USING MOTION-TRIGGERED CAMERAS TO ESTIMATE

HABITAT USE BY COLLARED PECCARIES

THESIS

Presented to the Graduate Council
of Texas State University-San Marcos
in Partial Fulfillment
of the Requirements

for the Degree
Master of SCIENCE

by

Meredith P. Longoria, B.S.

San Marcos, Texas
December 2004

ACKNOWLEDGEMENTS

First, I thank Texas State University-San Marcos, and Texas Parks and Wildlife Department for providing funding. I thank Dr. Butch Weckerly, my thesis advisor, for his guidance, patience and assistance in the field, and for giving me the opportunity to chase elk in the Redwoods. I thank Dr. Randy Simpson for inspiration, guidance, and for forcing his Vertebrate Natural History class to help me set up my camera stations. I thank Dr. Jim Ott for taking a leap of faith by agreeing to serve on the graduate committee of a complete stranger, and for his advice.

Thanks to everyone at Chaparral Wildlife Management Area, especially Chip Ruthven, Jim Gallagher and David Synatzke, for allowing me access to the property and facilities, and for their patience, assistance and advice. Thanks to Dr. Tim Gabor who graciously sent me his peccary telemetry data.

Thanks to everyone who assisted me in the field, especially the students in Dr. Simpson's Vertebrate Natural History class (summer 2003) who sacrificed blood, sweat and tears. I thank my family for providing endless encouragement, love and support. I especially thank my husband who made many sacrifices for me over the last 2 years so that I could return to school. I also thank Stephanie Shelton and Deena Francis for helping with GIS, and soon-to-be-Dr. Todd Swannack for his indispensable advice.

This project is registered with and certified by the Institutional Animal Care and Use Committee (Approval No. NbdaWY03).

This manuscript was submitted on November 12, 2004.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

USING MOTION-TRIGGERED CAMERAS TO ESTIMATE HABITAT USE BY COLLARED PECCARIES

By

Meredith P. Longoria, B.S.

Texas State University –San Marcos

December 2004

SUPERVISING PROFESSOR: FLOYD W. WECKERLY

Motion-triggered cameras (MTC) are used in a variety of wildlife research applications; however, few studies outline how to use MTC to collect reliable data on habitat use. Herein I outline how to use MTC for collecting reliable data on habitat use of collared peccaries (*Pecari tajacu*). Using MTC to measure habitat use of collared peccaries or other group-living ungulates is appealing because MTC can be used in a variety of environmental conditions, less time and effort is required to collect data than more commonly used methods, and unlike radio telemetry MTC can accommodate group size information. Group size may influence habitat use. I examined four issues that affect the reliability of MTC data: (1) the number of cameras needed to photograph collared peccaries at unbaited camera stations, (2) whether peccaries were alarmed by the presence of MTC, (3) the minimum distance needed between camera stations to obtain independent data, and (4) the proportion of landscape occupied by peccaries at 1, 2, 3,

and 4-week intervals in order to estimate the probability of peccaries visiting unbaited camera stations. Four camera stations were established, each with 4 MTC positioned so that pairs of cameras were facing each other and perpendicular to the other pair of cameras. The study was conducted at Chaparral Wildlife Management Area (CWMA) in south Texas from March – November 2003. Two camera stations were established in closed-canopy habitat and 2 were established in open-canopy habitat. The influence of the number of MTC per station, habitat type (closed versus open canopy) and diel period on the number of peccaries counted in photographs and number of photographs taken across 7 consecutive 4-day time intervals was compared among camera stations using repeated measures analyses of variance. I did not detect a greater number of peccaries, relative to the number of cameras, with >1 camera per station, and neither closed-canopy habitat nor photographs taken in the dark with a flash resulted in fewer peccaries counted or fewer photographs of peccaries taken. No avoidance or alarm response was associated with MTC as there were no differences in alarm behavior, number of peccaries counted in photographs, or number of photographs of peccaries taken at camera stations over 7 consecutive 4-day time intervals. The estimated maximum diameter of peccary home ranges calculated from telemetry data gathered at CWMA in 1994 and 1995 was 1.8 km. I surveyed 90 sign stations (0.25 ha circular plots) each week over 2 11-week sampling episodes for the presence of 0-4 day-old peccary sign (tracks, feces). From this data I estimated that peccaries occupied 25-50% of the landscape within 1-week intervals, 70-80% within 2-week intervals, >80% within 3- and 4-week intervals. Therefore, I recommend that stations have 2 opposite-facing cameras to insure that all peccaries are photographed and that camera stations at CWMA are ≥1.8 km apart to collect independent data.

INTRODUCTION

The use of motion-triggered cameras (MTC) in wildlife studies has increased over the last 20 years (Seydack 1984, Mace et al. 1994, Fridell and Hovingh 1995, Jacobson et al. 1997, Sweitzer et al. 2000, Long et al. 2003). MTC have been used to study nest predation, presence of species, activity and behavior patterns, population monitoring, feeding ecology and habitat use (Cutler and Swann 1999). A number of studies have provided guidelines for using MTC to estimate population size and detect presence of a variety of wildlife species (Bull et al. 1992, Kucera and Barrett 1993, Foster and Humphrey 1995, Koerth and Kroll 2000, York et al. 2001, Harrison et al. 2002). However, there are no guidelines that outline how to use MTC to collect reliable data on habitat use.

Currently, radio telemetry is one of the most widely used methods for gathering information on habitat use (White and Garrott 1990). Drawbacks of using radio telemetry include time-intensive field work, and expensive equipment and supplies (Bookhout 1996). In order to attach radio-transmitters, animals must be trapped, handled and sometimes sedated. Also, the morphology of some animals, such as the collared peccary (*Pecari tajacu*), does not facilitate attachment of transmitters with collars and instead may require surgical procedures to implant transmitters (Ilse and Hellgren 1995a, Gabor and Hellgren 2000). More importantly, analyses of habitat use data require independent observations (Swihart and Slade 1985, White and Garrott 1990, Bookhout

1996, Hansteen et al. 1997). However, radio-tagging more than 1 individual per group violates the requirements of independence because the movements of individuals within a group may be coordinated. Telemetry studies do not provide information on group size or local abundance of conspecifics. However, group size or local abundance may be a factor influencing habitat use (Thirgood 1996, Coulson et. al. 1997, Payer and Coblentz 1997, Borkowski 2000, Gabor and Hellgren 2000, Kiefer and Weckerly *In Press*). Most studies that included group size information in habitat-use studies of group-living ungulates used direct observation (Ilse and Hellgren 1995a,b, Thirgood 1996, Cutler and Swann 1999, Gabor and Hellgren 2000, Gabor et al. 2001). Direct observation is time and labor intensive, and animals may not be detected as a result of obstruction by terrain and dense vegetation (Bookhout 1996).

Herein, I develop guidelines for using MTC to gather data on habitat use in collared peccaries (hereafter peccaries) without baiting. Most methods describing the use of MTC in wildlife studies have suggested baiting to increase likelihood of animals visiting camera stations, or to increase likelihood of detecting all animals in the surrounding area on film (Kucera and Barrett 1993, Jacobson et al. 1997, Koerth et al. 1997, Sweitzer et al. 2000, York et al. 2001, Harrison et al. 2002). However, baiting camera stations in habitat use studies might bias data by attracting animals to habitat that might not normally be used (Bull et al. 1992, Mace et al. 1994, Bookhout 1996, Cutler and Swann 1999). Peccaries were chosen as the subject animal to explain use of MTC because they are group-living, are active day and night, and inhabit densely vegetated landscapes where they are difficult to observe. One advantage of using MTC is that group size information can be obtained from photographs and included in habitat use estimates. However, in order for MTC to be effective, 1) accurate group size estimates from photographs are needed, 2) minimum distance between camera stations must be determined to maintain independence, 3) camera stations should not influence habitat use patterns, and 4) estimating the likelihood that camera stations will be visited by peccaries would be useful. The possibility that some individuals will not be visible in photographs has not been examined. Often only one MTC is used per station (Seydack 1984, Kucera and Barrett 1993, Hernandez et al. 1997, McCullough et al. 2000, Sweitzer et al. 2000, Martorello et al. 2001). It is possible that some animals will not be counted as a result of obstruction from camera view by vegetation or conspecific animals, reduced visibility in dark conditions, or due to behavioral response of animals to cameras (Seydack 1984, Hernandez et al. 1997, Karanth and Nichols 1998, Cutler and Swann 1999, Wegge et al. 2004). Distance between camera stations should be governed by movement patterns of peccaries to reduce likelihood of photographing the same peccaries at adjacent, simultaneously-operating camera stations (Swihart and Slade 1985, White and Garrott 1990, Bookhout 1996). This would allow data collected among camera stations to meet the condition of independence, which is required of many statistical procedures used to analyze habitat use and selection data (Swihart and Slade 1985, White and Garrott 1990, Bookhout 1996). Moreover, it would be useful to provide investigators with an estimate of how frequently unbaited camera stations are likely to be visited by peccaries. Assessing the proportion of the landscape (study area) occupied by peccaries over time should provide investigators with a rough estimate of the proportion of unbaited camera stations visited by peccaries.

Consequently, my objectives were to: (1) determine how many cameras were needed per station, (2) assess whether peccaries were alarmed by the presence and operation of MTC, (3) determine distance between camera stations needed to reduce the possibility of photographing the same animals in adjacent, simultaneously-operating stations, and (4) estimate the proportion of landscape occupied by peccaries at 1, 2, 3, and 4-week intervals.

