HABITAT SELECTION AND MOVEMENT PATTERNS OF CATTLE AND WHITE-TAILED DEER IN A TEMPERATE SAVANNA

A Thesis

by

JARROD JASON DEPEW

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

August 2004

Major Subject: Rangeland Ecology and Management

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Approved as to style and content by:

M. Keith Owens (Co-Chair of Committee)	X. Ben Wu (Co-Chair of Committee)
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August 2004

Major Subject: Rangeland Ecology and Management

ABSTRACT

Habitat Selection and Movement Patterns of Cattle and White-tailed Deer in a
Temperate Savanna. (August 2004)
Jarrod Jason Depew, B.S., Texas Tech University
Co-Chairs of Advisory Committee: Dr. M. Keith Owens
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This study investigated the use of high resolution satellite imagery in research involving habitat selection, and movement patterns of white-tailed deer and cattle in a semi-arid landscape. Vegetation classification was developed based on Ikonos satellite imagery that was then used to define habitat selection and characterize movement paths of deer and cattle to allow a better understanding of these 2 species. Pasture attributes were also measured to determine animal distribution throughout the study area in relation to roads, fences, water location, and supplemental feeders. Three cattle and 3 free ranging white-tailed deer were used during 3 trials to test seasonal differences in habitat selection and spatial distribution across the pasture.

Ikonos satellite imagery was classified to a final classification accuracy of 83.6%. Seven vegetation classes were defined in the classification with 1 class of bare ground/ herbaceous that represents interspaces between shrub vegetation. Classification accuracy was obtained using a ½ meter buffer to all ground control points increasing the accuracy from 71.29%.

All physical pasture attributes were significant to animal distributions in the study area when compared to the random distribution. Roads and water location were most important to cattle during the spring and summer. White tailed deer use of the pasture was more dependent on vegetation characteristics than physical attributes. Both cattle and deer selected habitat patches with a proportionately large percentage of bare-ground/interspaces (>40%). Deer were predominately found in areas containing higher percentages of shrub species, while cattle were found in areas containing a mixture of larger tree species in addition to shrub complexes.

Travel velocity and path tortuosity were measured to determine effects of vegetation attributes on animal movements. Both cattle and deer followed fairly linear paths (Fractal Dimension<1.2). Factors contributing to path tortuosity included mean patch size, number patches, and patch fractal dimension. Travel velocity was also measured and compared to vegetation association attributes. Travel velocity was significantly different between seasons for white-tailed deer however cattle and deer comparisons were not significant across the 3 trials. Number of patches, patch fractal dimension, mean patch size, and patch area were significant in the travel velocity model.

DEDICATION

This thesis is dedicated to Larry Allen Depew (April 25, 1949 – May 12, 2002); a good friend, an exceptional mentor, and an excellent father whose support and guidance was always there when you needed it. I know you’re huntin’ some good country up there, so pick out a good one for me Ol’ Timer.

ACKNOWLEDGEMENTS

Research projects of this caliber require so many people that deserve recognition that an acknowledgements section becomes a daunting task. I would like to start by thanking Dr. Keith Owens for allowing me to work on this project, for advice about science, for help with statistics most of us have not heard of, and for determining what is ecologically important out of the results. Most of all, I would like to thank him for his patience during trying times throughout this project.

Next, I would like to thank an excellent committee for their advice and technical support: Dr. Bob Lyons, whose advice on cattle grazing, GPS collars, and general help in the field was greatly appreciated; Dr. Susan Cooper, whose advice on deer activity and deer ecology in general was invaluable; and last but not least, X. Ben Wu, whose advice on remote sensing and GIS databases made the project run a lot smoother.

I would also like to thank the staff at the Texas Agricultural Experiment Station-Uvalde for their help. Oscar Sauceda for penning cattle and working them through the chutes, and Eva Rivera for taking care of travel plans and other office “stuff”. A special thanks goes to Rose Cooper, whose help in the field was invaluable as we learned what “ground truthing” is really about.

I would especially like to thank my family for all of their support through this past 3.5 years. A special thanks goes my mom (Connie Depew) for helping with finances during the tight months and overall support throughout the duration of this study. I would also like to extend a special thanks to Sommer Harrison, whose support and constant pressure to finish for the past year has helped make this thesis happen. Although most of my friends did not understand the drive to continue on in an educational endeavor, they have been loyal and always had the time to listen about “Grad School”.

Last but not least, I am going to break into acknowledgement uncharted territory. I would like to thank my study site, located in beautiful western Uvalde County. A 12-15 hour day of busting through blackbrush and cat claw in the 100^+ degree heat will make anyone appreciate the finer things in life. Another thanks must go out to the rattlesnakes that I encountered, nothing will warm one's heart like that rattling when you know you are the only human for 10 square miles, especially in that canyon that I have come to affectionately call "Hell's ½ Acre". I have actually caught myself carrying on conversations with these guys just a few feet away, probably due to mild heatstroke, just like they were old friends. These experiences also make one appreciate all that is natural and the privilege to have worked in such an interesting ecosystem.

All said and done, this has been an enjoyable endeavor in beautiful country with good people every step of the way.

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CHAPTER I

INTRODUCTION

The use of satellite imagery and geographic information systems (GIS) has increased in recent years for ecological studies exploring habitat use and change of vegetation composition over time. Advances in satellite remote sensing have allowed fine scale classification of attributes that were previously unavailable primarily due to large pixel size of Landsat TM and SPOT imageries (Aspinall 2002). Satellite imagery is also becoming more accessible and some can be ordered for specific time periods to match study objectives.

The Ikonos satellite (Space Imaging, Inc.) was launched in September 1999 and provides multiple levels of resolution and geo-processing. Remotely sensed imagery used for this research has a horizontal accuracy of 15m CE and a resolution of 1 meter. Previous available satellite imagery generally had large pixel size for spectral bands and some had slightly smaller pixel size for panchromatic bands. Examples of these imageries would be the Landsat TM (30 meter pixel size) and the SPOT satellite (10 meter panchromatic band).

Cattle and white-tailed deer (*Odocoileus virginianus texanus* Raf.) are economically important to southwest Texas landowners, with beef cattle economic value estimated at $212 million dollars and economic value for hunting estimated at $48 million dollars in the Edwards Plateau for 2000 (Wyse and Anderson 2000). Leasing potential for hunting in Texas has long been recognized (Berger 1973) and has become a substantial additive income to traditional livestock production practices on many ranches.

Many factors affect the use of landscapes by livestock and wildlife. Cattle use areas differently due to terrain characteristics, water availability, mineral placement, and

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This thesis follows the style and format of the Journal of Range Management.

manmade structures (Cook 1966, Roath and Krueger 1982, Senft et al. 1987, Owens et al. 1991). Forage distribution, forage quality and plant associations also play a significant part in cattle distribution throughout pastures (Roath and Krueger 1982). Periodic spot grazing by herbivores may keep forage in early developmental stages, enhancing palatability later in the growing season (McNaughton 1984).

Physical features of landscapes and environmental elements also influence white-tailed deer selection of plant communities, but not always in a predictable manner (Pollock et al. 1994, Bello et al. 2001). Recent advances in tracking equipment have made the study of animal habitat selection and movement analysis more efficient. Satellite imagery, Global Positioning Systems (GPS), and Geographic Information Systems (GIS) have made it possible to observe animal behavior patterns with higher resolution than was previously available to researchers (Vavra and Ganskopp 1998, Ganskopp et al. 2000).

How species perceive their habitat has also seen renewed interest in the past 20 years (Dicke and Burrough 1988, Wiens et al. 1989, Johnson et al. 1992, With 1994a, Gross et al. 1995). Studies have focused on how season (Beier and McCullough 1990), habitat attributes (Owens et al. 1991, Pollock et al. 1994, Pastor et al. 1997), species competition (Cohen et al. 1989, Loft et al. 1991, Kie et al. 1991), and juxtaposition of micro-habitats (Etzenhouser et al. 1998) affect grazing and browsing animals.

In this thesis I describe vegetation classification of a southwest Texas ranch using Ikonos satellite imagery (chapter II). The resulting classification was then used to determine habitat use by cattle and white-tailed deer across 3 seasons (chapter III). Shrub association composition around animal locations was measured to determine what mixtures of shrub species were selected. Physical attributes of the pasture (roads, fences, water locations, and supplemental feeders) were also measured to determine their relationships to animal distributions across the study pasture. Finally, the attributes of shrub patches were measured against travel velocity and path tortuosity to determine what affects they had on animal movements (chapter IV).

CHAPTER II

VEGETATION CLASSIFICATION OF TEMPERATE SAVANNA ECOLOGICAL SITES USING IKONOS SATELLITE IMAGERY

The use of satellite imagery and geographic information systems (GIS) has increased in recent years for ecological studies exploring habitat use and change of vegetation composition over time. Advances in satellite remote sensing have allowed fine scale classification of attributes that were previously unavailable primarily due to large pixel size of Landsat TM and SPOT imageries (Aspinall 2002). Satellite imagery is also becoming more accessible and some can be ordered for specific time periods to match study objectives.

The Ikonos satellite (Space Imaging, Inc.) was launched in September 1999 and provides multiple levels of resolution and geo-processing. Geo-processing improves positional accuracy of imagery in relation to the earth's surface and is measured in terms of circular error (CE). Circular Error is the radius that would be drawn to encompass 90% of possible locations. Remotely sensed imagery used for this research has a horizontal accuracy of 15m CE. Ikonos images obtained for the study area contained 4 spectral bands with a resolution of 4 meters and 1 panchromatic band with a resolution of 1 meter. Previous available satellite imagery generally had large pixel size for spectral bands and some had slightly smaller pixel size for panchromatic bands. Examples of these imageries would be the Landsat TM (30 meter pixel size) and the SPOT satellite (10 meter panchromatic band). Imageries with large pixel size have generally been used for landscape change and regional vegetation coverage maps, but do not have fine enough resolution for fine scale vegetation mapping (Aspinall 2002). High pixel resolution increases the effort of the classification process, due to the required accuracy of ground-truthing. The latest GPS technologies must be employed to reduce as much error as possible in precisely locating ground truth points.

Creating thematically classified images using Ikonos imagery has had varying success in different environments. In marine environments, where there is little spectral variation, accuracy for classified images may be as low as 50% (Mumby and Edwards 2002) while in urban environments, where spectral variation may be huge, classification success may increase to 90% (Meinel et al. 2001). The accuracy of a classification is also affected by the number of classes included in the analysis. Generally, the more classes required in the classification, the lower the overall accuracy (Congalton and Green 1999).

Objectives of this research were to determine the feasibility of using high resolution Ikonos satellite imagery for classifying vegetation in semi-arid savanna vegetation and to develop a vegetation classification for semi-arid savanna suitable for small scale foraging studies.

Study Area

The study was conducted on the Harris Ranch (29º 15’ .020’’ N, 100º 5’ 54.01’’ W) located approximately 32 km west of Uvalde, Texas. The study area is located in a transitional zone between the Edwards Plateau and the South Texas Plains eco-regions. The southern Edwards Plateau region is dominated by shallow soils covering caliche (calcareous) subsoils with rough surface textures (Gould 1975). The northern South Texas Plains region is described as softly rolling terrain containing clay to sandy loam soil types. Elevation on the study site ranges from roughly 300 meters to 380 meters (USGS DEM). Weather records from the Texas Agricultural Experiment Station in Uvalde, TX show average rainfall to be 61.74 cm with a peak in June and another slight peak in September. The area is prone to drought conditions during late summer months.

