concentrated on habitat variables around located dens. Twenty-five nest boxes and 3 natural dens (snag, burrow 1, and a rock outcropping) were used by more than one individual ringtail. These sites were duplicated in subsequent analyses as they represented independent observations throughout the sampling period. Duplicate use of particular den sites was additionally included in the following analyses to increase the sample size, as approximately 36% of dens were of repeat usage. The 30 habitat variables obtained from den plots for each den site were initially subjected to a principal component analysis. The PCA created 6 sets of factor scores (Table 2) that were used as variables in a MANOVA and DFA. The first three factors explained 39.5% of the total variation in den sites, and 60.8% was explained by all 6 factors.

A MANOVA was performed on the PCA scores to test for habitat differences between den types for both genders. As would be expected, dens were significantly different (*F*=19.9, *df*= 12.556, *P*<0.000) in riparian and upland habitats. The canonical scores plot (Fig. 10) shows nest boxes centrally located with the most overlap among above and below-ground natural den types. Above-ground dens had the largest variation in habitat variables and the smallest overlap among the den types. The loadings for the horizontal axis were higher than the loading for the vertical axis, which translates into more discrimination than the horizontal axis (Table 3).

Factor scores 1 and 3 had the most effect on the horizontal axis. Factor 1 positively influenced the plot, whereas factor 3 negatively influenced the plot. Factor 1 of the PCA scores was positively influenced by number of algeritas (*Mahonia*

Table 2. Component loading from principal component variables attributed to *Bassariscus astutus* den sites, Tom Green and Irion Counties, Texas, 2008 – 2009.

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
# small pecans	-0.183	-0.068	-0.656	-0.107	0.307	-0.360
# large pecans	0.050	0.341	-0.381	-0.418	0.015	0.465
# small oaks	0.545	0.082	0.132	0.635	-0.117	0.013
# large oaks	0.368	0.191	0.733	0.015	0.005	-0.109
# of other trees species	0.235	-0.386	-0.057	-0.400	0.191	0.091
Mesquite	0.139	0.029	0.017	0.450	-0.285	0.067
Catclaw	-0.153	-0.063	0.311	0.034	-0.133	0.102
Hackberry	-0.311	-0.415	0.218	0.174	-0.171	0.409
Persimmon	0.322	0.156	-0.011	-0.517	0.034	0.598
Yucca	-0.220	-0.291	0.140	0.040	-0.192	0.253
Juniper	0.245	-0.187	-0.112	-0.430	-0.526	-0.207
Tasajillo	0.311	-0.533	0.067	-0.183	0.458	-0.244
Prickly pear	-0.015	-0.823	-0.042	0.040	0.349	0.014
Algerita	0.808	-0.320	0.013	0.209	-0.107	0.043
# shrub species	0.735	-0.638	0.030	0.056	-0.094	0.040
# .5-1 m shrubs	0.548	-0.731	0.064	0.165	-0.094	-0.125
# 1-2 shrubs	0.701	0.041	-0.077	-0.261	-0.028	0.434
% rock cover	-0.310	-0.788	0.097	0.100	0.183	0.236
% shrub cover	0.168	-0.323	-0.298	-0.249	-0.242	-0.412
% cactus cover	-0.320	-0.464	0.159	0.182	-0.018	0.240
% grass cover	-0.185	0.111	0.525	-0.434	-0.329	-0.103
% forb cover	0.179	0.042	-0.135	-0.108	0.723	0.165
% bare ground	-0.090	0.095	0.629	-0.157	0.066	-0.149
% water cover	-0.006	0.212	0.422	-0.121	0.202	-0.279
% wood debris	0.251	0.431	-0.610	0.421	-0.078	0.099
Average canopy 10 m	0.652	0.364	0.297	0.033	0.101	0.083
Average canopy 5 m	0.467	0.510	0.370	0.128	0.411	0.033
Canopy cover 0 m	0.513	0.183	-0.085	-0.084	0.128	-0.320
# of course woody	0.391	0.104	-0.401	0.055	-0.301	-0.025
Direction of opening	-0.268	0.171	-0.034	0.559	0.278	0.072