STUDY AREA

Research was conducted on the 61.5-km^2 Chaparral Wildlife Management Area (CWMA), in Dimmit and LaSalle Counties, Texas (Figure 1). CWMA is located in the South Texas Plains ecological region (Hatch et al. 1990). Common woody species included honey mesquite (*Prosopis glandulosa*), prickly-pear (*Opuntia lindheimeri*), acacias (*Acacia* spp.), whitebrush (*Aloysia gratissima*), hog-plum (*Colubrina texana*), brasil (*Condalia hookeri*), spiny hackberry (*Celtis pallida*), and Texas persimmon (*Diospyros texana*). Common herbaceous species included croton (*Croton* spp.), partridge pea (*Chamaecrista fasciculata*), coreopsis (*Coreopsis nuecensoides*), Lehmann lovegrass (*Eragrostis lehmanniana*), fringed signalgrass (*Brachiaria ciliatissima*), hairy grama (*Bouteloua hirsuta*), and hooded windmill grass (*Chloris cucullata*). The landscape consisted of a variety of habitat types ranging from areas with 100% woody canopy cover to open areas with as little as 0% canopy cover composed mainly of grasses and other herbaceous species (Gabor et al. 2001). Five major habitat types identified by Gabor and Hellgren (2000) were mesquite-prickly-pear (45.1% of CWMA), mesquite-mixed brush (31.8%), mesquite-prickly-pear-whitebrush (10.8%), mesquite-whitebrush (8.5%), and mixed brush. The climate was characterized by hot, dry summers and mild winters with an average daily high in July of 37°C, and an average daily low in January of 5°C (Stevens and Arriaga 1985). Average (± SD) annual precipitation was 64 ± 22 cm

(Hellgren et al. 1995). Topography was flat to gently rolling with elevations of 145-206 m. Peccary density at CWMA was an estimated 9.7 peccaries/km^2 (Gabor et al. 2001).

METHODS

Camera Surveys

Four camera stations were established ≥1.6 km apart. Each camera station consisted of a circular, 18-m diameter plot with 4 DeerCam® DC-100 scouting cameras (Non Typical Inc., 860 Park Lane, Park Falls, WI 54552). Pairs of cameras were positioned 18 m apart facing each other and perpendicular to one another (Figure 2). Cameras were spaced 18 m apart because DeerCam DC-100 is sensitive to motion within that distance. The DeerCam DC-100 uses a passive infrared sensor to trigger an automatic 35mm Olympus® Infinity camera (Olympus America Inc., Two Corporate Center Drive, Melville, NY 11747) to take a photograph when an animal enters the detection zone. The infrared sensors in the MTC detect both motion and temperature differences. The detection zone (area an animal must enter to trigger the camera) is cone-shaped and extends 6-18 m from the MTC, depending on ambient air temperature (sensitivity decreases with increasing air temperature). Because the average maximum daily temperature in July at CWMA was >29°C, camera sensitivity was set to high (the most sensitive setting) as recommended by the manufacturer. DeerCam DC-100 were chosen because they were less costly than other MTC, and they lacked external cables susceptible to animal damage (Hernandez et al. 1997, Sweitzer et al. 2000). MTC were mounted on wooden blocks that were attached firmly to metal t-posts driven into the ground to avoid accidental repositioning of cameras by strong wind or animals

(Hernandez et al. 1997). MTC were attached to metal t-posts at a height of approximately 25-30 cm from ground level, slightly below average peccary shoulder height, so that peccaries would activate cameras upon entering the detection zone (Lochmiller 1987, Karanth and Nichols 1998, Sweitzer et al. 2000). Tall grasses and low tree limbs that might move in the wind and trigger cameras were trimmed or removed. In order to maximize number of photographs of peccaries, camera stations were located on the east side of CWMA where sign was frequently detected during the first 11 sign surveys (see below). Many photographs of peccaries were needed to assess accuracy of group size estimates at camera stations. One station was baited once with corn approximately half-way through the study due to low numbers of photographs. Corn was used as bait since staff at CWMA noted that peccaries were frequently attracted to areas baited with corn. Two stations were placed in areas with dense woody vegetation with closed canopy (closed habitat), and two were placed in areas with open canopy (open habitat) with less-dense woody vegetation to examine possibilities of vegetation obstructing peccaries from camera view (Figure 3). MTC were loaded with 400 ISO, 24-exposure DX-coded film and programmed for a 2-min delay between photographs. 400 ISO film was used in order to facilitate maximum flash range. Cameras were programmed to record day, month, and time of exposure on each photograph. Cameras were active for 28 days (3-30 August 2003) and were examined every 4 days to ensure cameras were operational and to replace film. This portion of the study took place in August due to high temperatures which may reduce camera sensitivity and thereby increase error in detecting peccaries by reducing the number of peccary photographs obtained.

To determine the number of cameras needed per station, several analyses were performed. I first used repeated measures analysis of variance (RM ANOVA) to compare the number of photographs of peccaries, and number of peccaries counted in photographs taken by 1 camera, 2 opposite-facing cameras, 2 adjacent-positioned cameras, 3 cameras and 4 cameras per station (Zar 1996, Quinn and Keough 2002, Figure 2). The cameras at each station representing 1 camera, 2 opposite-facing cameras, 2 adjacent-positioned cameras, and 3 cameras in the analyses were randomly chosen. The number of photographs of peccaries were calculated by counting the number of photographs of peccaries taken by 1 camera, 2 opposite-facing cameras, 2 adjacent-positioned cameras, 3 cameras, and 4 cameras (each calculated separately) and dividing each of those values by the number of cameras (for comparing results of having 1 or more cameras per station), and by the number of days (4) in each of 7 time intervals. Data for response variables were examined in 4-day intervals to accumulate photographs of peccaries. Number of peccaries counted in photographs (hereafter peccaries counted) were calculated by dividing the total number of peccaries counted in photographs by the number of cameras, and 4 (time interval). In this RM ANOVA camera station was the repeated unit and was crossed with fixed factors of number of cameras (5 levels), time interval (7 levels), and habitat (2 levels).

A second series of 3-factor RM ANOVA was performed to test for the influence of diel period on the number of photographs and peccaries counted. Interference caused by flashes from opposite-facing cameras firing simultaneously, or decreased visibility in the dark, even with a flash, could result in fewer photographs of peccaries or fewer peccaries counted in photographs taken in the dark versus the daylight (Karanth and

Nichols 1998). Camera station was again treated as subject factor, crossed with number of cameras, time interval, and diel period as fixed factors. Habitat was not included as a factor (see Results) because habitat type did not significantly affect number of photographs or peccaries counted as determined by the first series of 3-factor RM ANOVAs. A sequential Bonferroni procedure was used to adjust significance levels ($P < 0.025$) in order to reduce Type I error rates resulting from multiple tests on the same family of data (Zar 1996, Quinn and Keough 2002).

To determine whether peccaries triggered more than one camera at the same time upon entering a station, the proportion of peccary photographs taken by more than one camera per station in ≤10 min., ≤5 min., and ≤2 min. intervals were calculated. If multiple cameras in a station were triggered simultaneously by peccaries it may be possible to more accurately assess herd size by comparing photographs of the same herd from more than one angle.

The alarm behavior of peccaries in photographs was assessed to determine whether camera activity scared peccaries away which could lead to a systematic bias in estimates of habitat use. Peccaries display bristling (alarm posture) when threatened or startled by raising the stiff hairs along their dorsum, especially within the collar region near the base of the head (Schweinsburg and Sowls, 1972). I measured alarm behavior based on the extent of bristling and number of peccaries running away from cameras. Each photograph was assigned an alarm rank of 0 for no peccaries with bristles raised or running, 1 for ≥1 peccary with bristles partially raised, 2 for ≤50% of peccaries with bristles fully raised, 3 for >50% peccaries with bristles fully raised, 4 for ≤50% running with bristles raised, and 5 for >50% running with bristles raised. Differences in alarm rank of peccaries in photographs taken across the 7 time intervals and by habitat were examined using another RM ANOVA. Camera station was again treated as the repeated unit and crossed with habitat and time interval. Diel period was not be included as a factor in the RM ANOVA since there were no photographs of peccaries taken in daylight at 1 of the camera stations. Instead, differences in alarm rank of peccaries in photographs taken in the dark versus daylight were explored using a randomization test of a 2-sample *t* test because the assumption of independence was not met (Quinn and Keough 2002). Residual plots were examined for each of the above RM ANOVAs conducted, and assumptions of normality and similar variances were met.

Distance Between Camera Stations

To determine distance needed to maintain sample independence between MTC stations, (i.e., reduce the possibility of photographing the same animals in adjacent stations), I analyzed home range data gathered in 1994 and 1995 (Gabor and Hellgren 2000) from radio-tagged peccaries at CWMA. Gabor and Hellgren (2000) used the 95% adaptive kernel method to estimate home range size (Worton 1989, 1995, Kernohan et al. 1998). I examined home range size by fall-winter and spring-summer, and by east and west side of CWMA because Gabor et al. (2001) noted that peccary home range size was larger in fall-winter ($F_{3,85} = 4.25$, $P = 0.008$), and on the west side of CWMA ($F_{1,23} = 27.01$, $P < 0.001$) where feral pigs (*Sus scrofa*) are sympatric with peccaries. I used the diameter of the mean home range size as an estimate of the minimum distance required between camera stations to obtain independent data (Swihart and Slade 1985, White and Garrott 1990, Bookhout 1996).