The study site consists of the Prairie Pasture (849 ha) and the West Prong Trap (260 ha). Soil types occurring on the study site are described in Table 2.1. Range sites associated with these soil types include Shallow Ridge, Igneous Hill, Stony Ridge, Clay Loam, Clay Flats, and a small area of Loamy Bottomland. Shrub vegetation of these range sites are described following the Soil Conservation Service Soil Survey for Uvalde

County, Texas (Stevens and Richmond 1970). Shallow ridge range sites are characterized by mixed shrub communities predominantly consisting of purple sage (*Leucophyllum frutescens* Berl.), guajillo (*Acacia berlandieri* Benth.) and Texas persimmon (*Diospyros texana* Scheele.). Shrub vegetation occurring on Igneous Hill range sites includes mesquite (*Prosopis glandulosa Torr*.), whitebrush (*Alloysia gratissima* Hook), Texas persimmon, shrubby bluesage (*Salvia ballotiflora* Benth), and black brush (*Acacia rigidula* Benth.). Stony Ridge range sites contain shrubs such as guajillo, white-brush, black brush, prickly pear cactus (*Opuntia lindheimeri* Engelm.), and other mixed shrubs in less abundance. Clay Loam range sites are characterized by mesquite and chaparral type plants. Clay Flat range sites commonly have mesquite, white-brush, and some lotebush (*Ziziphus obtusifolia* Gray.). Drainage areas on the study site commonly contain live oak (*Quercus virginiana* Mill.), Hog plum (*Colubrina texensis*) and sugar hackberry (*Celtis laevigata* Willd) interspersed with mesquite and Texas persimmon.

Table 2.1. Soil types occurring in the Prairie and West Prong pasture ranked by land area

Soil Type	Abbreviation	Land Area (ha)	% Area
Devon	DE	3.6	0.32
Frio Clay Loam	FOA	4.0	0.36
Knippa Clay	KNA	44.7	4.03
Uvalde Clay Loam	UVB	52.8	4.76
Ector Rocky Outcrops	ERE	76.9	6.93
Montell_Clay	MOA	88.2	7.95
Ingram Stony Soils	IND	104.5	9.42
Ingram Gravelly Soils	IGC	294.6	26.57
Olmos Ector	OMB	439.3	39.62
Total Area		1108.7	

Materials and Methods

Ikonos satellite images were taken in June 2001. The images were taken during mid afternoon hours resulting in some shade lines on larger shrubs. Ikonos imagery comes standard geometrically corrected with a guaranteed horizontal accuracy of 15 meters CE and is delivered in 11-bit format. Five bands were acquired, 4 spectral bands (Blue, Green, Red, and Near Infrared (NIR)) and 1 panchromatic band. Color bands have a resolution of 4 meters and the panchromatic band has a resolution of 1 meter with all bands being delivered as individual files. Images are referenced using WGS (World Geodetic Survey) 84 datum and UTM (Universal Transverse Mercatur) coordinates.

Ikonos images in separate spectral bands and the panchromatic band were merged to form a multi-spectral image with 1-m resolution prior to starting the classification. An image of Normalized Difference Vegetation Index (NDVI) was created to aid in the classification process. NDVI are calculated using the formula ((NIR band – Visible Red band) / (NIR band + Visible Red band)) * 255. It was used to help differentiate shrub-dominated pixels from pixels containing a majority of bare ground or herbaceous cover.

Soil data for the study area were developed by digitizing the county soil survey maps using ArcView 3.2a (Environmental Systems Research Institute). The digitized polygons were used to create areas of interest (AOI) that corresponded to each individual soil type. Since vegetation classification was the primary objective, these polygons were edited to include areas adjacent to individual soil types that contained similar vegetation characteristics. The new polygons were also edited to reduce overlapping areas. These modified areas of interest were determined by *a priori* knowledge and studying the satellite imagery to determine areas of visual similarity.

Unsupervised classifications were conducted in each of the 9 soil type AOI's (Fig 2.1) using Erdas Imagine 8.5. Pixels were grouped into 50 different spectral classes that were subsequently used for the unsupervised classification. The one exception was Ingram Stony Soils where only 30 classes were used for the unsupervised classification.

Upon observing the data generated using 50 classes, it was determined by visual interpretation that 30 classes gave a more accurate representation of the vegetation occurring on this soil type. This difference may have occurred due to reducing variation between spectral assignments and allowing the classes to have more distinct characteristics.

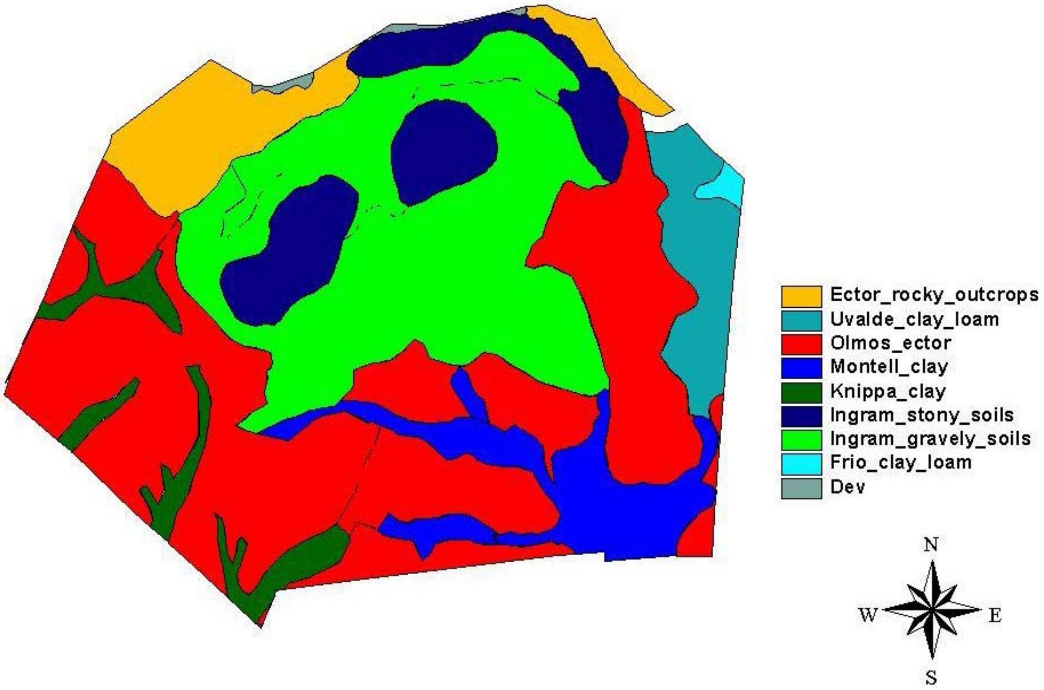

Fig. 2.1. Spatial position of soil types occurring in the Prairie and West Prong pastures.

Training classes were collected during the summer of 2001 with a Trimble TSC1 (Trimble Incorporated) following the acquisition of the remotely sensed images. Classes of training data had several different tree and shrub species including oak, white-brush, blackbrush, guajillo, purple sage, and mesquite. Training data was used only as an aid in the classification due to insufficient samples in each class of vegetation and most of the training data was acquired post image acquisition after many forbs present had senesced. Separation matrices used on unsupervised classifications of vegetation occurring on soil types proved to be more efficient for distinguishing vegetation classes when the entire study area was considered. Separability matrices determine the spectral relationship between classes formed during unsupervised classification. Several matrices exist with variations on separation formulas used to calculate final class relationships, and the transformed divergence separation matrix was chosen for this study because of its ease of application to determine breakpoints in the spectral data. Transformed divergence matrices are based on a covariance weighted distance between spectral class means with possible values ranging from 0 through 2000 (Lillesand and Kiefer 2000) with lower values representing a closer relationship between classes and values closer to 2000 representing greater spectral separability. Classes are separated based on these relationship values and user discretion. The break point at which to separate classes as spectrally different is subjective and is often determined by visual observation of the remotely sensed image (Erdas Field Guide 1999). Once a classification is completed, a classification accuracy assessment is run to determine the percent of pixels classed accurately. When a classification accuracy assessment is low, this demonstrates that some classes either are not separable or are separable and need to be re-classed. Classifications are generally considered acceptable when accuracy approaches 85% (Anderson et al. 1976, Congalton and Green 1999).

Ground truthing is the process of verifying the classified image against randomly selected and sampled ground control points. Sampling consists of navigating to the exact point location and recording the shrub species present or bare ground if no shrub is present. Random points are essential for accuracy assessment to limit user bias in collection of points located in easily accessible areas. Random points were generated in ArcView 3.2a, with location attributes set to be at least 5 meters from soil type boundaries and other ground truthing point locations. Ground truthing points were otherwise randomly selected, and were not stratified across the soil types. Ground truthing points were then downloaded to a Garmin e-trex legend GPS unit that was used to navigate to the area of the control point. Prints of the satellite image were then used to determine the exact location of the ground control points. Initially, shrubs and surrounding vegetation were mapped to strengthen classification accuracy. Due to collection bias, this technique was not used in the classification accuracy assessment but did give user confidence in the accuracy assessment based on visual comparison of classified images and mapped areas corresponding to ground control points. Digital photographs were taken for each ground control point to reduce return field trips and to observe surrounding vegetation to get the best possible classification. One meter pixel size demands increased thoroughness of ground control data collection. To help correct for GPS and user error in ground truth collection, ½ meter buffers were used for the final classification accuracy assessment. A buffer with a ½ meter radius was applied to each ground control point to reduce small scale error in data collection and software processing.

After ground control points for each soil type were collected and suitable classification accuracy obtained, the final classification image was created. This image was used for the habitat selection study in chapter III. The final classified image was created by merging (stacking) the individual images from each soil type into 1 image file that provides a continuous map of the study site with all described vegetation classes present.

Results

Results of the classification process varied for the different soil types. Producer's and user's accuracies were calculated for each individual vegetation class within each soil type. Producer's accuracy is obtained by taking the number of points classified correctly for a class divided by the number of ground control points in that class whereas the user's accuracy is the number of points classified correctly for a class divided by the number of points classified as that class (Congalton and Green 1999). Errors of commission occur when points are included into a category in which they do not belong whereas an error of omission occurs when points are excluded from a class that they should be grouped in.

Table 2.2. Classification accuracy assessment by soil type for the Prairie and West Prong pasture

Soil Type	Vegetation Class	Reference Total	Classified Total	# Correct	Producers Accuracy	Users Accuracy
De	Mixed brush	29.0	25.0	22.0	75.9	88.0
	Oak	0.0	2.0	0.0	0.0	0.0
	Bareground	21.0	23.0	18.0	85.7	78.3
	Total	50.0	50.0	40.0	80.0	80.0
Ere	Mixed brush	28.0	33.0	25.0	89.3	75.8
	Oak	5.0	4.0	3.0	60.0	75.0
	Bareground	13.0	9.0	7.0	53.9	77.8
	Total	46.0	46.0	35.0	76.1	76.1
Foa	Mixed brush	7.0	8.0	6.0	85.7	75.0
	Mesquite/ whitebrush	14.0	14.0	13.0	92.9	93.9
	Bareground	4.0	3.0	3.0	75.0	100.0
	Total	25.0	25.0	22.0	88.0	88.0
Igc	Mixed brush	19.0	24.0	16.0	84.2	66.7
	Mesquite	6.0	3.0	2.0	33.3	66.7
	bareground	25.0	23.0	20.0	80.0	87.0
	Total	50.0	50.0	38.0	76.0	76.0
Ind	Mixed brush	15.0	16.0	14.0	93.3	87.5
	Mixed brush 1	6.0	7.0	6.0	100.0	85.7
	Bareground	29.0	27.0	26.0	89.7	96.3
	Total	50.0	50.0	46.0	92.0	92.0
Kna	Mixed Brush	20.0	23.0	17.0	85.0	73.9
	Mesquite	21.0	18.0	18.0	85.7	100.0
	Bareground	9.0	9.0	6.0	66.7	66.7
	Total	50.0	50.0	41.0	82.0	82.0
Moa	Mixed brush	25.0	26.0	23.0	92.0	88.5
	Oak	11.0	10.0	9.0	81.8	90.0
	Bareground	14.0	14.0	13.0	92.9	92.9
	Total	50.0	50.0	45.0	90.0	90.0

Table 2.2 continued

Soil Type	Vegetation Class	Reference Total	Classified Total	# Correct	Producers Accuracy	Users Accuracy
Omb	Mixed brush	26.0	25.0	21.0	80.8	84.0
	Texas persimmon	1.0	3.0	1.0	100.0	33.3
	Bareground	23.0	22.0	19.0	82.6	86.4
	Total	50.0	50.0	41.0	82.0	82.0
Uvb	Mixed brush	25.0	27.0	23.0	92.0	85.2
	Mesquite	12.0	11.0	10.0	83.3	90.9
	Bareground	13.0	12.0	11.0	84.6	91.7
	Total	50.0	50.0	44.0	88.0	88.0
Overall Accuracy		**421.0**	**421.0**	**352.0**	**83.6**	

These accuracy values, as well as the overall accuracy for all vegetation classes combined are presented in Table 2.2. Overall accuracy was derived by dividing the total ground control points classified correctly by the total number of ground control points collected multiplied by 100 to give the percent accuracy of the classification. A ground control point was considered correctly classified if a corresponding pixel of the same value was located within a ½ meter radius of the point.