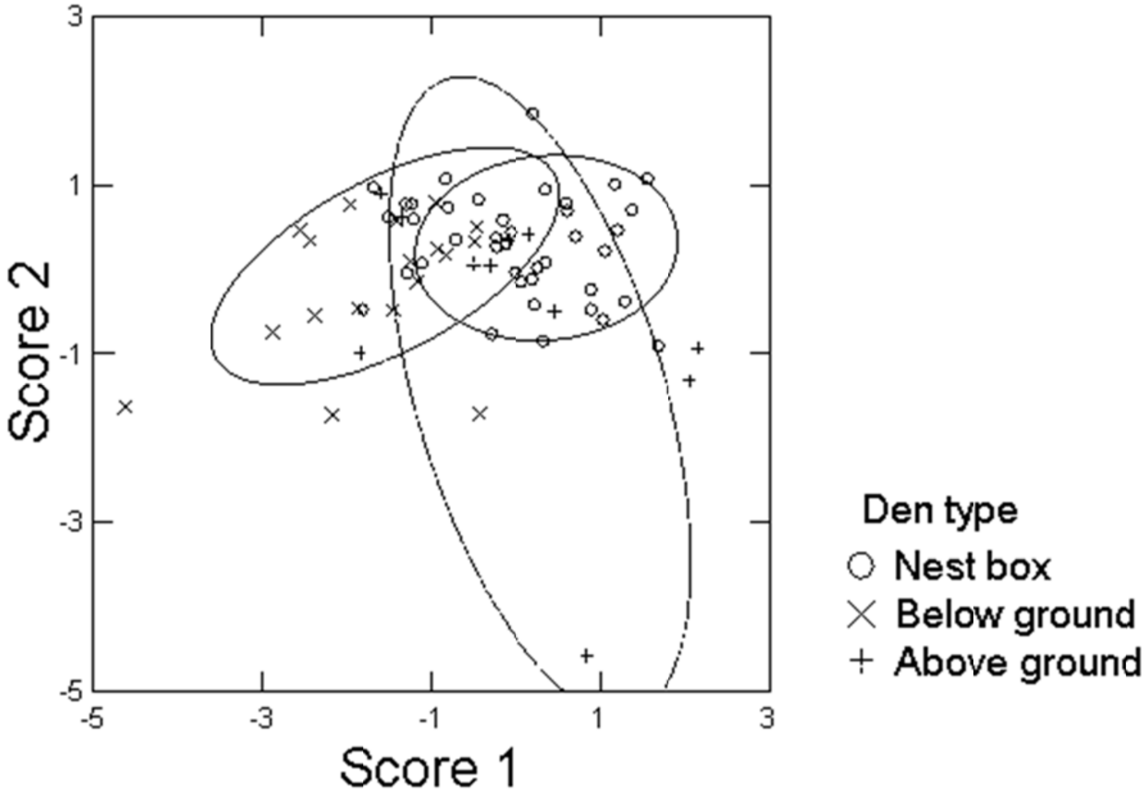

Fig. 10. The canonical score plot from the discriminant function analysis separating den type for *Bassariscus astutus* (n=286) based on habitat variables.

Table 3. Loadings from the discriminant function analysis on principal component factors derived from habitat variables for ringtail den site analysis.

PCA Factor	Score 1	Score 2
1	0.798	0.175
2	0.238	0.778
3	-0.700	0.357
4	-0.223	0.016
5	0.036	-0.582
6	-0.252	0.244

trifoliolata), number of shrub species, number of 1-2 m shrubs, and average canopy cover at 10 m. Number of large pecans (*Carya illinoinensis*), percent shrub cover, and number of course woody debris negatively affect factor 3 of the PCA scores.

Factor scores 2 and 5 had the most effect on the vertical axis. Factor 2 positively influenced, whereas factor 5 negatively influenced the plot. Factor 2 of the PCA scores was negatively affected by number of prickly pear cactus (*Opuntia* spp.), percent rock cover, and number of 0.5-1 m shrubs. The percent forb cover, number of tasajillos (*Opuntia leptocaulis*), and average canopy at 5 m positively affected factor 5 of the PCA scores.

In order to assess uniformity of den types, a jackknifed classification matrix was used. Nest boxes were correctly reclassified 70% of the time, below-ground dens 75% of the time, and above-ground dens 43%. The overall re-classification for den types was 68% (Table 4).

Seasonal denning habits were interpreted using Pearson's chi-square test. Den types were significantly different by season (χ^2=45.3, *df*=6, *P*<0.000). Analysis of den type and season by gender were significant as well. Female seasonal den type selection was significant (χ^2=37.0, *df*=6, *P*<0.000), as was that for males (χ^2=22.5, *df*=6, P<0.001).