Sign Surveys

Ninety sign stations were established at CWMA and distributed as uniformly as possible (Figure 1). The number of sign stations was determined based on the maximum number of stations that could be surveyed within 2 days. To maintain similarity in size to camera stations, sign stations were circular plots 25 m in diameter. Mean straight-line distance between adjacent stations was 0.61 ± 0.10 km (range: 0.28 - 1.03 km, $n = 90$). Sign surveys were conducted weekly (5-7 days apart) for 11 consecutive weeks in the spring (March 29 - June 6) and 11 consecutive weeks in late summer and fall (August 23 - November 1). Two separate 11-week surveys were conducted because Gabor et al. (2001) noted distinct differences in peccary home range size between spring-summer ($\bar{x} = 1.12 \pm 0.84$ km^2) and fall-winter ($\bar{x} = 1.46 \pm 0.98$ km^2) at CWMA. Each survey, stations were examined on foot for presence or absence of recent (0-4 day-old) collared peccary sign (tracks, scat, browse marks on forage, and scent marks). Peccary sign 0-4 days old was categorized as recent because that time interval would allow recent distribution of peccaries to be measured with a low rate of misclassifying sign age (Weckerly and Ricca 2000). Age of sign was determined by comparison with sign of known age. Peccary tracks were distinguished from feral pig and white-tailed deer (*Odocoileus virginianus*) tracks based on size and shape. Not only are white-tailed deer and feral pig tracks usually larger than peccary tracks, but feral pigs have two dewclaws on their hind limbs whereas peccaries have only one, and white-tailed deer tracks have a different shape. Data from sign surveys were used to determine the proportion of the landscape occupied by peccaries at 1, 2, 3 and 4-week intervals during spring and summer-fall to provide investigators with an estimated probability of peccaries visiting unbaited camera stations. I noticed during the course of conducting sign surveys that when rainfall occurred ≤4 days prior to surveys, sign was detected at fewer stations. To evaluate whether recent rain influenced sign detection, I regressed the amount of precipitation (in cm) which occurred ≤4 days prior to each sign survey to a mean proportion of stations with sign. The mean proportion of stations with sign was calculated from 3 sets of sign stations (n =18 for each) so that adjacent stations were far enough apart to maintain independence of sign data. Each set of stations included only those stations which had not yet been included in any other set. Data was log transformed to meet the assumption of similar variances (Zar 1996, Quinn and Keough 2002). An inverse relationship would indicate that less sign was detected with more rain. Such a relationship was detected, therefore 3-4 adjacent stations were grouped together to increase likelihood of finding sign at stations and to collect independent data.

RESULTS

Across the 28 days, 966 photographs of 17 different species were taken (Table 1). The proportion of photographs of peccaries, white-tailed deer, other mammals, and birds was 0.31, 0.26, 0.12, and 0.11, respectively. The remaining photographs were of people, vehicles, or nothing discernable. Peccaries were detected at each station an average of 50.9% of the 28 days.

Number of Cameras Per Station

There was no difference in number of photographs taken by 1, 2 opposite-facing, 2 adjacent, 3 or 4 cameras, across time intervals (TI), or by type of habitat (Table 2). No second or third order interactions were detected (Table 2). The mean number of photographs of peccaries taken per camera each day was 0.71 ± 0.31 (Figure 4).

There was also no difference in number of peccaries counted among photographs taken by $\geq$1 camera, across time intervals, or by type of habitat (Table 2). Again, no second or third order interactions were detected (Table 2). The mean daily number of peccaries counted per number of cameras (4, 3, 2 opposite-facing, 2 adjacent-positioned, and 1 camera) was 1.22 ± 0.15 (Figure 4).

Since I detected no affect due to habitat on number of photographs or peccaries counted, it was not included as a factor in tests for the influence of diel period (diel hereafter). There was no camera×TI×diel interaction detected for number of photographs or for peccaries counted (Table 2). There was also no camera×diel or camera×TI interaction detected for either response variable. However, a significant TI×diel interaction was detected for number of photographs, and for peccaries counted (Table 2). The number of photographs of peccaries taken in the dark with a flash was greater during every time interval except for time interval 2 (Figure 5). This suggests that darkness did not reduce the number of peccaries detected in photographs. The mean daily number of photographs taken in the dark with a flash was 1.68 $\pm$ 0.81, and the mean daily number of photographs taken in the daylight was 0.85 $\pm$ 1.00. The number of peccaries counted in the dark with a flash was also greater during every time interval except the second (Figure 6). The mean daily number of peccaries counted in the dark with a flash was 2.73 $\pm$ 1.54, and 1.99 $\pm$ 2.25 in the daylight.

There were no instances in which all 4 cameras at a station were triggered within 2, 5 or 10 min intervals (Table 3). Three of 4 cameras at a station were rarely (2-4%) triggered, regardless of time intervals (min). When 2 of 4 cameras at a station were triggered, 33% of the time it occurred in $\leq$2 min, and 41% of the time it occurred in $\leq$ 10 min.

Alarm Response of Peccaries

There was no difference in mean alarm rank of peccaries across time intervals ($F_{4,8} = 0.45$, $P = 0.770$), in closed versus open habitat ($F_{1,8} = 0.12$, $P = 0.742$), and I detected no habitat×TI interaction ($F_{4,8} = 0.45$, $P = 0.770$). Also, there was no difference found in alarm rank of peccaries in photographs taken in the dark versus daylight ($t_{18} = 1.11$, $P = 0.431$). The mean alarm response was 0.76 ± 0.90, which suggests that peccaries were not alarmed by MTC.

Distance Between Camera Stations

The largest mean home range size (km^2) estimated from telemetry data gathered by Gabor and Hellgren (2000) was 2.44 ± 1.25 km^2 and occurred on the west side of CWMA during Fall/Winter (Table 4). The corresponding home range diameter (km) was 1.76 ± 1.26 km. The smallest mean home range size (km^2) was 0.79 ± 0.47 km^2 and occurred on the east side of CWMA during Spring/Summer. The corresponding home range diameter (km) was 0.34 km. These estimates suggest that 1.76 km is the minimum distance needed between adjacent camera stations at this site to maintain independent data.

Proportion of Landscape Occupied

There was an inverse relationship ($F_{1,20} = 31.25$, $P < 0.001$) between the proportion of stations at which sign was detected and amount of precipitation which occurred ≤ 4 days prior to each sign survey (Figure 7). The y-intercept suggests that the proportion of stations where sign was detected at 1-week intervals, accounting for the influence of rain, was 0.23. The proportion of stations (adjusted to accommodate imperfect detection) where sign was detected at 1, 2, 3, and 4-week intervals suggests that peccaries occupied over half (50 – 60%) of the stations within 1 week, 70 – 80% within 2 weeks, 80 – 87% within 3 weeks, and 80 – 90% within 4 weeks (Figure 8).

DISCUSSION

Using MTC as outlined to collect data on habitat use could serve as an attractive alternative method for estimating habitat use of peccaries and other group-living ungulates since they can be used in a variety of environmental conditions, may require less time and labor than both VHF telemetry or direct observation, may cost less than VHF telemetry, and can provide group size information to include in habitat use estimates (Kucera and Barrett 1993, Cutler and Swann 1999, McCullough et al. 2000, Sweitzer et al. 2000). Other information may also be obtainable from photographs taken by MTC that may be of interest to investigators, such as activity patterns, interaction with conspecifics, and grouping behavior in relation to habitat. In addition, it is even possible to collect data on more than one species simultaneously using MTC, such as collared peccaries and feral hogs or white-tailed deer, which could result in an enormous savings in money and time. A few of the disadvantages of using MTC to collect habitat use data include not being able to identify individual animals, material costs, and the possibility of equipment theft.

I explored several factors that could affect the reliability of data obtained from MTC including the number of cameras per station, habitat, diel period, and the possibility of camera stations influencing behavior. The number of cameras per station did not influence the number of photographs of peccaries, or the number of peccaries counted.

Accordingly, one might not expect to see differences in the proportion of cameras triggered simultaneously by peccaries. However, peccaries would have to cross the exact center of camera stations, where the detection zones of all 4 cameras overlap, in order to trigger all 4 cameras simultaneously. Also, high August temperatures may have reduced the detection zones to <18 m. The longer cameras remain operational, the more opportunities to take photographs of peccaries. In my study, camera data was collated over 4 days. Consequently, the problem with multiple cameras not taking photographs of peccaries simultaneously did not appear to influence the number of peccaries counted. The proportion of simultaneously triggered cameras per station in combination with the RM ANOVA results suggests that there is little advantage to having more than 2 cameras per station. Therefore, I recommend a minimum of 2 opposite-facing cameras per station.

I detected no difference in the number of photographs or peccaries counted in closed versus open habitat. Even considering removal of vegetation in the path of the cameras, dense vegetation at closed habitat camera stations might still be expected to reduce the number of peccaries counted when compared to stations in open habitat, but there was no evidence to suggest that this occurred. Therefore, dense vegetation did not appear to influence the number of photographs or peccaries counted.