The final classification was comprised of 7 vegetation classes occurring within the study area and a category that included bareground and herbaceous vegetation (Fig. 2.2). The vegetation classes were “guajillo, purple sage, and whitebrush”, “blackbrush, guajillo, and Texas persimmon”, “mesquite, whitebrush, Texas persimmon and guajillo”, “blackbrush and guajillo”, “mesquite, whitebrush, and desert willow”, “oak, whitebrush and Texas persimmon”, “bare ground and herbaceous”, and “guajillo and hog plum”.

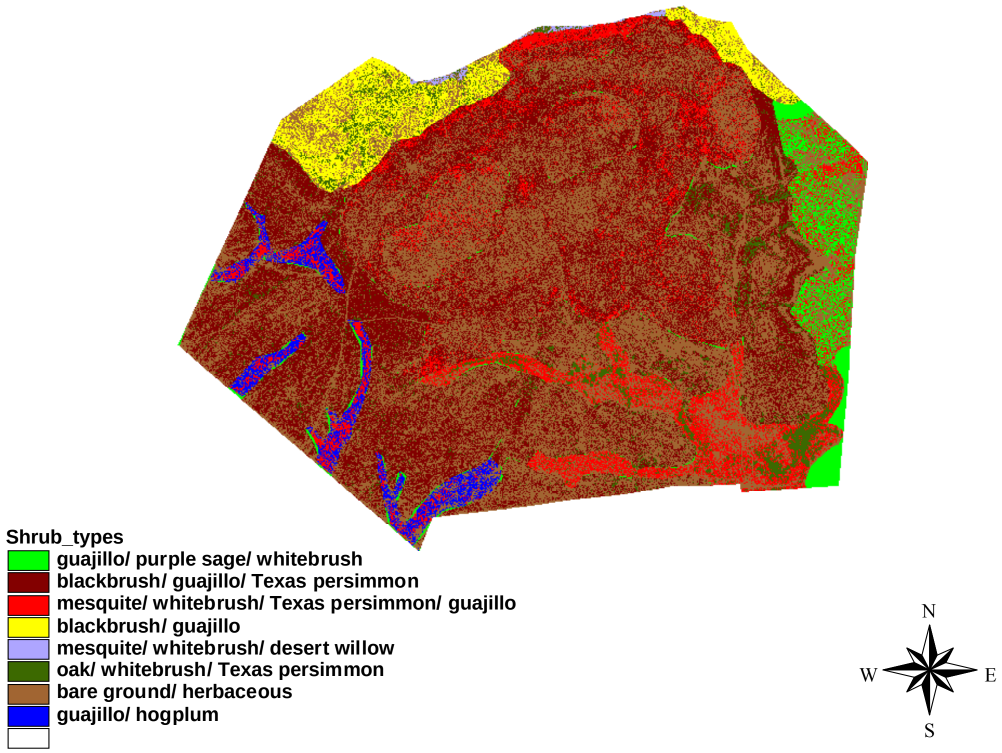

Fig. 2.2. Final vegetation classes derived from the unsupervised classification of the Prairie and West Prong pastures.

Discussion

Remote sensing has become a powerful tool in the study of plant communities (Sparrow et al. 1997, Aspinall 2002, Thomas et al. 2003). Improvements in satellite sensors have made plant community classification more feasible and increased the suitability of remotely sensed images for use in habitat studies and changes in vegetation patterns over time.

The use of printed satellite images to help locate precise ground control points increased user confidence in the final classification. This practice allowed data to be collected accurately despite the errors in geo-referencing and inherent inaccuracies of GPS navigation. Sources of error that could reduce classification accuracy include collection of ground control data by more than one observer, delayed collection of ground control data, errors in image interpretation at ground control points, and the classification scheme itself (Congalton and Green 1999). Multiple observers and errors in map interpretation, especially interpretation of maps in areas bordering 2 possible class assignments, are major problems in most remotely sensed classification accuracy assessments (Congalton and Green 1999). The amount of error that could be attributed to multiple observers was not tested in this study.

The simple random sampling method used to generate ground control points also has potential problems when accuracy assessments are conducted. The most common problem, and one observed in this study, is the generation of more points in the shrub community segments occupying more land area (Congalton and Green 1999, Lillesand and Kiefer 2000) in each soil type, leading to smaller samples in shrub communities occupying less land area. Labor and time constraints limit the number of total ground control points that can be collected. It is suggested that 50 ground control points be observed for each class in the classification scheme (Lillesand and Kiefer 2000), which would have resulted in 1350 total ground control points for the total study area if every community type occurring in each soil type was individually sampled. The consideration of time and manpower was addressed by generating 50 ground control points for each soil type leading to a total possible of 450 ground control points. The Ector rocky outcrop soil type only had 46 ground control points due to inaccessible terrain. The Frio clay loam soil type had very little area in the study pasture and therefore only 25 ground control points were tested. Other methods of generating ground control points also have potential problems that could affect accuracy assessment results. These methods include stratified random sampling that tests each class in the classification, however the classification must be complete before the ground control points can be generated causing the ground control points to be collected late in the process (Congalton and Green 1999). In this study, ground control points were collected before the final classification was complete.

Given the poor initial accuracy assessment, remotely sensed images and the ground control points were carefully examined to determine the potential sources of error. Several sources of error were isolated by observing the ground control point values and the classified values of the image. First, the ERDAS 8.5 software had errors in the accuracy assessment tables it generated. The software actually showed the ground control point to be present in a pixel correctly corresponding to the ground control point however the accuracy assessment table showed the 2 values to be different. The source of this error could not be determined by visual observations of the image or coordinate system used. The 2nd observation of interest was the proximity of ground control points to corresponding vegetation clumps. Although the use of printed images helped in locating ground control locations, the 1 meter resolution of the images still made exact location difficult to identify. When the ½ meter buffer was applied to the computer generated ground control points, the corresponding accuracy assessment increased from 71.29 to 83.6%. This substantial increase in accuracy indicates that current accuracy assessment has inherent errors and that more work needs to be done to determine the appropriate buffer distance for such an assessment approach.

Conclusion

Ikonos satellite imagery provided adequate spatial and spectral details for classification of vegetation types occurring in south Texas temperate savanna grasslands for use in habitat utilitization studies. Small pixel size led to possibly decreased accuracy due to both user error in ground control point acquisition and errors in geo-referencing of the satellite images. Final classification accuracy of 83.61% was acceptable for the proposed uses of this classification. Generally, 85% classification accuracy is considered acceptable for studies although the level of accuracy required is dependent on the type of use of the classification. Final vegetation classes were developed using *a priori* knowledge of ecological sites as well as training data collected shortly after Ikonos satellite imagery was acquired.

Using fewer shrub classes would lead to higher classification accuracy but did not yield a fine enough classification for the desired habitat assessment. Ecological sites occurring within each soil type were grouped individually, resulting in sharp boundaries along perimeters of soil types. Transition zones could possibly be isolated as individual vegetation classes, but accuracy typically declines when more classes are included and increased field collection of ground control points was prohibitive.

CHAPTER III

HABITAT SELECTION AND PASTURE UTILIZATION BY WHITE-TAILED DEER AND CATTLE

Cattle and white-tailed deer (*Odocoileus virginianus texanus* Raf.) are economically important to southwest Texas landowners, with beef cattle economic value estimated at $212 million dollars and economic value for hunting estimated at $48 million dollars in the Edwards Plateau for 2000 (Wyse and Anderson 2000). Leasing potential for hunting in Texas has long been recognized (Berger 1973) and has become a substantial additive income to traditional livestock production practices on many ranches.

Recent trends in Texas land ownership have been toward recreation and away from traditional agricultural uses (Wilkins et al. 2000). As land fragmentation and changing agricultural use patterns of rangelands occur, management for indigenous and domestic species will also change. The trend toward land as an aesthetic investment will increase the importance of wildlife habitat management and the need for compatibility with livestock grazing. There is a clear need for knowledge of how these economically important ungulates use their respective environments before management can responsibly be applied.

Many factors affect the use of landscapes by livestock and wildlife. Cattle use areas differently due to terrain characteristics, water availability, mineral placement, and manmade structures (Cook 1966, Roath and Krueger 1982, Senft et al. 1987, Owens et al. 1991). Cattle utilization of pastures can also be affected by brush abundance under varying biomass conditions (Owens et al. 1991) and selection of travel routes requiring less physical exertion can also affect animal distribution in pastures (Ganskopp et al. 2000). Forage distribution, forage quality and plant associations also play a significant part in cattle distribution throughout pastures (Roath and Krueger 1982). Periodic spot grazing by herbivores may keep forage in early developmental stages, enhancing palatability later in the growing season (McNaughton 1984).

Physical features of landscapes and environmental elements influence white-tailed deer selection of plant communities, but not always in a predictable manner. White-tailed bucks selected relatively open areas of *Hilaria*, *Leucophylum*, and *Acacia-Celtis* vegetation types (5-118 ind/ha) in northeastern Mexico during times when thermal stress was expected (Bello et al. 2001) whereas shrub communities with high canopy cover (>85%) and high woody species diversity were selected in south Texas (Pollock et al. 1994). In a more northern environment, white-tailed deer did not exhibit a preference for certain habitats for most of the year, except that use of swamps, bogs, and herbaceous areas increased during the winter at the expense of forested areas. Temperature influenced diel movement patterns in winter and summer months, with animals being active at periods to avoid temperature extremes.

Recent advances in tracking equipment have made the study of animal habitat selection and movement analysis more efficient. Satellite imagery resolution, Global Positioning Systems (GPS), and Geographic Information Systems (GIS) have made it possible to observe animal behavior patterns with higher resolution than was previously available to researchers (Vavra and Ganskopp 1998, Ganskopp et al. 2000). These new technologies were used to to define spatial use of plant communities by cattle and white-tailed deer in southwest Texas. GPS collars on individual animals allowed behavior to be monitored without human interference thereby reducing potential bias based on an individual animal's level of tolerance to human activity.

Materials and Methods

Pasture Attributes

Pasture attributes of the Prairie pasture (1109 ha) on the Harris Ranch (29º 15' .020'' N, 100º 5' 54.01'' W) were mapped and recorded during winter 2001 by a variety of methods, with the final product being an Arcview GIS database. A detailed description of the study pasture is in Chapter I.

Roads were mapped using a Trimble TSC1 Global Positioning System (GPS) with real time differential correction offered by Omnistar. All terrain vehicles were used to map roads in the study area. Perimeter fences had been digitized previously using United States Geological Survey (USGS) Digital Ortho Quadrat (DOQ) images. Corrections and fence additions were mapped using the Trimble TSC1 GPS unit. The digitized locations previously collected and the new fence additions were merged in Arcview 3.2a. Watering locations were collected using the Trimble unit described above with the same differential correction system. Watering locations considered in this study were permanent man-made fixtures and provided watering opportunities for cattle and deer at all times during the trial periods. Natural water locations were seasonal and were not considered significant or monitored in this study. Soybean feeders constructed to supplementally feed white-tailed deer were also included in the analysis to determine their effect on pasture use by white-tailed deer. All feeders were erected prior to the trial period by the landowner and were enclosed to deter cattle use of the soybean products. Since cattle were not allowed access to the feeders, no analysis was run to determine effect of these feeders on cattle behavior.