Seasonal den type selection of all individuals (males and females combined) was not significant (χ^2=22.5, *df*=6, *P*=0.051). Females selected nest boxes more frequently in the winter and fall, and above-ground natural dens more in the summer months. Males showed the same high level of nest box selection in the winter and fall. Both genders had a more varied and balanced selection of den types in the summer months.

Table 4. Results from the jackknifed classification matrix section of the discriminant function analysis for den types selected by *Bassariscus astutus*. The actual (observed) are in rows and the re-classification presented in columns.

	Expected			
Classification Observed	Nest Box	Below-ground	Above-ground	% Correct
Nest box	139	43	25	70
Below-ground	11	40	2	75
Above-ground	15	5	15	43
Total	165	79	42	68

A concurrent student at Angelo State University began conducting dietary analyses on ringtail scats, as a side project of the habitat and den site selection of this study. His study required collecting scats from the tops of nest boxes and determining food items by major food type. Scat was determined to be ringtail based on location of deposition, size and segmentation patterns (Elbrock 2003). Scat was collected from the subset of nest boxes checked monthly. Scat was cleared from the tops of nest boxes in both riparian and upland habitats. Over the course of my study, presence and absence of scat was recorded by month. From these data, riparian nest boxes had deposits of scats (2 or more), indicative of establishment of a latrine, 33% of the time, whereas upland nest boxes had latrines 40%. Barja and List (2006) had shown that ringtails deposit latrines in areas that aid in scent dispersal as well as for visual markers for conspecifics. Both riparian and upland nest boxes had the highest percentages of scat during the spring (March – April). Upland boxes had evidence of a latrine 78% of the time (35 of 45 monitoring events), and riparian boxes had latrines 49% of the time. During the winter the percentages for both habitats of nest boxes saw the lowest percentages of scat deposition. Riparian and upland boxes in the winter (December – February) had evidence of latrines only 24 and 28% of the time, respectively. Only two boxes, 45W (upland) and M1 (riparian) had presumed ringtail scat present during all seasons.

DISCUSSION

Capture and Den Site Use

Nest boxes proved to be more useful in capture of ringtails than live traps. Capture success, not including recaptures or reuse during monthly monitoring of boxes, was 3.3% (13 of 390). Toweill (1976) captured 9 individual ringtails from April 1974 to June 1975, but did not report his trap success. Montacer (2009) reported capturing 28 individual ringtails a total of 37 times during 2,260 trap nights giving her a trap success of 2.9%, which included recaptures. Yarchin (1988) captured 6 individual ringtails a total of 90 times during 402 trap nights, for a trap success including recaptures of 20%. Yarchin documented trapping success to be highest in the spring (36%) and lowest in the summer (7.5%). Ackerson (2001) had a capture success of 5.2% over 983 total trap nights (17 new and 34 recaptures) using Havahart live box traps. The primary differences between other ringtail research and this study were the use of nest boxes. My trap success of 3.3% was comparable to that in other studies with the exception of Yarchin (1998). My study has shown the value of nest boxes as a means of capturing individuals and their importance for ringtail den sites.

Mortality, of ringtails in this study, either from collaring or natural causes, was higher than desirable, as 38% (5 of 13) died during the sampling period. Interestingly, all deaths were female ringtails (F1, F3, F4, F5, and F6) with duration of monitoring ranging from 39 to 178 days. Individual ringtails were radio-collared for durations ranging from 39 to 344 days, with a mean duration of 182 days. Because of high mortality efforts to radio-collar were terminated in the summer of 2009, and all efforts placed on habitat data collection. Nest boxes however were still checked for presence or absence of ringtails. Mortality reports are limited in ringtail telemetry studies. Montacer (2009) reported 8 of her 10 collared ringtails to have died, with survival periods ranging from 1 to 240 days. Ackerson (2001) reported 6 deaths, of her total 17 radio-collared ringtails, as a result of avian and mammalian predation, with 1 death of unknown origins for a population of ringtails studied at Elephant Mountain, Brewster County, Texas. Ackerson (2001) further reported that the highest number of deaths occurred in the spring. Other researchers make no mention of mortality in their research. Toweill (1976) followed 9 ringtails (5F, 4M) for periods ranging from 3 to 190 days, but did not address mortality. Ringtail longevity in the wild is not known, but captive raised ringtails can live for over 16 years (Poglayen-Neuwall and Toweill 1988). It is not clear whether ringtails are merely sensitive to the radio-collaring, if collars increase susceptibility to predation, or if they have a low survival rate in nature. It is interesting that all deaths in this study were female ringtails and there was no seasonal pattern with mortality.