Diel period did not appear to influence detection of peccaries. The number of photographs and number of peccaries counted was higher in the dark than in the daylight in all but the second 4-day time interval. Because more peccaries were detected in the dark in most time intervals, neither flash interference caused by opposite-facing cameras nor decreased visibility at night appeared to affect detection of peccaries.

It is unlikely that camera stations influenced peccary behavior since no relationship was detected between mean alarm-rank of peccaries across time intervals and habitat type. Change in alarm-rank of peccaries over time would be expected if camera stations stimulated an alarm response. There were also no differences detected in alarm-rank of peccaries in photographs taken in the dark with a flash versus in the daylight, nor in the number of photographs or peccaries counted earlier or later in the study. Evidence of peccaries rubbing on camera housing was another indication that peccaries showed no aversion to MTC. Mud was found on camera housing and close-up photographs of peccaries occurred throughout the study.

I recommend 1.8 km (straight-line distance) between camera stations to obtain independent data from adjacent camera stations at CWMA, as that was the largest estimated mean peccary home range diameter. Reported estimates of peccary home range sizes within the United States show some variation from one study location to another. Diameters of home range size estimates for peccaries in Arizona calculated using the minimum convex polygon (MCP) method ranged from 1.13 – 2.44 km (Schweinsburg 1971, Bigler 1974, Supplee 1983, Day 1985, Bellantoni and Krausman 1993, Sowls 1997). Regardless of method used, diameter of peccary home range estimates in west and south Texas were similar to those reported for CWMA, with diameters ≤1.8 km (Bissonette 1982, Oldenburg et al. 1985, Ilse and Hellgren 1995b, Gabor and Hellgren 2000, Gabor et al. 2001, Green et al. 2001). In the rainforests of French Guiana and Venezuela, the diameters of peccary home range sizes (0.62-1.26 km) were slightly smaller than those reported for peccary populations in the southwestern United States (Castellanos 1985, Judas and Henry 1999). It appears that in more arid regions of their distribution peccary home range diameter tends to be slightly larger than in less arid regions. Therefore, I recommend increasing the straight-line distance between camera stations to 2.5 km to accommodate larger home range sizes in more arid regions of peccary distribution, such as Arizona. In more tropical regions of peccary distribution, a distance of 1.0 km between adjacent camera stations may be adequate.

An inverse relationship was detected between the amount of recent rain and number of stations with sign. At some stations I either failed to detect sign that was present in weeks with more rain or, due to rain, sign left by peccaries was gone by the time I surveyed the stations. The intercept for the regression indicated that probability of detecting peccary sign across the landscape, accounting for rain reducing the detection of sign, was 0.23. When data was examined in groups of 3 – 4 as a way to account for imperfect detection of sign, upwards of 50% of sign stations (or correspondingly camera stations) may be visited by peccaries within 1 week. At 2 and 3 week intervals, 70% and 80% of camera stations respectively may be visited by peccaries. More often than not, most guidelines for using MTC suggest baiting camera stations to increase likelihood of detecting animals (Kucera and Barrett 1993, Jacobson et al. 1997, Koerth et al. 1997, Sweitzer et al. 2000, York et al. 2001, Harrison et al. 2002). These findings, however, indicate that it is plausible that peccaries will visit unbaited camera stations.

Some problems to be avoided in future applications of using MTC to estimate habitat use of peccaries include regularly trimming all vegetation in the detection zone to reduce triggering MTC from vegetation moving due to wind (Kucera and Barrett 1993, Rice et al. 1995). Also, cameras should be attached higher than the average height of peccaries to avoid peccaries rubbing on camera housing which could reposition MTC, or could result in close-up shots of peccaries blocking other peccaries from view of the camera. There were several photographs in which animals were too close to determine species, which could have been avoided if cameras were attached to metal t-posts at a higher distance from the ground than 25-30 cm. Since the mean shoulder height of peccaries in Texas was 49.3 ± 0.40 cm (Lochmiller 1987), I recommend attaching cameras to metal posts 50 cm above ground level to reduce such problems. Also, to increase the accuracy of overlapping camera detection zones, slight differences in topography should be taken into consideration when considering height of camera placement. When cameras are operated during warmer seasons (temperatures >29°C), distance between opposite-facing cameras should be reduced slightly to account for decreased detection zone caused by high ambient temperatures (indicated in most MTC user manuals). If cameras will be exposed to direct sun for prolonged periods of time, building a shade for the camera housing is recommended. There were several times when the LCD display on cameras were inoperative, most likely as a result of overexposure to direct sun (Kucera and Barrett 1993, Rice et al. 1995, Hernandez et al. 1997). If LCD displays do not read the number of exposures on the film, I recommend collecting and replacing the film to ensure that peccaries are not missed as a result of film running out prematurely. Hernandez et al. (1997) suggested aligning cameras so that they face N and S when possible to avoid problems from direct sun exposure. Finally, cameras at each station should be checked at minimum every 4 days to ensure operation and to collect and replace film and batteries as needed (Kucera and Barrett 1993, Rice et al. 1995, Hernandez et al. 1997, Cutler and Swann 1999).

Taking these guidelines and recommendations into consideration, using MTC should be considered as a viable alternative to traditional methods for estimating habitat use of collared peccaries, and if modified slightly, may be applicable to studying habitat use of other group-living ungulates such as feral hogs and white-tailed deer as well. In summary, MTC stations need not be baited, data can be collected in a variety of environmental conditions, less time and effort is required than with direct observation and VHF telemetry, and local abundance or groups size data can be included when estimating habitat use, which may be particularly appealing when studying group living animals.

LITERATURE CITED

Bellantoni, E. S., and P. R. Krausman. 1993. Habitat use by collared peccaries in an urban environment. Southwestern Naturalist 38:345-351.

Bigler, W. J. 1974. Seasonal movements and activity patterns of the collared peccary. Journal of Mammalogy 55:851-855.

Bissonette, J. A. 1982. Ecology and social behavior of the collared peccary in Big Bend. National Park Service Monograph Series 16.

Bookhout, T. A. 1996. Research and management techniques for wildlife and habitats. Allen Press, Lawrence, Kansas, USA.

Borkowski, J. 2000. Influence of the density of sika deer population on activity, habitat use, and group size. Canadian Journal of Zoology 78:1369-1374.

Bull, E. L., R. S. Holthausen, and L. R. Bright. 1992. Comparison of 3 techniques to monitor marten. Wildlife Society Bulletin 20:406-410.

Castellanos, H. G. 1985. Home range size and habitat selection of the collared peccary in the state of Guarico, Venezuela. Page 50 *in* Proceedings of the Peccary Workshop, Tucson, Arizona.

Coulson, T., S. Albon, F. Guinness, J. Pemberton, and T. Clutton-Brock. 1997. Population substructure, local density, and calf winter survival in red deer (*Cervus elaphus*). Ecology 78:852-863.

Cutler, T. L., and D. E. Swann. 1999. Using remote photography in wildlife ecology: a review. Wildlife Society Bulletin 27:571-581.

Day, G. I. 1985. Javelina research and management in Arizona. Phoenix, Arizona. Arizona Game and Fish Department.

Foster, M. L., and S. R. Humphrey. 1995. Use of highway underpasses by Florida panthers and other wildlife. Wildlife Society Bulletin 23:95-100.

Fridell, R. A., and P. Hovingh. 1995. Experimental use of remotely-triggered cameras to monitor occurrence of timber rattlesnakes (*Crotalus horridus*). Herpetological Review 26:189-190.

Gabor, T. M., and E. C. Hellgren. 2000. Variation in peccary populations: landscape composition or competition by an invader? Ecology 81:2509-2524.

______, ______, and N. J. Silvy. 2001. Multi-scale habitat partitioning in sympatric suiforms. Journal of Wildlife Management 65:99-110.

Green, M. C., L. A. Harveson, and L. E. Loomis. 2001. Habitat selection by collared peccaries in Trans-Pecos Texas. Southwestern Naturalist 46:246-251.

Hansteen, T. L., H. P. Andreassen, and R. A. Ims. 1997. Effects of spatiotemporal scale on autocorrelation and home range estimators. Journal of Wildlife Management 61:280-290.

Harrison, R. L., D. J. Barr, and J. W. Dragoo. 2002. A comparison of population survey techniques for swift foxes (*Vulpes velox*) in New Mexico. American Midland Naturalist 148:320-337.

Hatch, S. L., K. C. Gandhi, and L. E. Brown. 1990. Checklist of the vascular plants of Texas. Texas Agricultural Experiment Station Report MP-1655. College Station, Texas, USA.

Hellgren, E. C., D. R. Synatzske, P. W. Oldenburg, and F. S. Guthery. 1995. Demography of a collared peccary population in south Texas. Journal of Wildlife Management 59:153-163.

Hernandez, F., D. Rollins, and R. Cantu. 1997. An evaluation of Trailmaster camera systems for identifying ground-nest predators. Wildlife Society Bulletin 25:848-853.

Ilse, L. M., and E. C. Hellgren. 1995a. Resource partitioning in sympatric populations of collared peccaries and feral hogs in southern Texas. Journal of Mammalogy 76:784-799.

_______, _______. 1995b. Spatial use and group dynamics of sympatric collared peccaries and feral hogs in southern Texas. Journal of Mammalogy 76:993-1002.

Jacobson, H. A., J. C. Kroll, R. W. Browning, B. H. Koerth, and M. H. Conway. 1997. Infrared-triggered cameras for censusing white-tailed deer. Wildlife Society Bulletin 25:547-556.