Three cows and 3 white-tailed deer were observed during a spring, summer, and winter trial during 2001 and 2002. Four deer were used during the summer trial due to collar availability. Animal locations were recorded using Lotek (Lotek Inc.) 2200 Global Positioning System collars. The GPS collars used in these trials were capable of recording 5000 animal locations before downloading of data was required. When differential correction was applied, reported accuracy of individual animal locations was within ± 5 meters (Lotek Inc.). Each collar was constructed with activity sensors that detect both horizontal and vertical movements of the collar. These movements were summed over a 4 minute interval and then averaged for the hourly observation. Three trials were conducted to record samples taken during different seasons. Trials were conducted in May and June of 2001 (spring), August and September 2001 (summer), and mid-January to mid-March 2002 (winter). All trials were 40 days long and incorporated five 8-day segments. Each segment allowed a 3 day interval of observations collected every 5 minutes followed by a 5 day period of hourly observations. This sampling scheme allowed a longer total collection time (40 days) thereby reducing autocorrelation between intense sampling periods as well as increasing the field life of the collar batteries.

For analysis of spatial distribution of cattle and white-tailed deer locations, hourly data collected during 5 day periods were used to determine animal locations in relation to roads, watering points, fences, and (in the case of white-tailed deer) supplemental feeders. Data collected during intense 3 day sampling periods was not used in this study, but was used in a study of animal movement patterns (see Chapter IV). A maximum potential sample size of 600 locations was possible for each collar, although malfunction of collars sometimes limited this.

Habitat Selection

Habitat selection analysis involved several steps. First, Ikonos satellite imagery was processed and classified to 7 different plant associations (see Chapter II). One class identified as bare ground/ herbaceous cover was also created and represented interspace areas where no shrub canopy was present. The second step was to create buffers around each individual animal location and determine the shrub associations occurring within each buffer. A buffer with a 10 m radius was used as the area around the animals location that could be in the animals view shed (Cooper, pers. comm.). Step 3 involved calculating the percentage of each shrub association occurring around each animal location from the image analysis.

Observations were separated into 2 activity categories for cattle and deer. The 2 categories were active and inactive for both cattle and deer and represented periods of foraging and traveling (active), and periods of resting and light movements (inactive). Cattle activities were classed as active when the hourly average of the horizontal movements of the collars were >130 movements/ 4 minute period while periods with an hourly average of <130 horizontal movements/ 4 minutes were classed as inactive (R.K. Lyons, pers. comm.). Deer activities were also classified as active or inactive, but were determined by plotting the average activity sensor values over a 24 hour period. Time periods with higher horizontal movements were considered active while periods with noticeably lower activity periods were considered inactive. Horizontal activity readings varied by season and by collar, however an average hourly reading of >40 movements/ 4 minute period generally was used to define heightened activity. White-tailed deer active periods were from 2000-0600 (military time) for the spring trial, 1800-0700 for the summer trial, and 1800-2100 as well as 2300-0900 for the winter trial. The winter trial showed a drop in activity for the 2200 time period, so these were excluded from the analysis. All other time periods were considered inactive.

Statistical Analysis

Pasture Attributes

The frequency distribution of the observed distances to water, roads, feeders, and fences were compared to the distribution of randomly generated points within the pasture and to the population level distribution of pixels in the pasture. For each pasture attribute, a random sample of 600 points was taken in the GIS database, the distance to the closest pasture attribute was calculated, and then the frequency distribution was constructed using a 100m interval; smaller intervals were calculated but resulted in noisy distributions. This sampling procedure was repeated 25 times and the mean number of locations was calculated for each distance class to represent the random distribution. Additionally, the distance from each pixel in the GIS database to each pasture attribute was calculated to represent the population level distribution. If the animals were using the pasture randomly, then the random distribution should not have been significantly different than the observed values. A Chi-square analysis of frequency (Sokal and Rolf 1973) was conducted for each pasture attribute and each animal species.

Habitat Analysis

Habitat data was analyzed in a three step process. First, the composition and percentages of shrub associations for each 10 m buffered area for each animal location was calculated based on the 8 vegetation classifications from the ERDAS analysis. Each animal location was described by the vegetation classification. Second, these data were entered into a cluster analysis (McCune and Mefford 1995) in the PC-ORD software program to determine the percentages of each shrub association and the mixtures of these associations that were important to deer and cattle. Finally, the cluster information was merged with the activity level for each location and a categorical analysis of variance (CATMOD) was conducted to test how clusters of shrub associations were used in both active and inactive time periods for both cattle and deer across the 3 seasons.

Results

Pasture Attributes

Frequency distributions of the distances of animal locations to all the man-made structures were significantly different from the expected randomly distributed points and from the distribution of all points within the pasture at $\alpha=0.05$ (appendix A and B), with the exception of a single cow (collar 88) during the winter trial ($X^2=7.75$). This single cow's results for distances to roads were not significantly different from the random distribution.

During the spring trial, cattle were 9 times more likely to be found within 100 meters of water than the random distribution (Fig. 3.1) while in the summer trial cattle were 10 times more likely to be found within 100 meters of water than the random distribution (Fig. 3.2). Cattle did not exhibit any clear pattern of use or non-use at distances greater than 100m from water during the spring and summer trials. Results from the winter trial were mixed and included 6 cows. Cattle were moved 2 weeks into the trial due to calving and the grazing rotation. Three cattle from the incoming herd were already collared with exactly the same sampling sequence hence the GPS locations from those cows were used to complete the winter trial. Overall, the cattle used the pasture in a non-random manner, but 4 animals used the pasture away from known water locations while the remaining animals showed no clear trend in pasture use (Fig. 3.3). White-tailed deer showed less use of areas around water than was expected. The spring trial (Fig. 3.4) showed deer used areas moderately distant from available water (300-1500 meters). Summer and winter results showed a trend towards pasture use away from water areas (Figs. 3.5 and 3.6).

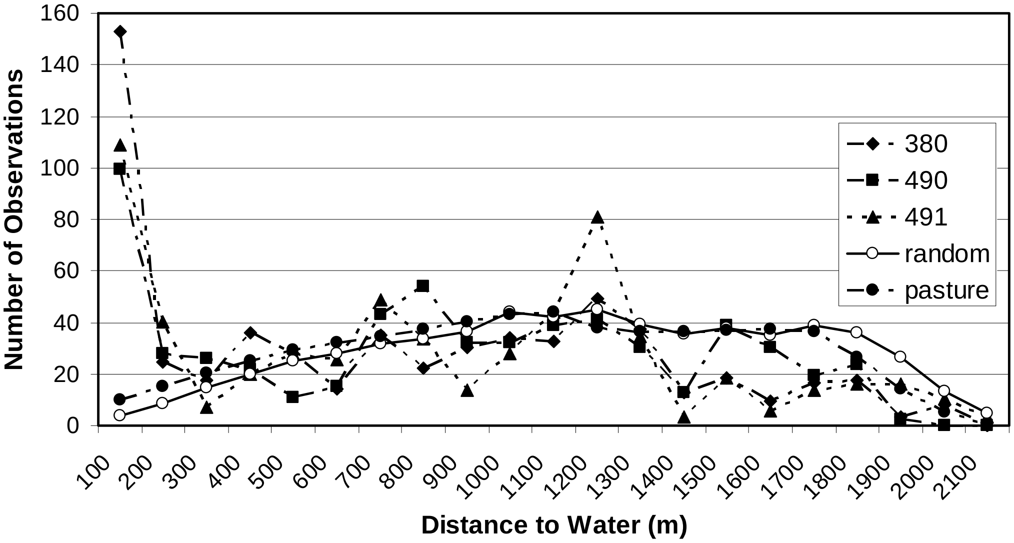

Fig. 3.1. Distance from water for animal observations (380, 490, and 491), random samples, and pasture level sampling for cattle in the spring of 2001 in a temperate savanna.

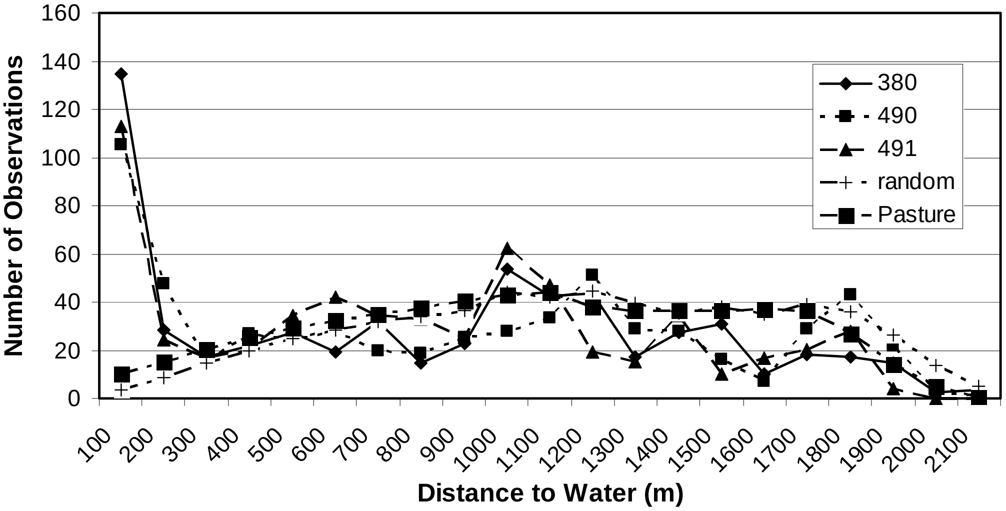

Fig. 3.2. Distance from water for animal observations (380, 490, and 491), random samples, and pasture level sampling for cattle during the summer of 2001 in a temperate savanna.

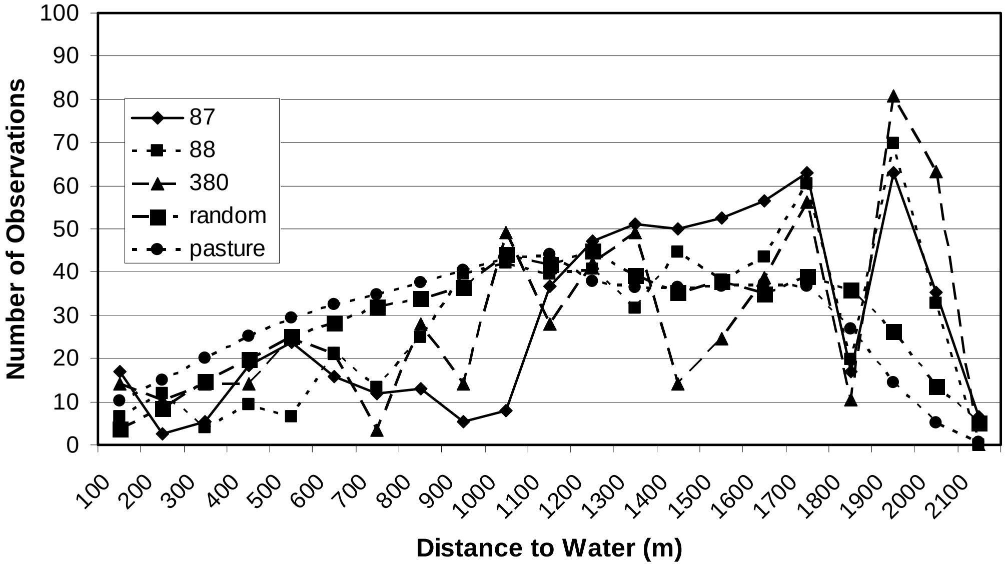

Fig. 3.3a. Distance from water for animal observations (87, 88, 380), random samples, and pasture level sampling for cattle during the winter of 2002 in a temperate savanna.