If radio-collars contribute to increased mortality, a possible solution might be to have transmitters implanted. By having transmitters implanted, any obstruction the radio-collars present would be alleviated. This would allow the ringtails to more freely move between any available dens and potentially have greater predator avoidance. Montacer (2009) studied a ringtail population in Palo Duro Canyon State Park, Texas, and suggested the bulk of the radio-collar, and not the mass, likely increases susceptibility to predation by catching on small crevices and cavities ringtails utilize.

The radio-collars used in my study were below 3% of total mass, and would not have obstructed their entrance into nest boxes. One ringtail was found dead inside of box 45W and the collar retrieved. The cause of death in this case is not certain, as predator avoidance was likely obtained by occupying the box. All other documented deaths were ones in which the carcass was found via the radio signal to open areas on the ground approximately 200 m from the nearest nest box in most cases.

Thermal Profiles

The thermal ecology of an animal plays an essential role in understanding relationships with its environment. Ringtails are endothermic mammals that require large amounts of energy to fuel and maintain a stable body temperature (T_b). During the winter months the differences between T_b and ambient temperature (T_a) is the greatest, and in order to maintain a stable T_b, energy demand must increase. Other ways of compensating for the increased energy demands are through thermal avoidance, increased fur thickness, behavioral modification, and changing periods of activity (Glanville and Seebacher 2010). In order to decrease heat loss in the winter, an animal is likely to select a den site with a higher thermal profile to minimize heat transfer. Conversely, in the summer months when T_a rises, den site selection would be expected to shift to cooler den sites.

In my study, temperature sensor devices (iButtons) were used to remotely characterize known den sites compared to ambient environmental controls. No previous studies have analyzed thermal den characteristics in ringtails. Most recent studies have focused primarily on reptiles and small mammals (Davis et al. 2008, Glanville and Seebacher 2010, Toussaint et al. 2010). Roze (2009) recorded the thermal profiles both inside and outside two types of porcupine (*Erethrizon dorsatum*) dens. Roze (2009) reported that for a rock den the inside-outside temperature differential was 13 °C and for a hollow log it was 9.4 °C on two separate days. During this study, 12 nest boxes and 5 natural dens were analyzed from October 2008 – October 2009. Four environmental controls were placed equally in riparian and upland habitats, along with 2 in cactus patches.

Monthly averages revealed the thermal stability of the nest boxes compared to natural dens and controls. Nest box dens were consistently below the temperatures recorded for cactus patches during the warm periods of the year, yet above those of burrow nest systems. A shift in den site usage was seen for female ringtails in the summer months (June – August), as above-ground dens (tree cavities, hollow logs) were chosen more frequently than nest boxes. This is likely a result of the nest boxes warming faster than natural tree cavities, and thereby the thermal avoidance by ringtails. Males in the summer months also moved from the boxes to more below-ground dens (burrow systems). The thermal profiles of these two types of dens selected by female and male ringtails in the summer had average temperatures below those of nest boxes.

The disproportionate use of nest boxes, in all but the summer months, support the thermal benefits of the boxes, in addition to other beneficial factors such as predator avoidance, protection from the elements, and use as latrines for territorial markings. Upland and riparian nest boxes during the winter months had average temperatures 0.4 °C and 0.5 °C above T_a, respectively. Monthly temperature averages for natural dens were colder than nest boxes by 0.8 °C in the winter months. The major difference that is not evident from these monthly averages is the stability and lack of major variations in temperature seen hourly in natural dens, especially burrows, compared with nest boxes. Research on raccoon (*Procyon lotor*) dens conducted by Stains (1961) found that the temperature inside dens was slow to change in response to outside temperature changes. His research points out a time lag of 5.2 hrs for rising versus 3 hrs for falling temperatures inside of dens. This trend was also seen in my nest boxes, as they provided some degree of insulation to changing T_a in the winter.