Judas, J., and O. Henry. 1999. Seasonal variation of home range of collared peccary in tropical rain forests of French Guiana. Journal of Wildlife Management 63:546-552.

Karanth, K. U., and J. D. Nichols. 1998. Estimation of tiger densities in India using photographic captures and recaptures. Ecology 79: 2852-2862.

Kernohan, B. J., J. J. Millspaugh, J. A. Jenks, and D. E. Naugle. 1998. Use of an adaptive kernel home-range estimator in a GIS environment to calculate habitat use. Journal of Environmental Management 53:83-89.

Kiefer, S. J., and F. W. Weckerly. *In Press*. Population density and body weight influences on home range size of feral hogs. California Fish and Game.

Koerth, B. H., C. D. McKown, and J. C. Kroll. 1997. Infrared-triggered camera versus helicopter counts of white-tailed deer. Wildlife Society Bulletin 25:557-562.

Koerth, B. H., and J. C. Kroll. 2000. Bait type and timing for deer counts using cameras triggered by infrared monitors. Wildlife Society Bulletin 28:630-635.

Kucera, T. E., and R. H. Barrett. 1993. The Trailmaster camera system for detecting wildlife. Wildlife Society Bulletin 21:505-508.

Lochmiller, R. L. 1987. Physical characteristics of neonate, juvenile and adult peccaries (*Tayassu tajacu*) from South Texas. Journal of Mammalogy 68:188-194.

Long, E. S., D. M. Fecske, R. A. Sweitzer, J. A. Jenks, B. M. Pierce, and V. C. Bleich. 2003. Efficacy of photographic scent stations to detect mountain lions. Western North American Naturalist 63:529-532.

Mace, R. D., S. C. Minta, T. L. Manley, and K. E. Aune. 1994. Estimating grizzly bear population size using camera sightings. Wildlife Society Bulletin 22:74-83.

Martorello, D. A., T. H. Eason, and M. R. Pelton. 2001. A sighting technique using cameras to estimate population size of black bears. Wildlife Society Bulletin 29:560-567.

McCullough, D. R., K. C. J. Pei, and Y. Wang. 2000. Home range, activity patterns, and habitat relations of Reeves' muntjacs in Taıwan. Journal of Wildlife Management 64:430-441.

Oldenburg, P. W., P. J. Ettestad, W. E. Grant, and E. Davis. 1985. Size, overlap, and temporal shifts of collared peccary herd territories in south Texas. Journal of Mammalogy 66:378-380.

Payer, D. C., and B. E. Coblentz. 1997. Seasonal varıation in California bighorn ram (*Ovis canadensis californiana*) habıtat use and group size. Northwest Science 71:281-288.

Quinn, G. P., and M. J. Keough. 2002. Experimental design and data analysis for biologists. Cambridge University Press, Cambridge, U.K.

Rice, G., T. E. Kucera, and R. H. Barrett. 1995. Trailmaster camera system: the dark side. Wildlife Society Bulletin 23:110-113.

Schweinsburg, R. E. 1971. Home range, movements, and herd integrity of the collared peccary. Journal of Wildlife Management 35:455-460.

________, and L. K. Sowls. 1972. Aggressive behavior and related phenomena in the collared peccary. Zeitschrift fur Tierrpsychologie 30:132-145.

Seydack, A. H. W. 1984. Application of photo-recording device in the census of larger rain-forest mammals. South African Journal of Wildlife Research 14:10-14.

Sowls, L. K. 1997. Javelinas and other peccaries: their biology, management, and use. Second edition. Texas A&M University Press, College Station, Texas, USA.

Stevens, J. W., and D. Arriaga. 1985. Soil survey of Dimmit and Zavala Counties, Texas, U.S. Department of Agriculture, Washington, D.C., USA.

Supplee, V. C. 1983. The dynamics of collared peccary dispersion into available range. Federal Aid in Wildlife Restoration Project W-78-R. Phoenix, Arizona. Arizona Game and Fish Department.

Sweitzer, R. A., D. VanVuren, I. A. Gardner, and W. M. Boyce. 2000. Estimating sizes of wild pig populations in the north and central coast regions of California. Journal of Wildlife Management 64:531-543.

Swihart, R. K., and N. A. Slade. 1985. Testing for independence of observations in animal movement. Ecology 66:1176-1184.

Thirgood, S. J. 1996. Ecological factors influencing sexual segregation and group size in fallow deer (*Dama dama*). Journal of Zoology 239:783-797.

Weckerly, F. W., and M. A. Ricca. 2000. Using presence of sign to measure habitats used by Roosevelt elk. Wildlife Society Bulletin 28:146-153.

Wegge, P., C. P. Pokheral, and S. R. Jnawali. 2004. Effects of trapping effort and trap shyness on estimates of tiger abundance from camera trap studies. Animal Conservation 7:251-256.

White, G. C., and R. A. Garrott. 1990. Analysis of wildlife radio-tracking data. Academic Press, San Diego, California, USA.

Worton, B. J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70:164-168.

_______. 1995. Using Monte Carlo simulation to evaluate kernel-based home range estimators. Journal of Wildlife Management 59:794-800.

York, E. C., T. L. Moruzzi, T. K. Fuller, J. F. Organ, R. M. Sauvajot, and R. M. DeGraaf. 2001. Description and evaluation of a remote camera and triggering system to monitor carnivores. Wildlife Society Bulletin 29:1228-1227.

Zar, J. H. 1996. Biostatistical analysis. Third edition. Prentice-Hall, Upper Saddle River, New Jersey, USA.

Table 1. Total number of photographs taken within 28 days of activity at each of 4 camera stations at Chaparral Wildlife Management Area, Dimmit and La Salle Counties, Texas, August 2003 Closed stations were placed in areas of dense vegetation and open stations were placed in areas with less dense vegetation

	Closed Stations		Open Stations		
	[a]Hogue	Rosindo	Mare	Año Nuevo	All Stations
Collared peccary (*Pecari tajacu*)	118	69	80	35	302
White-tailed deer (*Odocoileus virginianus*)	225	2	-	18	249
Raccoon (*Procyon lotor*)	5	-	4	38	47
Nine-banded armadillo (*Dasypus novemcinctus*)	1	-	6	5	12
Coyote (*Canis latrans*)	5	-	3	3	11
Bobcat (*Lynx rufus*)	9	2	9	6	26
Desert cottontail (*Sylvilagus audubonii*)	1	-	6	1	8
Opossum (*Didelphis virginiana*)	-	-	-	3	3
[b]Skunk	-	-	-	2	2
Badger (*Taxidea taxis*)	-	-	1	-	1
Feral pig (*Sus scrofa*)	6	-	-	-	6
Cow	-	-	-	2	2
Greater roadrunner (*Geococcyx californianus*)	9	4	43	33	89
[b]Dove	11	-	1	1	13
Great horned owl (*Bubo virginianus*)	1	-	-	-	1
Harris's hawk (*Parabuteo unicinctus*)	1	-	-	-	1
Common pauraque (*Nyctidromus albicollis*)	-	-	1	-	1
[c]Combination	5	-	-	-	5
Rain	-	-	-	1	1
Nothing discernable	29	27	40	48	144
Vehicle	7	-	20	3	30
Human	1	7	4	5	17
Total	434	111	218	204	966

[a]Habitat types· Hogue = Mesquite-Mixed brush, Rosindo = Mesquite-Prickly-pear, Mare = Mixed brush, Año Nuevo = Mesquite-Prickly-pear (less canopy cover than in Hogue)

[b] Unidentified species

[c]Both collared peccary and white-tailed deer were present in the same photograph

Table 2. Results of 2 repeated measures analyses of variance for number of photographs of peccaries and number of peccaries detected at camera stations at Chaparral Wildlife Management Area in Dimmit and La Salle Counties, Texas, August 2003. The first analysis had factors of camera, TI, and habitat. The second analysis had factors of camera, TI, and diel.

		Response Variable			
		Number of Photographs		Number of Peccaries	
Source of Variation	df[a]	*F*	*P*	*F*	*P*
[b]Camera	4	0 65	0 632	0 20	0 935
[c]TI	6	1 66	0 145	1 77	0 120
[d]Habitat	1	0 06	0 806	0 75	0 390
Camera × TI	24	0 15	0 999	0 25	0 999
Camera × Habitat	4	1 27	0 291	0 89	0 475
TI × Habitat	6	2 27	0 048	2 08	0 068
Camera × TI × Habitat	24	0 21	0 999	0 25	0 999
Camera	4	0 54	0 705	0 16	0 960
TI	6	1 63	0 141	2 06	0 060
[e]Diel	1	13.73	< 0 001*[f]	7 50	0 007*
Camera × TI	24	0 21	0 999	0 29	0 999
Camera × Diel	4	1 12	0 348	0 98	0 421
TI × Diel	6	2.87	0 011*	3 22	0 005*
Camera × TI × Diel	24	0 14	0 999	0 22	0 999

[a] Denominator degrees of freedom were 62 and 197, respectively, for first and second analyses.

[b] Camera = Number of cameras (1, 2 opposite-facing, 2 adjacent, 3, and 4).

[c] TI = Seven 4-day time intervals.

[d] Habitat = Open and closed habitats.

[e] Diel= Diel period; daylight or darkness.