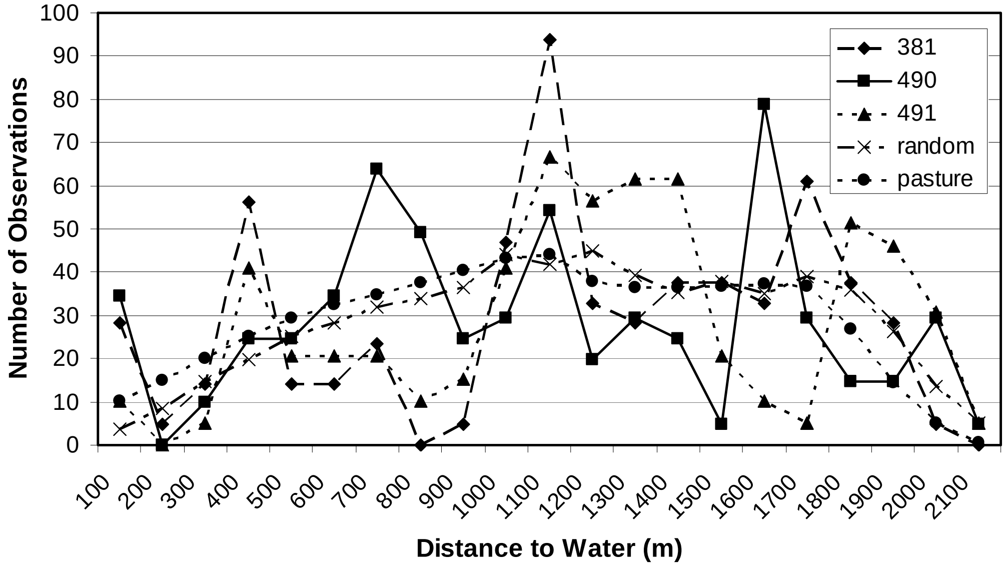

Fig. 3.3b. Distance from water for animal observations (381, 490, and 491), random samples, and pasture level sampling for cattle during the winter of 2002 in a temperate savanna.

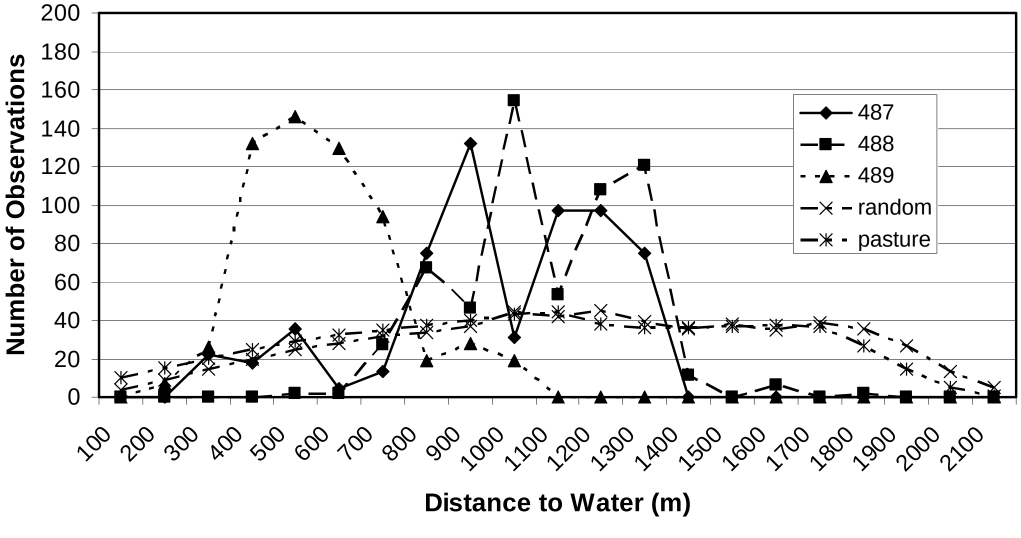

Fig. 3.4. Distance from water for animal observations (487,488, 489), random samples, and pasture level sampling for deer during the winter of 2001 in a temperate savanna.

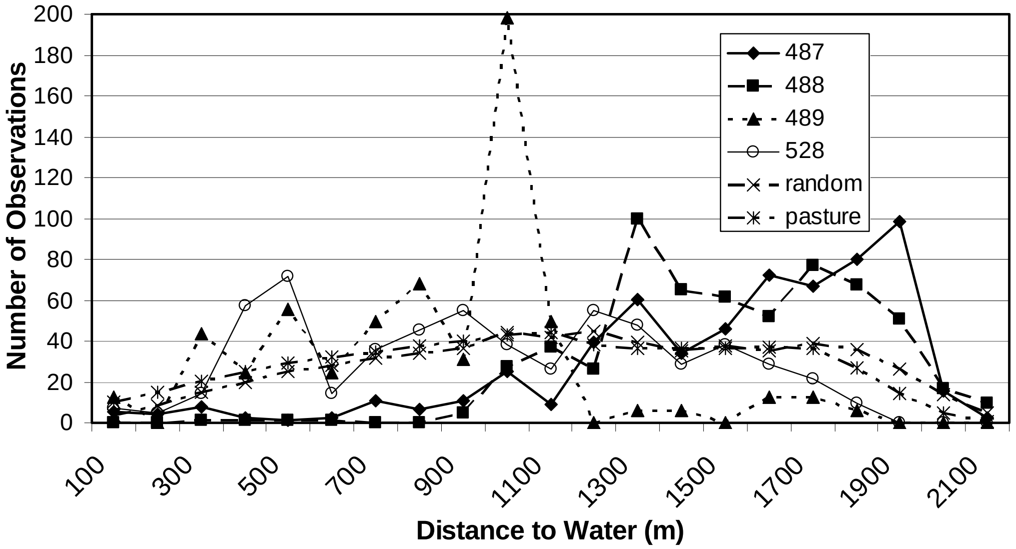

Fig. 3.5. Distance from water for animal observations (487,488, 489, and 528), random samples, and pasture level sampling for deer during the summer of 2001 in a temperate savanna.

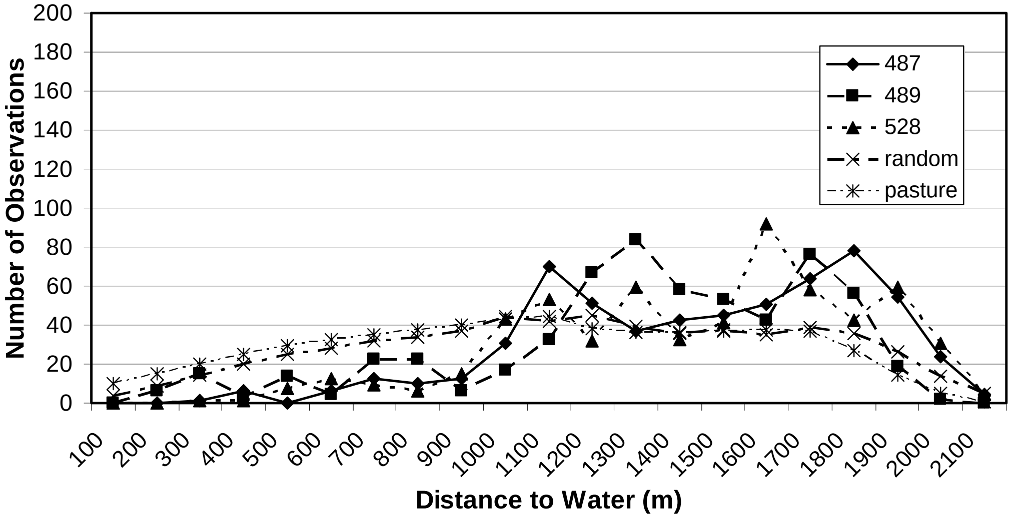

Fig. 3.6. Distance from water for animal observations (487, 489, and 528), random samples, and pasture level sampling for deer during the winter of 2002 in a temperate savanna

Roads in the pasture are well distributed with the furthest distance to a road being less than 600 meters. Roads did have a significant effect on cattle distribution during the spring and summer trials where animals were more likely to be found in areas within 100 meters of roads (Fig. 3.7 and 3.8). Winter trial results for cattle showed no trends and followed closely to the random distribution when visually compared (Fig 3.9a and 3.9b). Cow collar 88 was not significantly different from the random distribution(X^2=7.75) (Figure 3.9a). Visual interpretation showed increased use of areas within 100 meters of roads by white-tailed deer during the spring trial (Fig. 3.10). No clear patterns were noted when charts were visually compared for the summer trial (Fig. 3.11). Deer used areas within 100 meters of roads less than would be expected under a random distribution during the winter trial (X^2=46, Fig. 3.12)

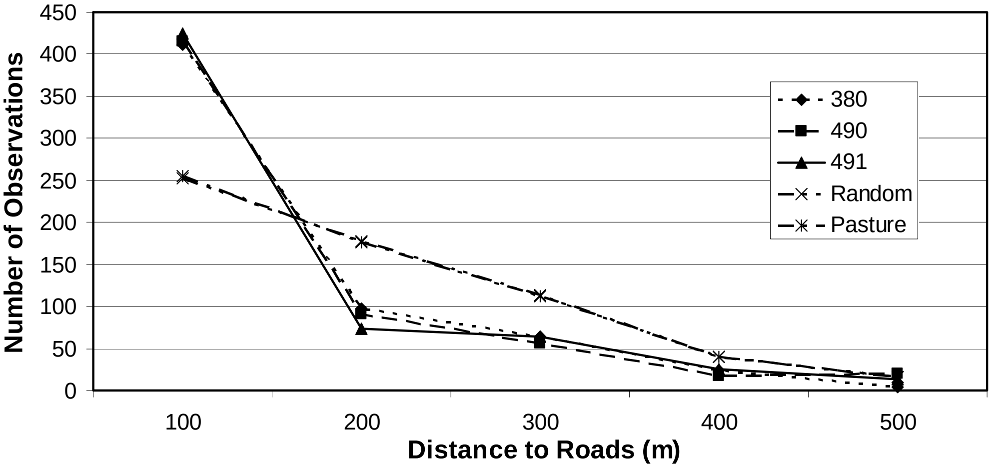

Fig. 3.7. Distance from roads for animal observations (380, 490, and 491), random samples, and pasture level sampling for cattle in the spring of 2001 in a temperate savanna.

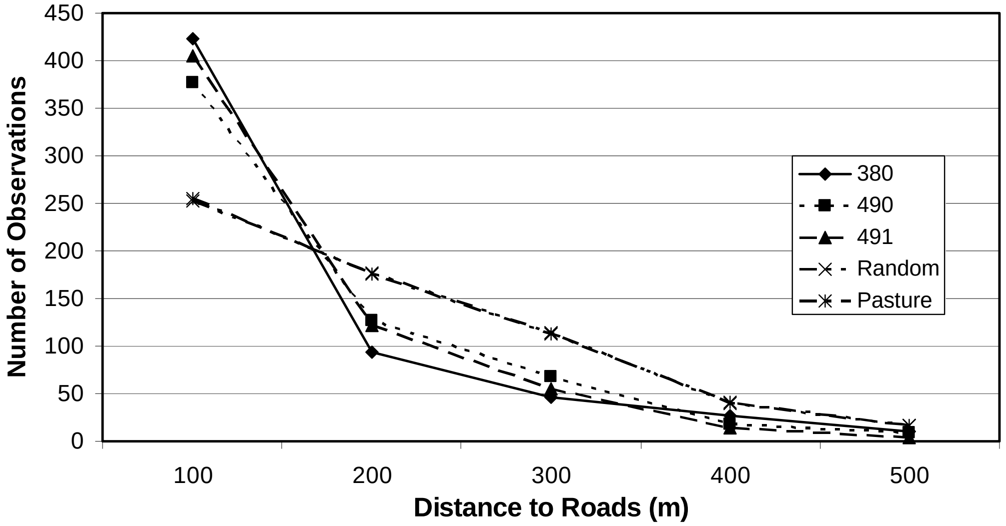

Fig. 3.8. Distance from roads for animal observations (380, 490, and 491), random samples, and pasture level sampling for cattle during the summer of 2001 in a temperate savanna.