In the summer months, ringtails avoided nest boxes (though use continued at a lower rate), instead utilizing below-ground and above-ground dens more often (Fig. 5). Riparian and upland nest boxes during the summer months were both on average 1.5 °C above T_a. Natural dens combined remained 0.9 °C cooler than T_a throughout the summer. Burrow system dens were the coolest of all den types in the summer with a seasonal average temperature of 26.8 °C, compared to the 28.5 °C seasonal T_a average, and above-ground dens averaged 28.6 °C in the summer. This shift to below or above-ground dens from nest boxes was documented for all radio-collared ringtails and continued until the beginning of the fall. The cactus patches were subjected to the largest temperature fluxes of any recording site. These sites averaged 1.9 °C above ambient for the duration of the summer, and were never used as den sites in this population of ringtails.

Den Site Selection and Habitat Analysis

Previous research on ringtail habitat selection has been included as a subset of an overall home range study, thereby, lacking any microhabitat description. Toweill and Teer (1980) studied ringtail home ranges and den habits in Kerr County, Texas. They found ringtails to use rock openings, hollow trees, and brush piles for 42, 34, and 24% respectively for all diurnal dens. Toweill and Teer (1980) further described the dens by percent composition of the 4 major plant communities on the study site, general description, and association of with other ringtails. Yarchin (1994) studied home ranges of ringtails in central Arizona, and found ringtails to disproportionately favored riparian vegetative communities. Yarchin speculated that ringtails avoid other habitat types that lack sufficient cover, consistent food sources, and denning areas.

The den site analysis portion of this study provided a specific description of the plant composition associated with den sites. The MANOVA found significant differences between den types in riparian and upland habitats (F=19.9, df= 6,2,283, P<0.000). This implies assortments of habitat variables are unique to each particular den type.

From the DFA score for PCA factor 1, and the horizontal axis of the DFA scores plot (Fig. 10), nest boxes had more canopy cover at 0 m, 5 m, and 10 m, and a higher amount of woody debris than above or below-ground den sites. From the DFA score for PCA factor 2, and the horizontal axis of the DFA score plot, below-ground dens had a higher percentage rock cover, number of shrubs 0.5 m to 1.0 m, and a higher number of prickly pear (*Opuntia* spp.). The vertical axis explains less discrimination than the horizontal axis on the DFA score plot. The DFA score for factor 5 of the PCA suggests sites towards the top of the score plot had a higher percentage of shrub cover, number of mesquites (*Prosopis glandulosa*), and number of junipers (*Juniperus* spp.).

Results from the jackknifed classification matrix reveal the uniformity of habitat variables from each den type. Overall 68% of dens utilized were correctly re-classified. Below-ground dens had a 75% correct re-classification. This is a result of the homogeneous habitat associations with such den types, as most burrows used had moderate canopy and shrub cover. Nest boxes were re-classified correct 70% of the time; primarily due to the fact most boxes had very similar canopy cover at 0 m, 5 m, and 15 m. Above-ground dens were only re-classified correct 43% of the time, ly a product of the varied habitats where such dens were located. Above-ground dens included tree hollows (both live and dead), hollow logs resting in open areas, and dense brush piles.

Throughout the checking of nest boxes from October 2008 – November 2009 scat was observed and recorded on boxes. Barja and List (2006) documented that ringtails deposited scat as a marker of territory and establishment of home ranges, and that scat is usually deposited in latrines (2 or more scats at a defecation point) with infrequent single scats on the margins of home ranges. They further reported that these latrines were deposited above-ground level, which likely increases scent dispersal and serve as visual markers towards other ringtails. From my monthly observations, it was rare to find a single scat on the top of a box with scat, and was equally as rare to find scat on boxes that previously had not been used as a latrine. Each month, boxes with scat were cleared of scat. From these observations, riparian nest boxes had evidence of ringtail latrines deposited 33.3% of the time, and upland boxes had a slightly higher percentage at 40%. It is likely that the nest boxes, owing to their height above-ground, aided in the scent dispersal of scat and served either as territorial establishment markers or possible means of maintaining social interactions. The higher percentage in upland habitats may perhaps be attributed to the accessibility of preferred resources and den sites in a less productive habitat area. As for riparian habitats, the somewhat lower percentage of latrine deposition might be conversely a result of the varied resources allotted ringtails in the area, as well as the higher percentage of naturally occurring resting sites. Infrequently scat was found at natural den sites, but when found, it was difficult to distinguish from other similar sized carnivores.

ECOLOGICAL AND MANAGEMENT IMPLICATIONS

The ringtail is an important mesocarnivore in much of western North America. Ringtails remain reasonably abundant in the proper habitats, but few, if any, studies have addressed population management in this species. This research has revealed that artificial nest boxes can be an important part of a management plan for ringtails.