[f] Significant at $P \leq 0.025$ (*).

Table 3. Mean (± SE) percentage of photographs of peccaries taken within 2 min, 5 min and 10 min intervals by 2, 3 or all 4 cameras per station (*n* = No. of stations).

No. Cameras per Station	≤ 2 min	≤ 5 min	≤ 10 min	*n*
4 of 4	0	0	0	4
3 of 4	1.24 ± 0.75	1.25 ±0.75	2.58 ± 1.73	4
2 of 4	28.37 ± 6.85	34.30 ± 8.32	38.02 ± 8.08	4

Table 4. Mean home range (95% adaptive kernel ± SE) area (km^2) and diameter (km) estimates of collared peccaries from telemetry data gathered by Gabor and Hellgren (2000) on the Chaparral Wildlife Management Area, Dimmit and LaSalle counties, Texas, 1994-1995.

	East Side				West Side			
	n	Area	SE	Diameter	*n*	Area	SE	Diameter
Fall - Winter	14	1.02	0.11	1.14	8	2.44	0.44	**1.76**
Spring - Summer	13	0.79	0.11	1.00	8	1.98	0.34	1.59

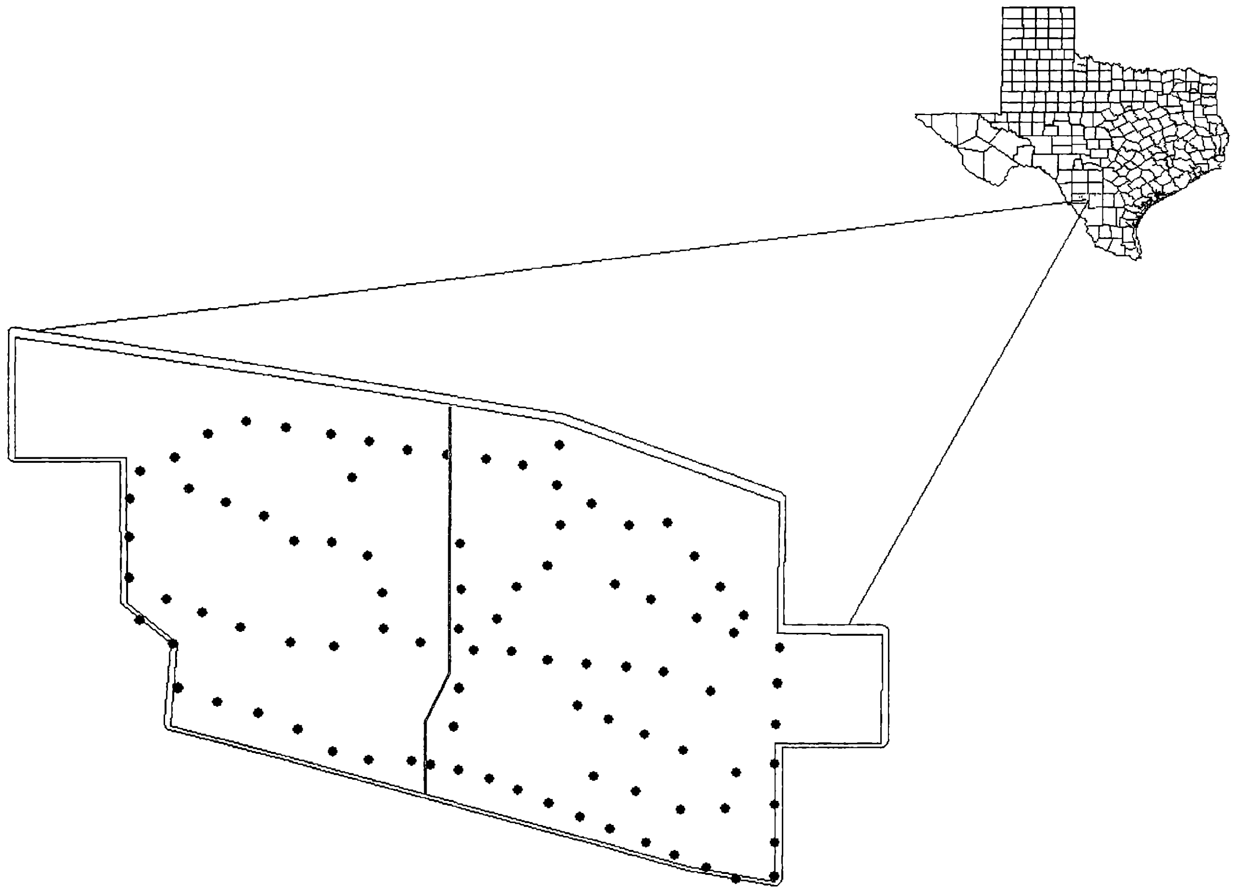

Figure 1. Map of Chaparral Wildlife Management Area, Dimmit and La Salle Counties, Texas. Dots represent sign stations. Line in center of map represents 2.5-m fence dividing east and west sides.

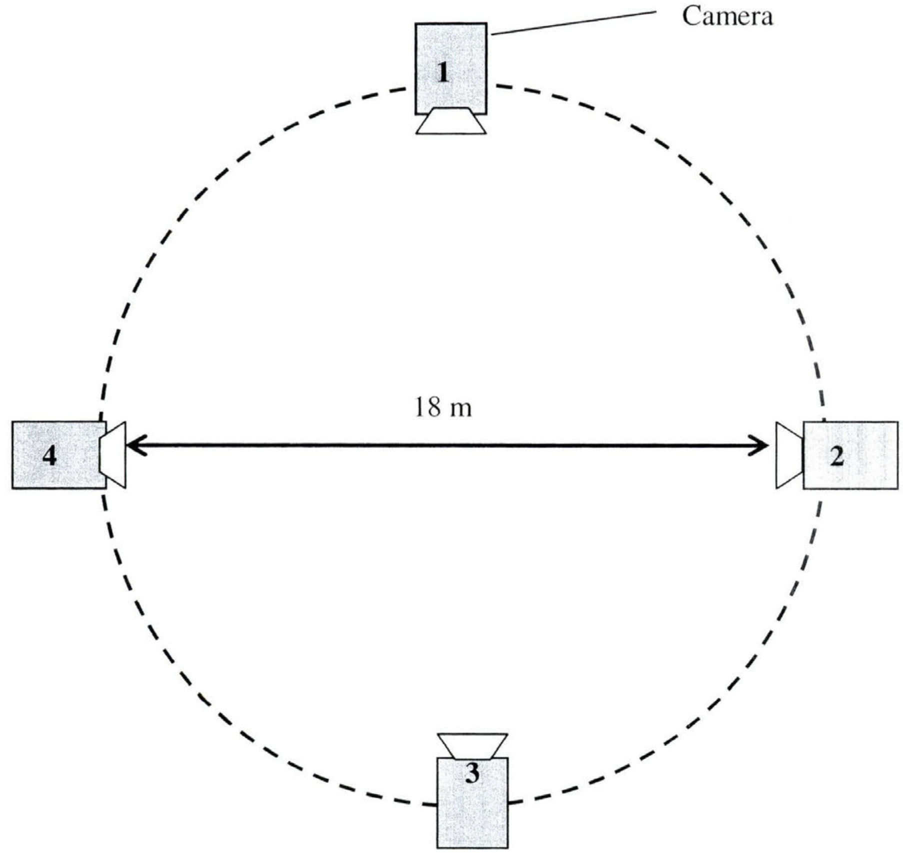

Figure 2. Camera station design depicting the position of the 4 cameras placed at each station at Chaparral Wildlife Management Area in Dimmit and La Salle Counties, Texas, August 2003. To determine the number of cameras needed per station, the number of photos of peccaries and number of peccaries counted in photographs taken by 4, 3, 2-opposite facing, 2-ajacent positioned and 1 camera were compared. Cameras 1 and 3 are examples of opposite-facing pairs, and 1 and 2 are examples of adjacent-positioned cameras. Opposite-facing cameras were 18 m apart.

Figure 1. Photographs depict the 4 camera stations established at Chaparral Wildlife Management Area, Dimmit and LaSalle counties, Texas, August 2003. Two stations (left) were placed in closed-canopy habitat, and 2 stations (right) were placed in open-canopy habitat to examine possibilities of vegetation obstructing peccaries from camera view.