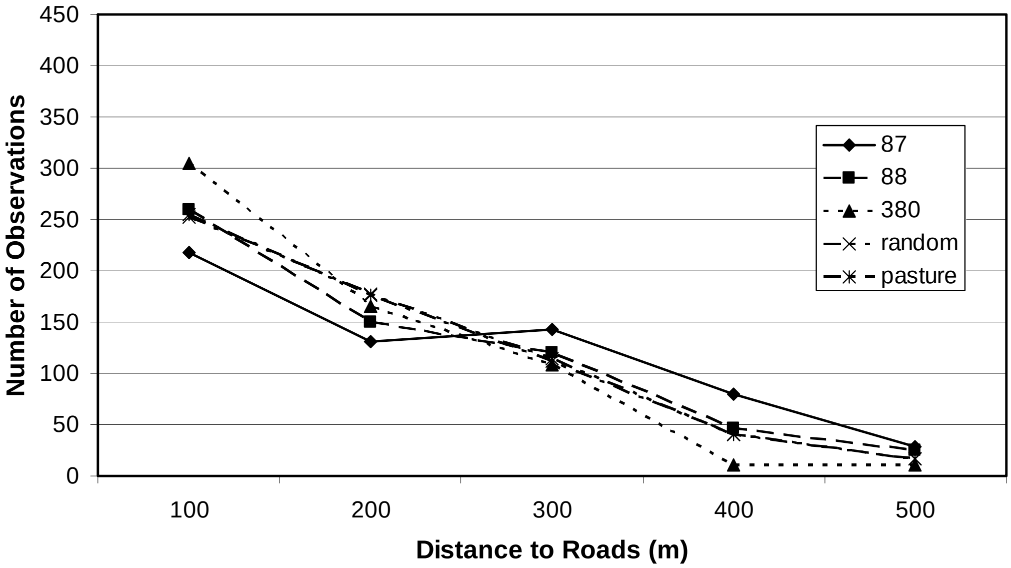

Fig. 3.9a. Distance from roads for animal observations (87, 88, and 380), random samples, and pasture level sampling for cattle during the winter of 2002 in a temperate savanna.

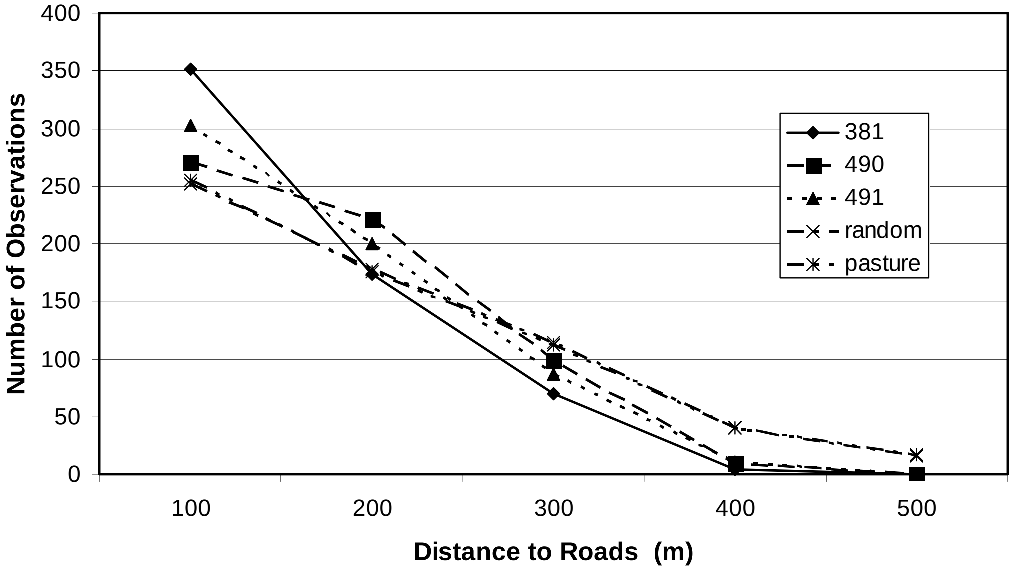

Fig. 3.9b. Distance from roads for animal observations (381, 490, and 491), random samples, and pasture level sampling for cattle during the winter of 2002 in a temperate savanna.

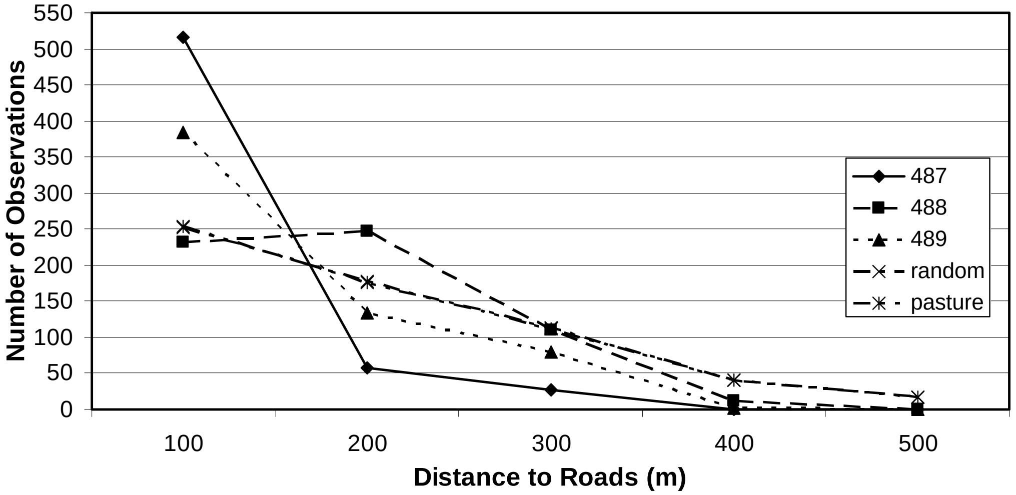

Fig. 3.10. Distance from roads for animal observations (487,488, 489), random samples, and pasture level sampling for deer during the spring of 2001 in a temperate savanna.

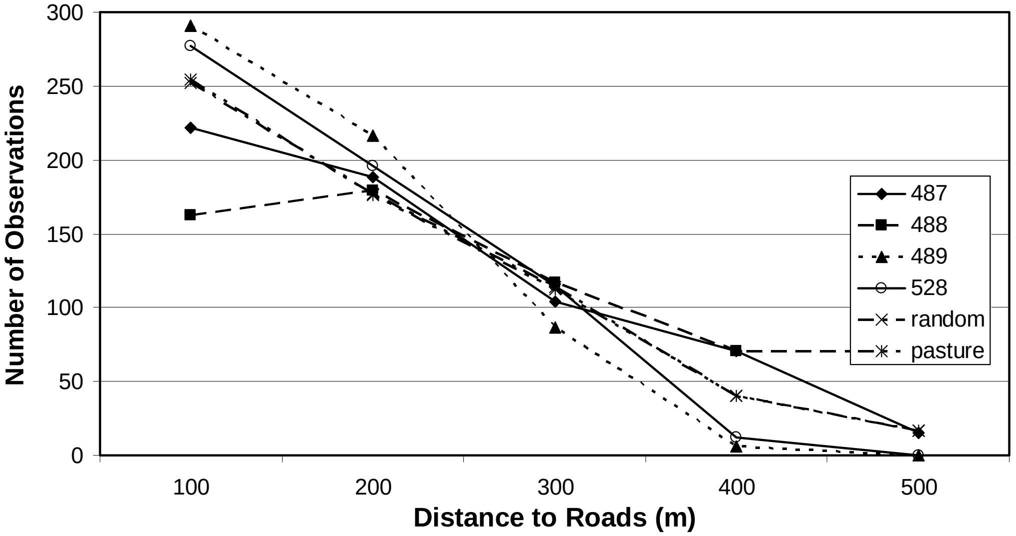

Fig. 3.11. Distance from roads for animal observations (487,488, 489, and 528), random samples, and pasture level sampling for deer during the summer of 2001 in a temperate savanna.

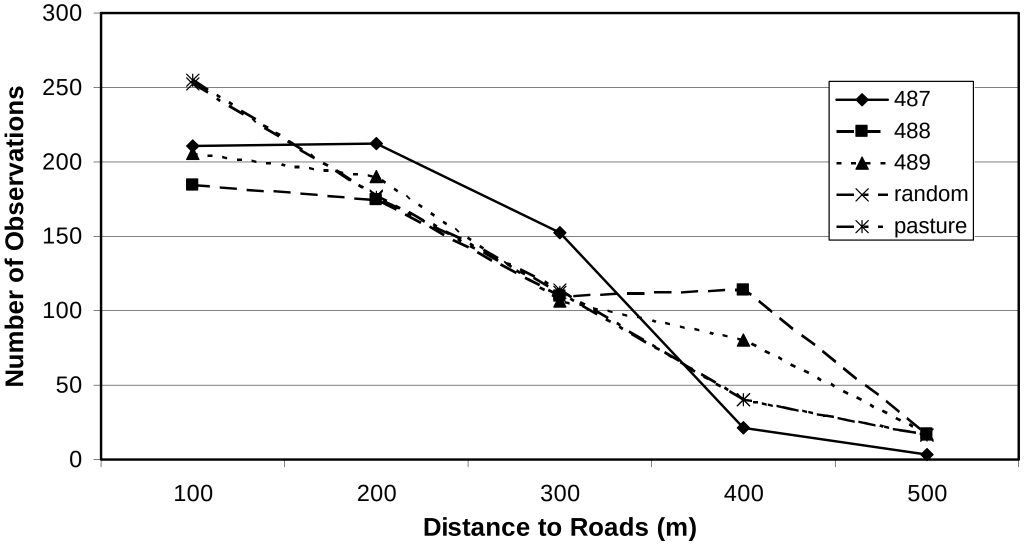

Fig. 3.12. Distance from roads for animal observations (487,488, 489), random samples, and pasture level sampling for deer during the winter of 2002 in a temperate savanna.

Fences in the pasture were mostly perimeter fences, with 2 short interior fences. Most of the fences were adjacent to a road so there was a slight degree of confounding between road and fences, but there were far fewer fences than roads so separate analyses were conducted. During the spring and summer trials, cattle were observed within 100 m of a fence more often than was expected for the random distribution (X^2 >83, Fig. 3.13 and 3.14). During the winter trial, 4 of the 6 collared cattle used areas of the pasture that were centrally located away from fence lines (Figs. 3.15a, 3.15b). Deer also showed a seasonal trend towards interior pasture use. During the spring, deer used pasture areas within 300 meters of fences more than expected under a random grazing distribution (Fig. 3.16). The summer trial (Fig. 3.17) results indicated no clear trends in deer locations in relation to fences however individual animals had high use in areas between 400 and 1000 meters from a fence. A trend toward pasture use in median to high distance categories (400-1000 meters) was also present during the winter trial (Fig. 3.18).

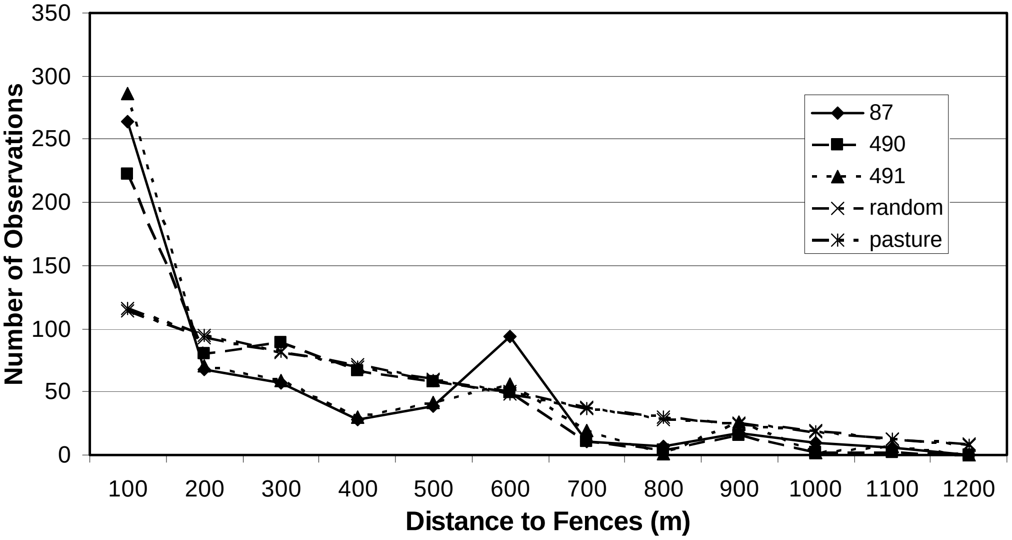

Fig. 3.13. Distance from fences for animal observations (87,490, and 491), random samples, and pasture level sampling for cattle during the spring of 2001 in a temperate savanna.