Ringtails do not construct their own dens; instead, they utilize already available sites (Gerht 2003). They commonly use rock outcroppings and brush piles, as well as hollow trees and logs (Schmidly 2004). The overall selection for nest boxes in this study was 69% across all seasons for both male and female *Bassariscus astutus*, suggesting the importance of the nest boxes in this population.

The nest boxes certainly provide a safe-haven for ringtails in escape from other predators, as the arboreal placement of the box, in addition to the diameter of the entrance would limit most ringtail predators. The thermal benefits to the nest boxes are also noticeable, especially in the fall, winter, and spring. Nest box thermal profiles revealed insulation properties, which likely play a role in their marked preference. With the exception of burrow systems and natural tree hollows, nest boxes were cooler in the spring and summer and warmer in the fall and winter compared to ambient temperatures. Furthermore, nest boxes likely serve as windbreaks, especially in open areas. Ackerson (2001) found that all ringtail dens studied were facing down the slope of steep canyon walls. This might explain any wind damping effects that the nest boxes afford ringtail den site selection. Another issue that merits further consideration is the proximity of nest boxes to available natural den sites. The nest boxes likely serve to supplement the number of natural den sites available. If natural den sites are limited in an area, ringtail populations might increase with available nest boxes, as seen in previous studies of other mammals (Lindenmayer et al. 2009). Lastly, the nest boxes likely aid in the establishment of territories through the fecal marking evidence apparent from monthly observations. This marking behavior might likely further aid ringtails in the maintenance of certain aspects of social structure (Barja and List 2006). Whether for predator avoidance, thermal stability, or social interactions, the nest boxes grant ringtails some ecological benefit.

The establishment of co-denning in ringtails was well documented in this study, occurring nearly 12.9% of the time (37 of 286). Same gender sharing of den sites occurred in 5 of the 37 (13.5%) documented observations, whereas mixed gender co-occupancy was found in 32 of 37 (86.5%) of the total co-occupancy events. Toweill and Teer (1980) reported solitary ringtail denning in all 268 observations of dens in their study. Adult ringtails are reported to den alone, with the exception of females denning with their kittens (Taylor 1954). The sharing of dens by members of the same gender could be attributed to familial relatedness, an increase in predator defense, or provide some thermal benefit. Mixed gender co-denning likely aids in the establishment of pair bonds. Den sharing was frequent through the year, and did not appear to be influenced by season. Only two times during this study did ringtails co-occupy dens other than nest boxes.

Den fidelity was obvious for nest boxes in the spring, fall, and winter. Female F2 was found to be loyal to a small number of riparian boxes; revisiting three previously used boxes 51% of the time. In early June 2009, F2 shifted usage to five different tree cavities located via radio-tracking. This shifting pattern towards natural dens was seen for the majority of female ringtails, and possibly is related to parturition and natal den selection, which occurs from May through June (Poglayen-Neuwall and Toweill, 1988). Female F7, used nest boxes 60% over the course of this study, and shifted towards snags and burrow systems in late May 2009. Females F5 and F6, were both found to utilize previously visited nest boxes 100% of the time. Males in general shifted usage patterns to log piles and rock dens slightly earlier than females, with the earliest shift from nest boxes occurring in early March of 2009. Throughout this study however, both genders of ringtails would sporadically utilize nest boxes in the summer, but never twice in a particular month. They would instead be found using a small selection of natural dens on numerous occasions. The repeat usage of dens was prominent was well, as roughly 36% of dens were revisited. Toweill and Teer (1980) found ringtails seldom reuse dens, except during extreme weather.

No ringtail that was captured, in either a riparian or upland nest boxes, was ever found shifting habitats. Those denning in riparian zones were never found in uplands, and those in uplands stayed in that habitat. There did not appear to be a seasonal habitat influence on den site selection. Perhaps, the aforementioned benefits of the nest boxes merely out-weighed any seasonal habitat benefit such as food availability, percentage of cover, or thermal stability.

Future Research

The findings from this research lead to several possible avenues for future ringtail research. First, future research should investigate the usage of implanted radio-transmitters into the body cavities of ringtails to determine whether the collar itself is the cause of higher mortality. This practice would enable future researchers of ringtails and similar sized animals to have a base line of comparison between externally and internally positioned radio-transmitters. The cost of such procedures must also be addressed, as they require the aid of a veterinarian. To take the animal away from its natural environment might also affect the social structure and territorial maintenance by the removal of the animal, as this process of surgical implantation requires the animal be kept under observation days after the procedure.