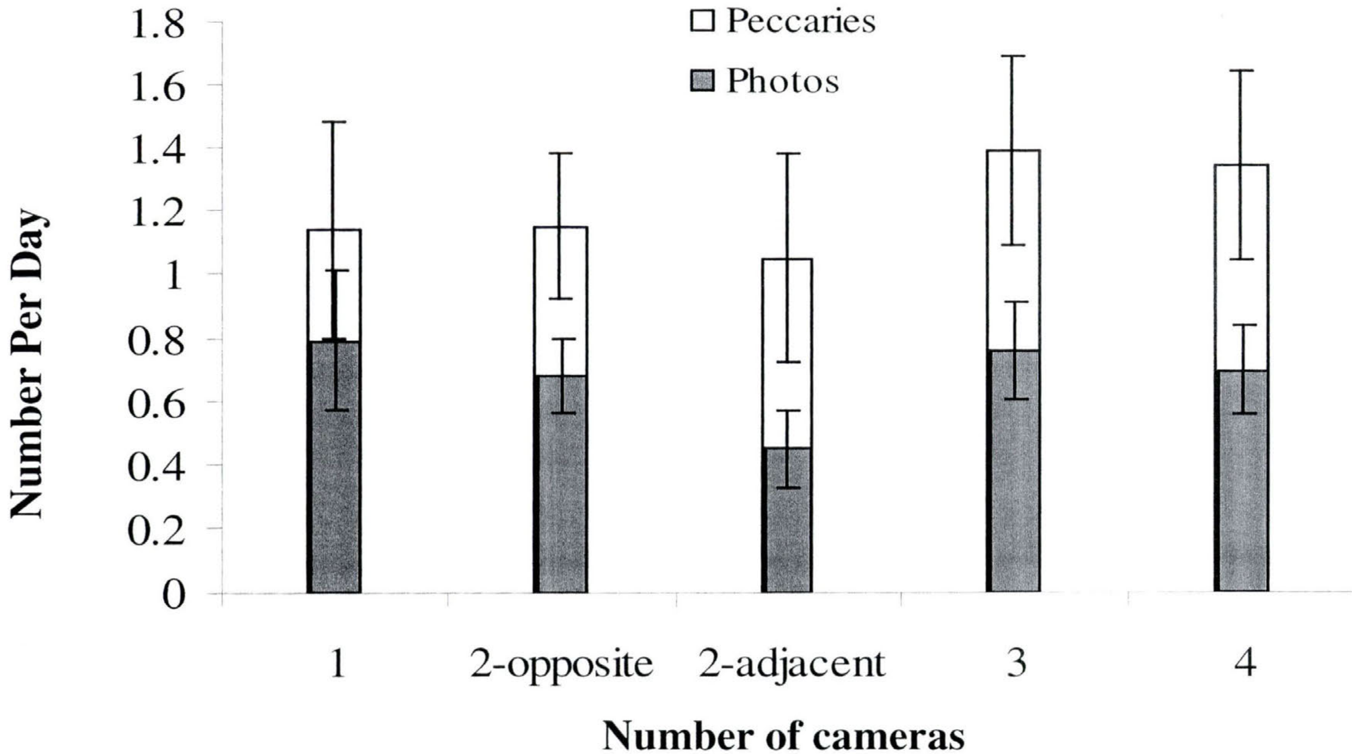

Figure 4. Black bars represent mean daily number of photographs of peccaries per camera per station, and white bars represent mean daily number of peccaries counted per camera per station at Chaparral Wildlife Management Area in Dimmit and LaSalle counties, Texas, August 2003. Error bars represent 1 SE.

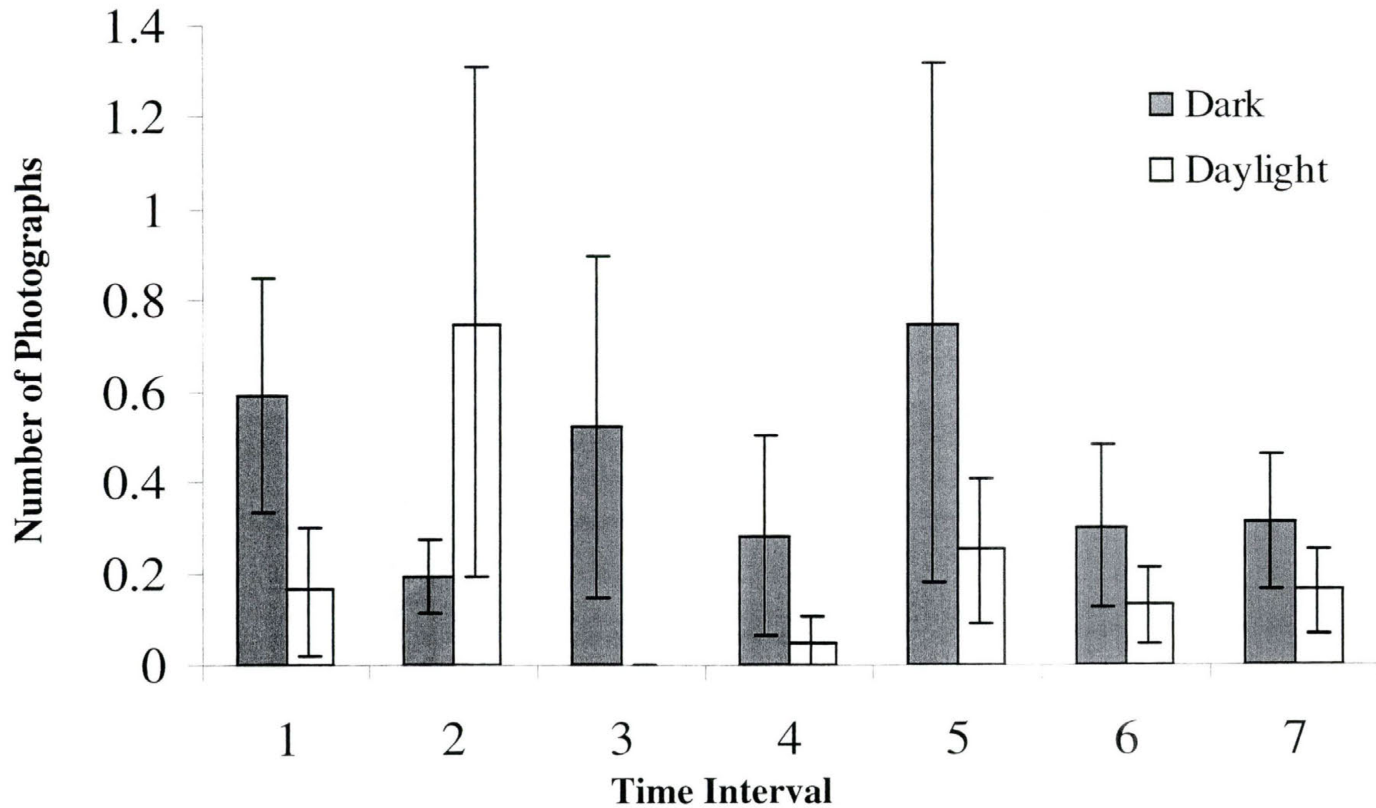

Figure 5. Mean daily number of photographs taken per camera per station by diel period across 7 4-day time intervals at Chaparral Wildlife Management Area in Dimmit and LaSalle Counties, Texas, August 2003. Error bars represent 1 SE.

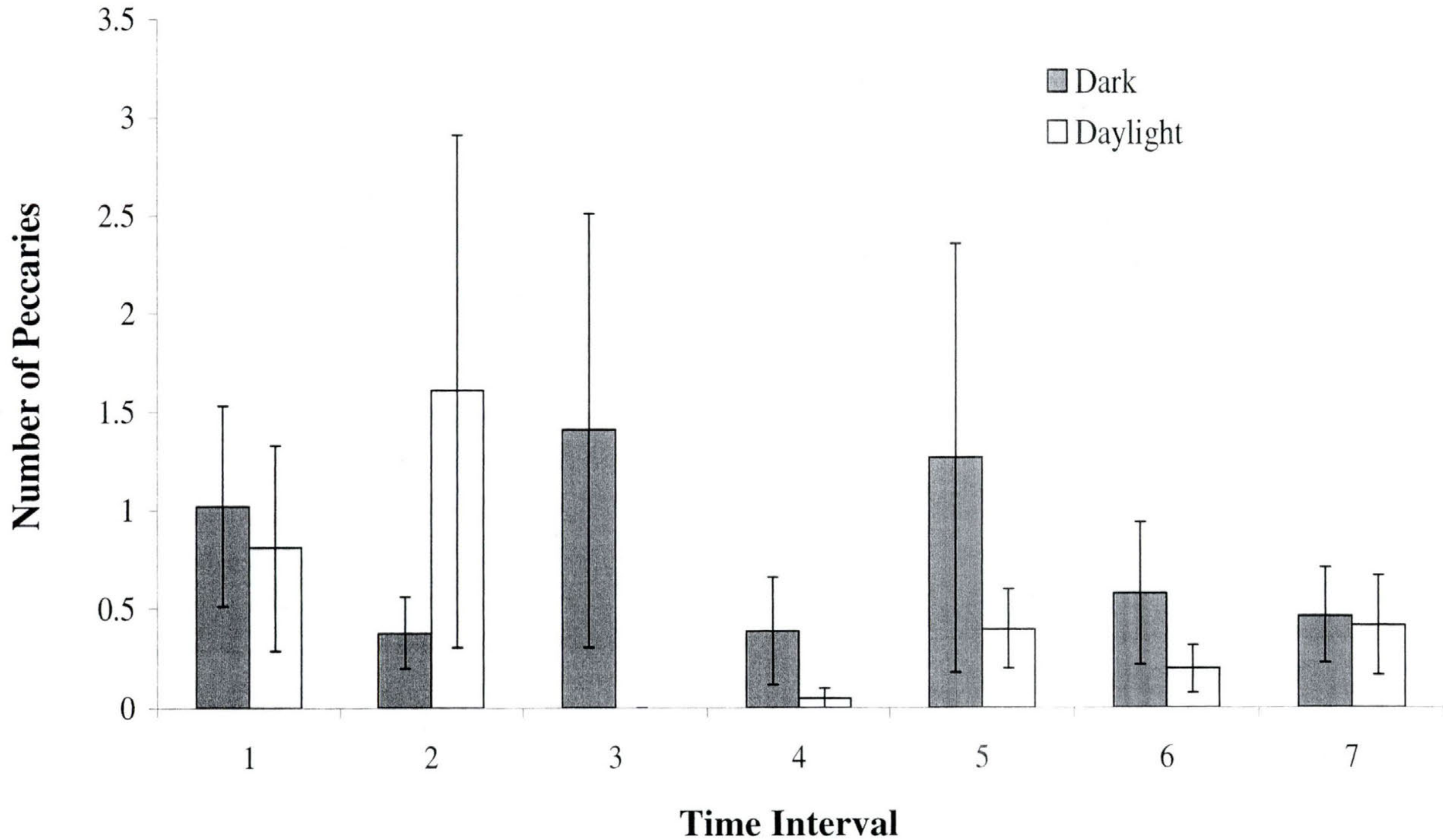

Figure 6. Mean daily number of peccaries counted per camera per station by diel period across 7 4-day time intervals at Chaparral Wildlife Management Area in Dimmit and LaSalle Counties, Texas, August 2003. Error bars represent 1 SE.