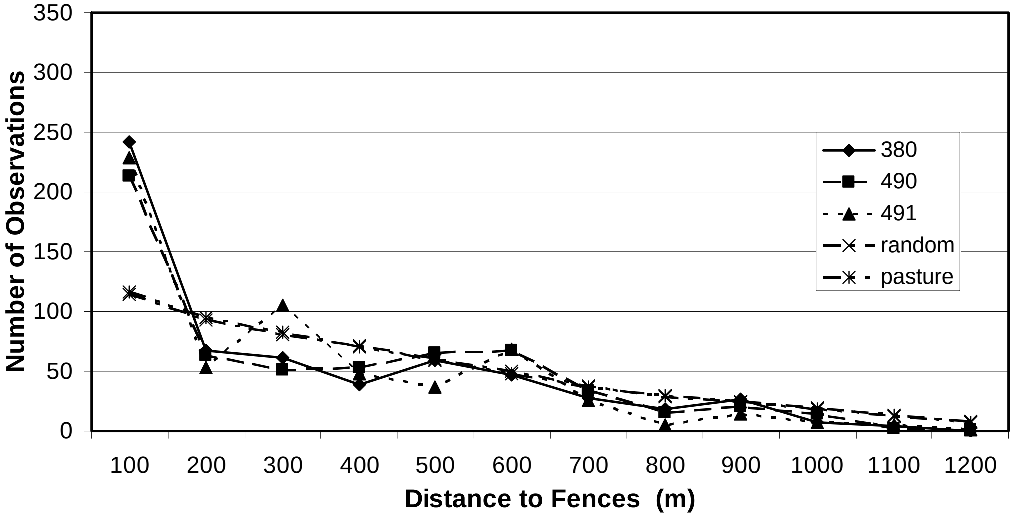

Fig. 3.14. Distance from fences for animal observations (380,490, and 491), random samples, and pasture level sampling for cattle during the summer of 2001 in a temperate savanna.

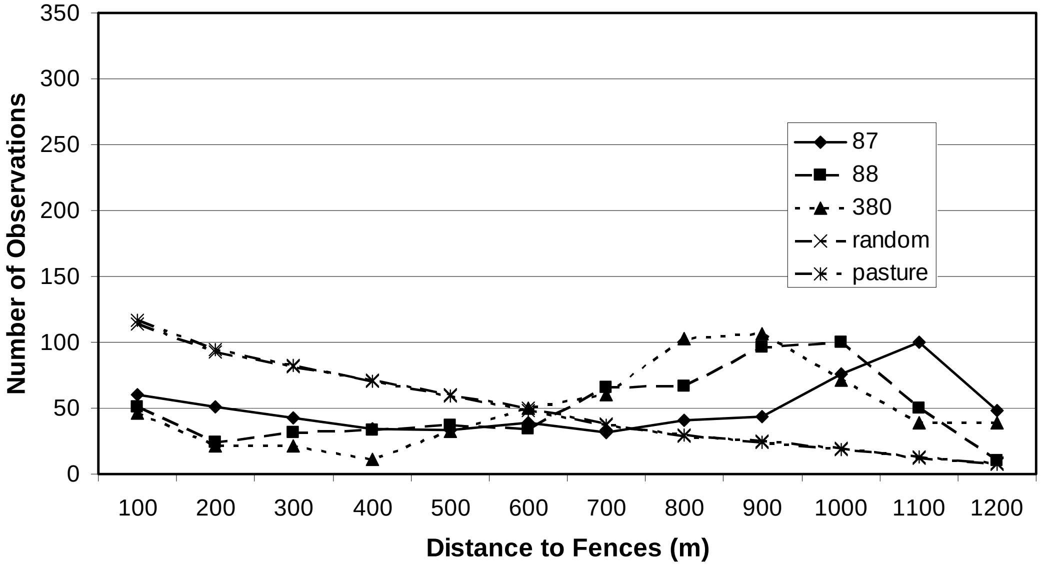

Fig. 3.15a. Distance from fences for animal observations (87,88, and 380), random samples, and pasture level sampling for cattle during the winter of 2002 in a temperate savanna.

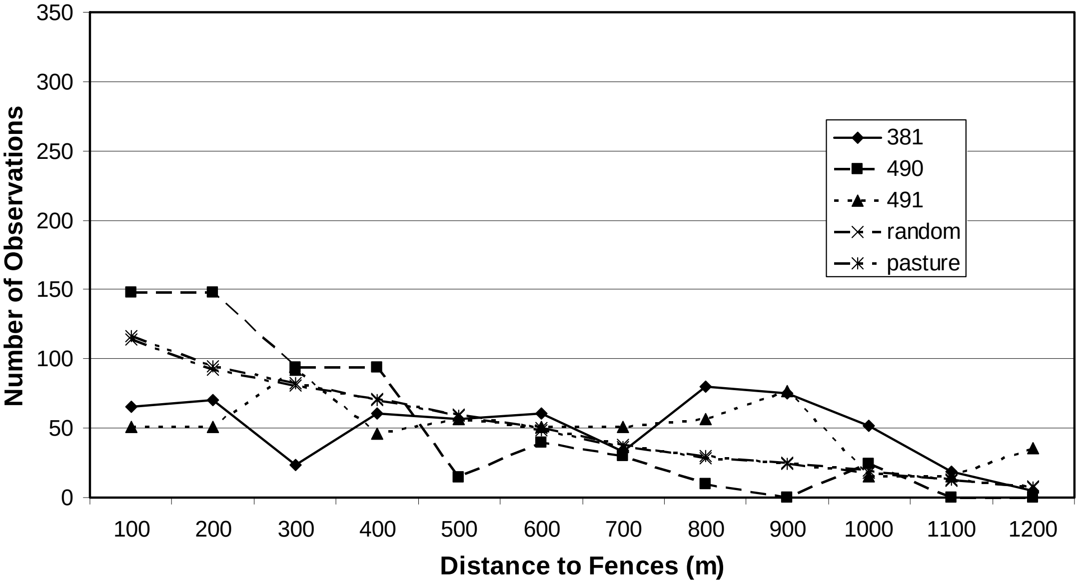

Fig. 3.15b. Distance from fences for animal observations (381,490, and 491), random samples, and pasture level sampling for cattle during the winter of 2002 in a temperate savanna.

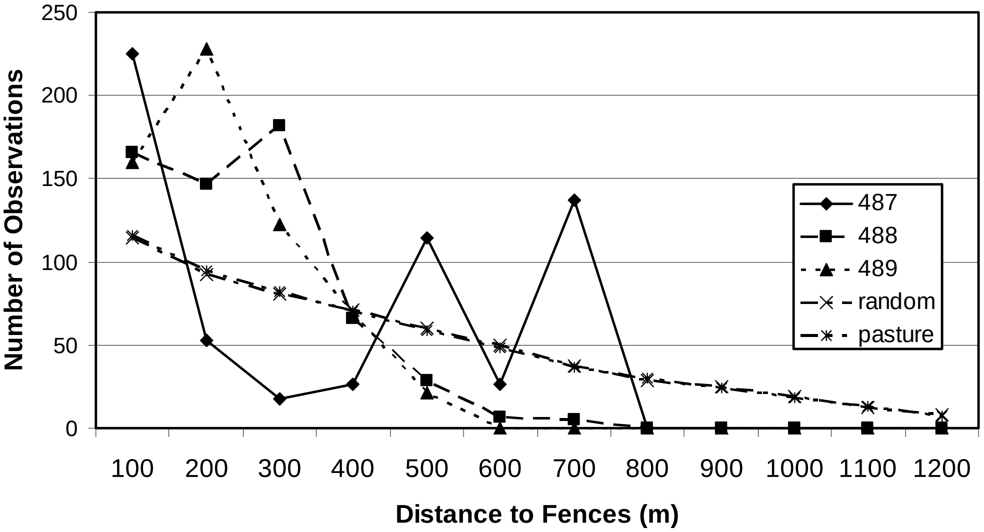

Fig. 3.16. Distance from fences for animal observations (487,488, 489), random samples, and pasture level sampling for deer during the spring of 2001 in a temperate savanna.

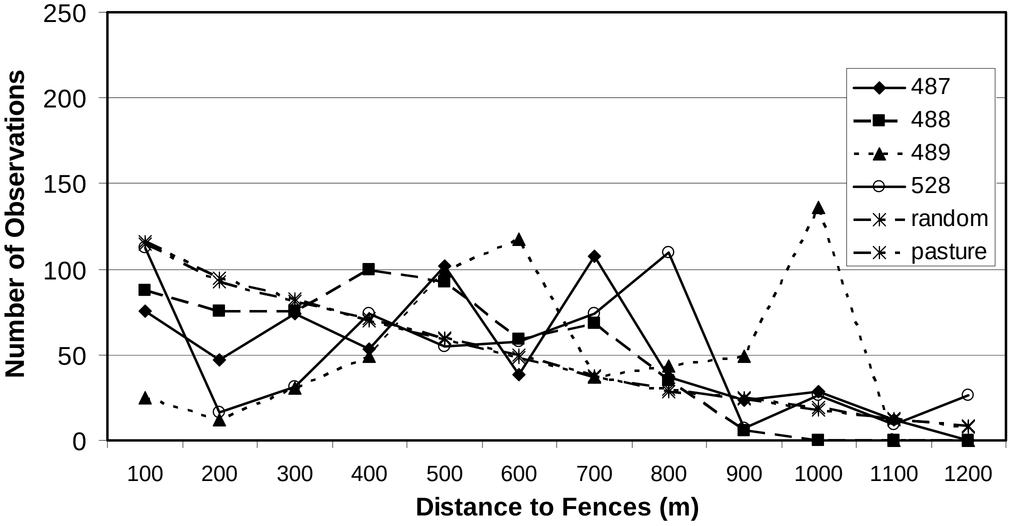

Fig. 3.17. Distance from fences for animal observations (487,488, 489, and 528), random samples, and pasture level sampling for deer during the summer of 2001 in a temperate savanna.

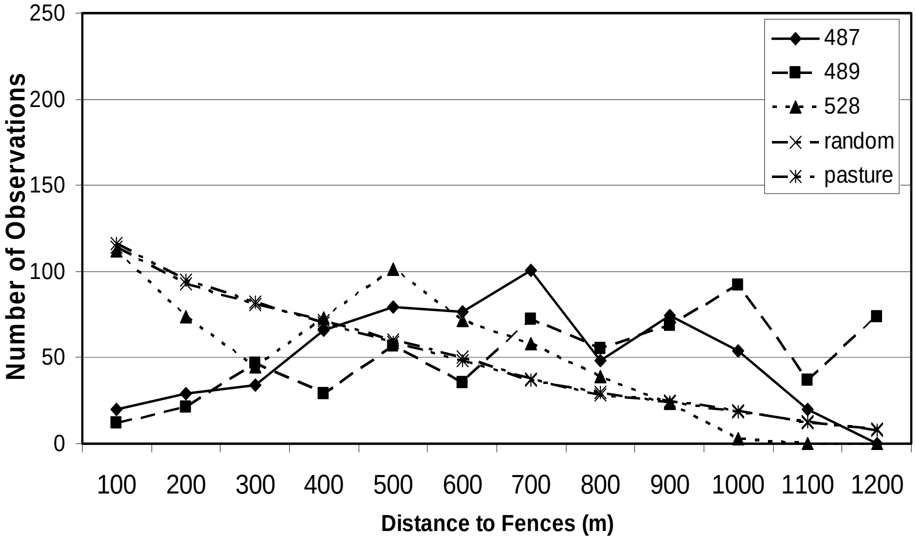

Fig. 3.18. Distance from fences for animal observations (487, 489, and 528), random samples, and pasture level sampling for deer during the winter of 2002 in a temperate savanna.

Deer locations in relation to existing soy bean feeders were also measured to determine how supplemental feeding affects animal distribution. Two of the deer (487 and 489) used areas within 600 meters of feeders while one deer (488) stayed in areas away from feeders entirely (X^2>209) (Fig. 3.19) during the spring trial. During the summer trial, all collared deer used areas away from the feeders, with one animal (489) extensively using areas around 1100 meters from feeders (X^2>152) (Fig. 3.20). Deer in the winter, used areas of the pasture close to the median distance for feeders in the pasture (900-1400m) (Fig. 3.21).