Another possible means of improvement is directed towards the use of data-loggers. The placement of thermal sensors in this study, were in previously known ringtail dens, and the number of devices was limited. Information on time of entrance and departure could only be verified through radio-tracking, as non-target animals, such as the Eastern fox squirrel (*Sciurus niger*) are inhabitants of the study area, and would not be excluded from entrance of nest boxes by size alone. These animals could change the temperature inside of a thermally monitored nest boxes by their presence. At one point in this study, a fox squirrel was captured and placed inside a nest box under laboratory conditions to detect the squirrel's thermal influence. The highest temperature induced by the squirrel was approximately 32 °C. These diurnal non-targets, however exhibit different periods of activity and would likely cause temperature increase during the nocturnally active hours of ringtails. Ringtails have been documented as having body temperatures of 37.6 °C (Chevalier 1984; Mugaas et al. 1993). From this information, coupled with the times of resting for ringtails, it would be feasible to assume that if more data-loggers were placed in all known nest box den sites located in this study, future researchers could more accurately determine seasonal nest box usage. Another possible problem with the data-loggers experienced in this study, was found during the summer months when the devices consistently recorded daily temperatures well above ringtail body temperature. It proved impractical to determine ringtail occupancy from thermal profiles alone. Another solution would involve selective programming of data-logging devices to initiate recording 1 to 2 hours before sunrise and cease sampling before the mid-day heat in the summer. Overall, the use of thermal sensors in nest boxes has revealed insights into thermal den preferences for ringtails, but future research is needed to determine seasonal activity patterns using thermal data-loggers.

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Appendix I. Geo-referenced locations of 84 nest boxes found on study area near Knickerbocker, Tom Green and Irion Counties, Texas.

Name	Latitude	Longitude
BOX 04W	31.22912	-100.70750
BOX 05W	31.23043	-100.70789
BOX 06W	31.22897	-100.71243
BOX 07W	31.23111	-100.71210
BOX 09W	31.23233	-100.71585
BOX 1W	31.21921	-100.71130
BOX Z8	31.21513	-100.70052
BOX 10	31.21929	-100.70323
BOX 10W	31.24012	-100.70773
BOX 11	31.21941	-100.70446
BOX 11W	31.24301	-100.70210
BOX 12	31.22161	-100.70873
BOX 12W	31.24045	-100.69889
BOX 13	31.22155	-100.70973
BOX 13W	31.23978	-100.70046
BOX 14W	31.24368	-100.70546
BOX 15W	31.24532	-100.70659
BOX 16	31.21957	-100.70108
BOX 16W	31.24510	-100.70919
BOX 17	31.22165	-100.69944
BOX 17W	31.24555	-100.70440
BOX 18	31.22308	-100.69927
BOX 18W	31.24739	-100.70670
BOX 19	31.22406	-100.69951
BOX 19W	31.24833	-100.70599
BOX 1W	31.21920	-100.71127
BOX 20	31.23020	-100.68899
BOX 20W	31.24814	-100.70428
BOX 21	31.22995	-100.68980
BOX 21W	31.24997	-100.70522
BOX 22	31.22935	-100.69568
BOX 22W	31.25024	-100.70262
BOX 23W	31.23715	-100.71982
BOX 24W	31.24606	-100.71500
BOX 25W	31.24520	-100.71379
BOX 26W	31.25133	-100.71957
BOX 28W	31.25021	-100.71656
BOX 29W	31.26024	-100.71769
BOX 2W	31.22322	-100.71454
BOX 30W	31.26052	-100.71403
BOX 33W	31.24466	-100.68423
BOX 34W	31.24485	-100.68689
BOX 39W	31.25050	-100.70201
BOX 3W	31.22508	-100.70968
BOX 41W	31.24594	-100.68253
BOX 43W	31.24698	-100.68480
BOX 44W	31.24722	-100.68744
BOX 45W	31.24799	-100.68737
BOX 47W	31.27438	-100.66803
BOX 4W	31.22920	-100.70766
BOX 50W	31.26988	-100.66911
BOX 5W	31.23046	-100.70806
BOX 6	31.20660	-100.70612
BOX 6W	31.22883	-100.71224
BOX 7	31.21017	-100.70207
BOX 7W	31.23113	-100.71217
BOX 9W	31.23228	-100.71586
BOX B	31.24267	-100.67533
BOX C	31.24473	-100.67364
BOX E	31.24668	-100.66937
BOX F	31.24734	-100.66845
BOX G	31.24905	-100.66620
BOX H	31.25270	-100.66244
BOX H1	31.25038	-100.66398
BOX I	31.25180	-100.66342
BOX J	31.25265	-100.66213
BOX M	31.25400	-100.66099
BOX M2	31.25490	-100.65977
BOX R1	31.25577	-100.66066
BOX R10	31.25831	-100.64284
BOX R2	31.25537	-100.65763
BOX R3	31.25690	-100.65595
BOX R4	31.25712	-100.65495
BOX R5	31.25783	-100.65281
BOX R6	31.25810	-100.65093
BOX R7	31.25840	-100.64890
BOX R8	31.25858	-100.64766
BOX R9	31.25867	-100.64460
BOX HS	31.24622	-100.67124
BOX X	31.25348	-100.65979
BOX X3	31.24279	-100.67649
BOX Z	31.25555	-100.69555
BOX Z10	31.21160	-100.70101
BOX Z11	31.20776	-100.70454