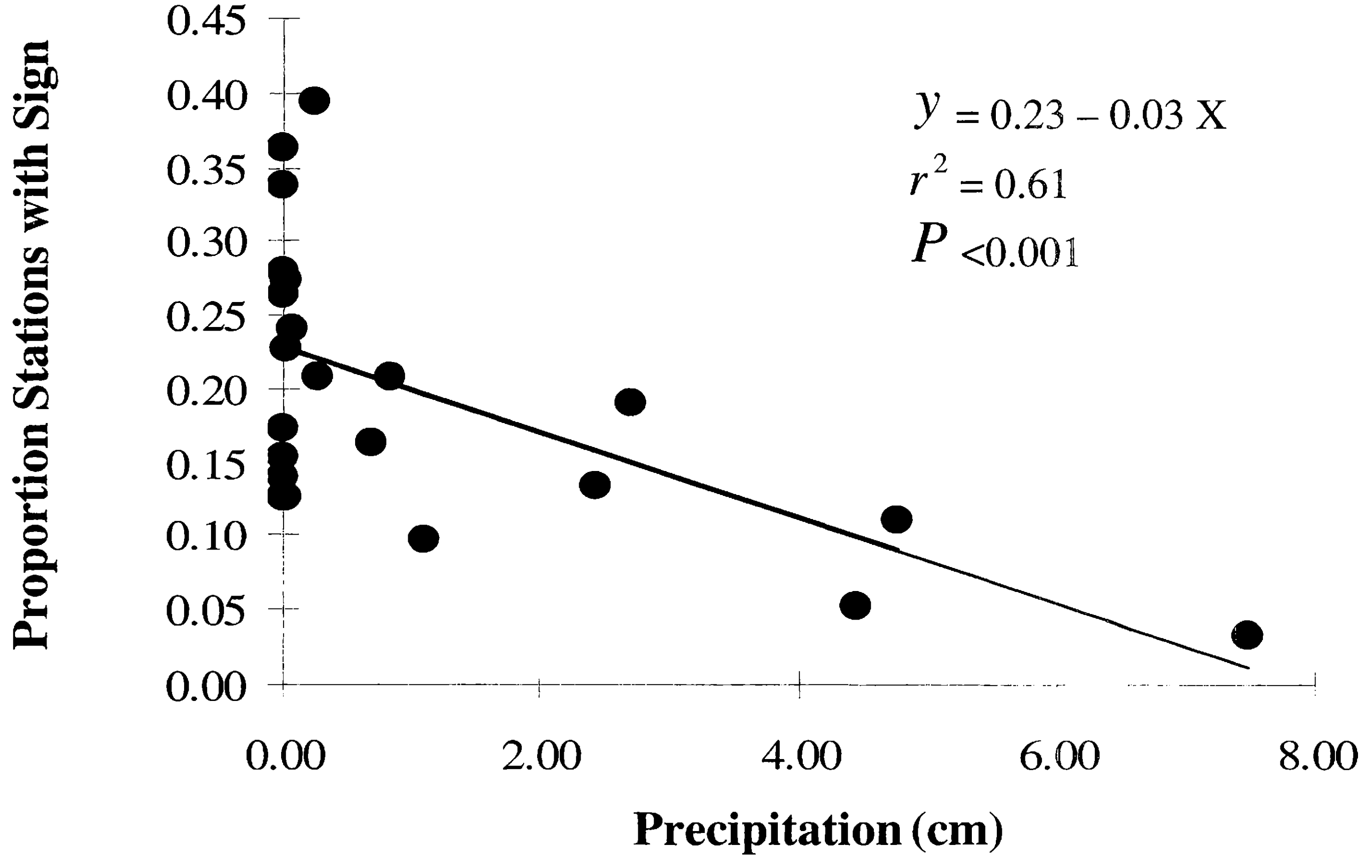

Figure 7. Relationship between the amount of precipitation which took place 4 days before each weekly sign survey and the mean proportion of stations at which sign was detected at Chaparral Wildlife Management Area, Dimmit and La Salle Counties, Texas, (March – November, 2003).

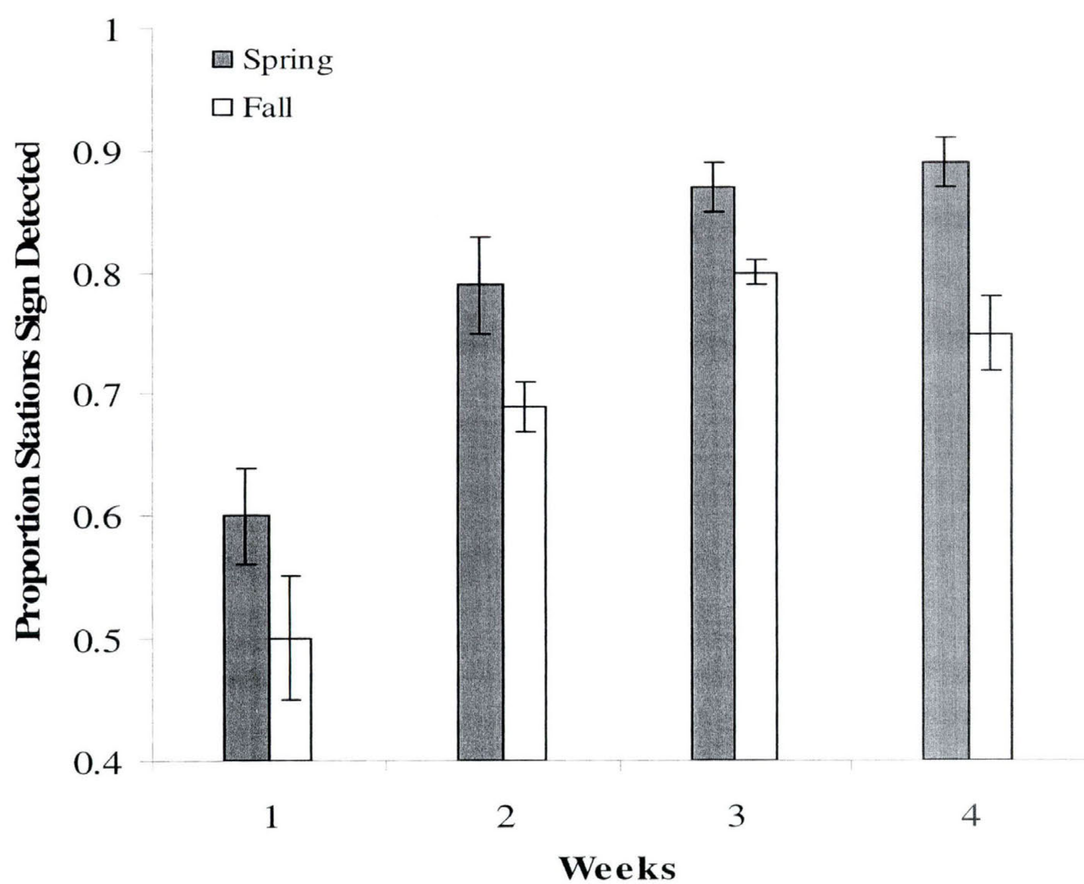

Figure 8. Proportion of stations at which sign was detected within 1, 2, 3, and 4 week intervals in both spring (March 29 – June 6) and fall (August 23 – November 1) of 2003 at Chaparral Wildlife Management Area, Dimmit and La Salle Counties, Texas. Error bars represent 1 SE.

VITA

Meredith Pederson Longoria was born in McAllen, Texas, on August 30, 1972, the daughter of Rexanne and Christopher Pederson. After completing her work at McAllen High School, McAllen, Texas, in 1990, she entered Texas State University-San Marcos (formerly Southwest Texas State University). During the summer of 1991, she attended University of Texas Pan American in Edinburg. She received the degree Bachelor of Science in Biology from Texas State University-San Marcos in December 1994. During the following years she was employed as a research technician with The University of Texas M. D. Anderson Cancer Center in Smithville, Texas. In June of 1997, she returned to Texas State University-San Marcos to pursue a teaching certificate. During the following years she was employed as a public school teacher for Austin Independent School District at Kealing Junior High. In January 2003, she entered the Graduate College of Texas State University-San Marcos.

Permanent Address: 2606 Lindsey Cove

Austin, Texas 78748-5151

This thesis was typed by Meredith P. Longoria.