Appendix II. Monthly average thermal profiles for upland nest boxes, December 2008 - October 2009, Tom Green and Irion Counties, Texas (Au1 and Au2 represent ambient upland controls).

Den	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct
19W	9.2	10.4	14.3	16.4	20.0	24.0					
20W	9.5	10.0	14.2	16.3	20.2	23.7	29.0	29.0	29.5	23.1	19.6
40W	9.2	9.8	14.1	16.2	19.6	23.7	28.9	29.2	29.1	23.2	20.5
41W	9.6	9.4	13.6	16.4	19.7	24.3	30.0	30.9	29.5	23.4	20.5
43W	10.7	10.1	13.7	16.5	20.0	23.4	28.8	29.1	29.1	23.2	20.0
45W	10.4	12.3	14.8	17.5	21.2	24.0	28.6	30.2			
Au1	9.1	10.3	14.1	9.8		24.5		27.2	29.4	23.6	19.9
Au2	9.2	9.9	13.9	16.4	19.7	23.8	28.9	28.9	29.1	22.9	19.6

Appendix III. Monthly average thermal profiles for natural dens and cactus patches from November 2008 - October 2009, Tom Green and Irion Counties, Texas.

Den	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct
Burrow 1	15.5	10.9	9.7	11.2	13.4	15.8	21.2	25.0	27.1	27.2	22.8	19.9
Burrow 2	15.6	10.1	10.0	13.4	15.8	18.8	21.7	26.6	26.2	28.6	23.6	20.3
Cactus 1		8.6	10.9	13.3	17.0	20.7	25.7	31.7	29.6	30.8	23.3	18.1
Cactus 2		9.8	8.9	12.8	17.4	20.3	24.6	29.6		30.3	23.0	19.9
Rock		10.5	9.9	13.3	16.6	25.0	27.5	30.3	29.7	30.5	24.3	21.3
Snag		8.8	9.3	13.4	15.9	19.6	24.1	28.2	28.6	28.9	24.5	21.9
Woodpile		8.9	8.9	11.9	15.0	16.8	21.7		24.4	25.9	21.4	19.4

Appendix IV. Monthly average thermal profiles for riparian nest boxes from October 2008 - October 2009, Tom Green and Irion Counties, Texas (Ar1 and Ar2 represent ambient riparian controls).

Den	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct
M1	21.1	14.9	9.6	9.2	14.2	16.8	21.4	23.8	28.7	28.6	28.6	22.7	19.9
M2			8.7	8.7	9.8	16.4	20.0	23.7	28.5	28.2	28.2	22.6	19.9
R1			9.4	9.8	13.7	16.2	19.9	23.8	28.7	28.8	28.9	23.4	20.3
R2	21.8	14.7	9.4	9.5	13.8	16.5	20.4	24.2	29.2	29.3	29.3	23.8	20.7
R5	21.7	16.5	9.8	9.7	13.8	16.3	20.1	24.2	28.5	28.8	28.8	23.6	20.8
R6	21.4	15.3	9.4	9.4	13.9	16.5	20.1	24.1	28.6	28.6	28.8	23.2	20.1
Ar1			9.2	10.4	15.1	17.6	20.8	23.7	27.7	28.0	27.8	22.7	20.4
Ar2			8.5	9.1	13.4	16.1	21.2	22.8	28.2	28.7	28.8	23.3	20.3