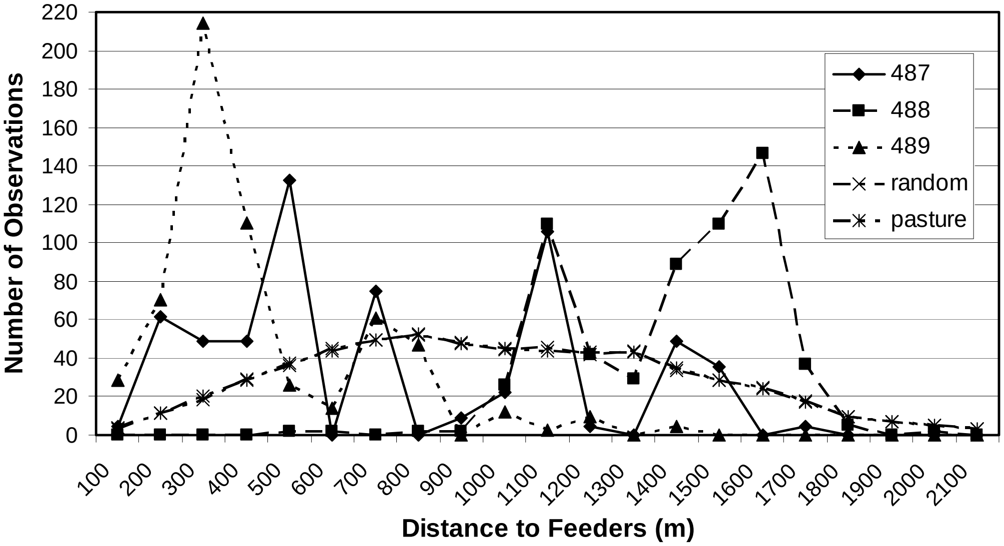

Fig. 3.19. Distance from feeders for animal observations (487,488, and 489), random samples, and pasture level sampling for deer during the spring of 2001 in a temperate savanna.

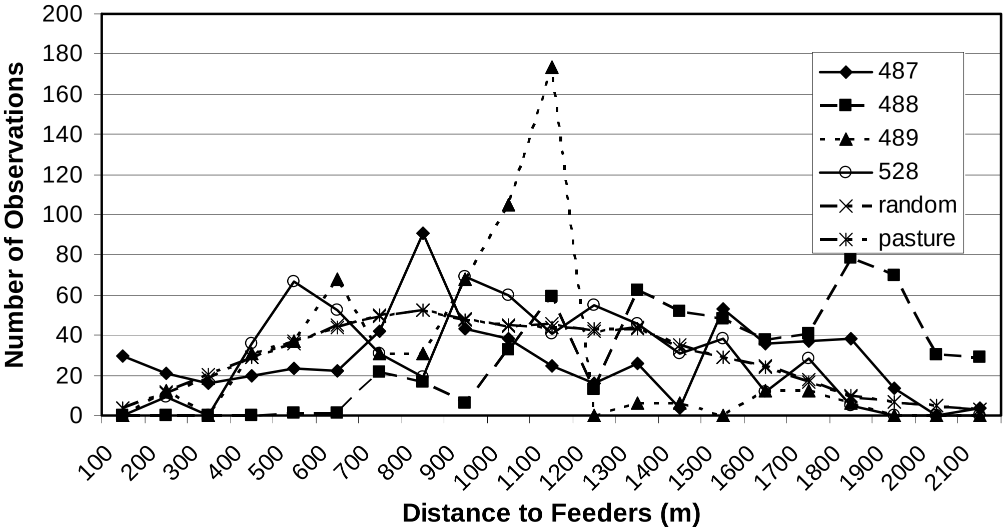

Fig. 3.20. Distance from feeders for animal observations (487,488, 489, and 528), random samples, and pasture level sampling for deer during the summer of 2001 in a temperate savanna.

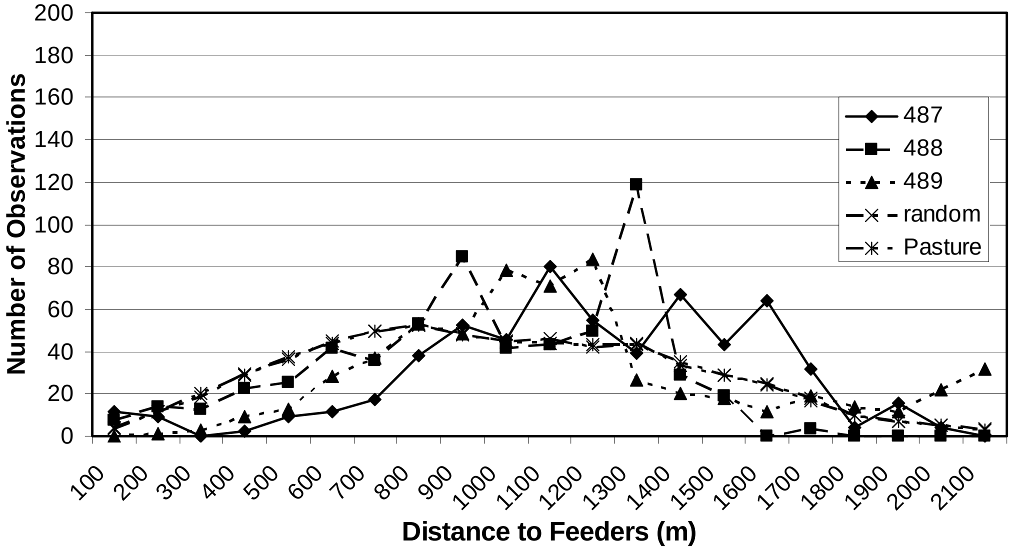

Fig. 3.21. Distance from fences for animal observations (487,488, 489), random samples, and pasture level sampling for deer during the summer of 2002 in a temperate savanna.

Table 3.1. Composition of vegetation classes occurring in the Prairie Pasture

Class	**Vegetation Composition**	**Shrub Species Acronyms**
1	*Acacia berlandieri*, *Leucophylum frutescens*, Aloysia gratissima	*Acbe*, *Lefr*, *Algr*
2	*Acacia rigidula*, *Acacia berlandieri*, *Diospyros texana*	*Acri*, *Acbe*, *Dite*
3	*Prosopis glandulosa*, *Aloysia gratissima*, *Diospyros texana*, *Acacia berlandieri*	*Prgl*, *Algr*, *Dite*, *Acbe*
4	*Acacia rigidula*, *Acacia berlandieri*	*Acri*, *Acbe*
5	*Prosopis glandulosa*, *Aloysia gratissima*, *Chilopsis linearis*	*Prgl*, *Algr*, *Chli*
6	Quercus virginiana, Aloysia gratissima, Diospyros texana	*Quvi*, *Algr*, *Dite*
7	Bare ground/herbaceous vegetation (Interspace)	
8	*Acacia berlandieri*, *Colubrina texensis*	*Acbe*, *Cote*

Habitat Selection

Analysis of vegetation clusters used by cattle and white-tailed deer yielded some interesting results. Final analyses were based on 8 vegetation clusters derived using a cluster analysis of animal locations and the vegetation classes occurring within 10 meters of each animal location (Fig. 3.22). Vegetation classes used to determine the final vegetation clusters are described in Table 3.1.

Not all the original classes from Chapter II are represented in the cluster analysis since some classes were not used by animals and were therefore not contained in any buffered locations. It is crucial to understand that the original 8 classes of shrub vegetation types were grouped into 8 clusters (Cluster A through H) representing vegetation assemblages that were important to the animals. These final clusters summarizing vegetation mixtures around animal locations were then analyzed to determine if certain vegetation clusters were used for active periods or for resting periods. This method allowed for the type of vegetation present to be compared to both the activity and the season of use for each species.

Vegetation clusters around active and inactive observations were different for the 2 animal species (p=0.0002) and were different in the 3 seasons of the study (p=0.036). Cattle used vegetation cluster A twice as often during the winter than in the spring or summer (Fig. 3.23, Fig. 3.24, and 3.25). Vegetation cluster D was used 3 times as much during the spring and summer when compared to the winter. All other vegetation clusters were used less than 20% of the time for both active and inactive categories except cluster C that was used 23% of the time during the spring.

Deer activity patterns across seasons followed a more diverse usage of available pasture resources in the spring and summer trials than that of cattle. Cluster A had the largest percentage of both active and inactive locations throughout all seasons of the year with almost 80% of active locations in winter and 60% of active locations in the summer. During the spring, deer spent 45% of inactive period in cluster A (Fig. 3.23), 16% in cluster D, and 18% in cluster H while active time periods were in cluster A (44%), cluster D (17%), and cluster G (18%). The summer trial had a majority of active periods in cluster A (62%) and cluster C (16%) (Fig. 3.24) while inactive periods were in cluster A (42%), and cluster E (29%).

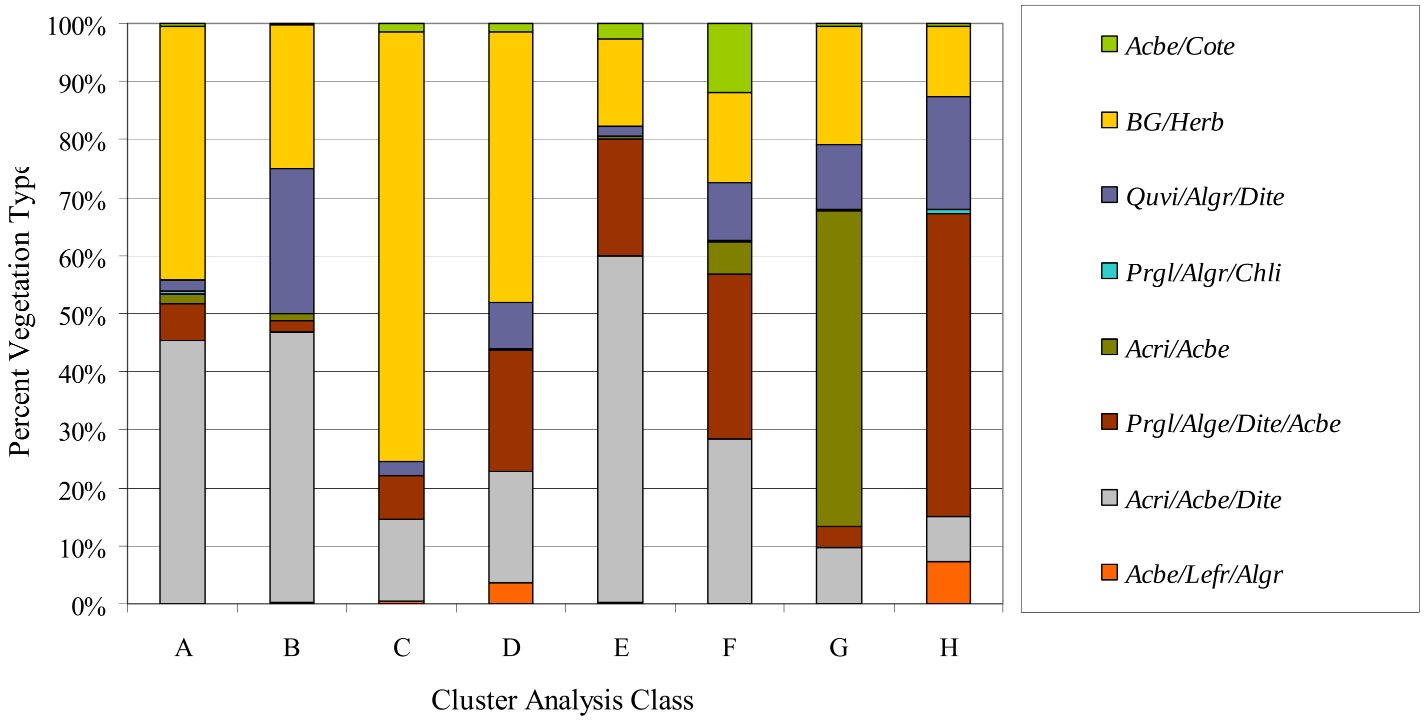

Fig. 3.22. Shrub association assemblages important to deer and cattle determined by animal location clusters in a temperate savanna. Clusters represent percentages of shrub associations occurring on the study site.

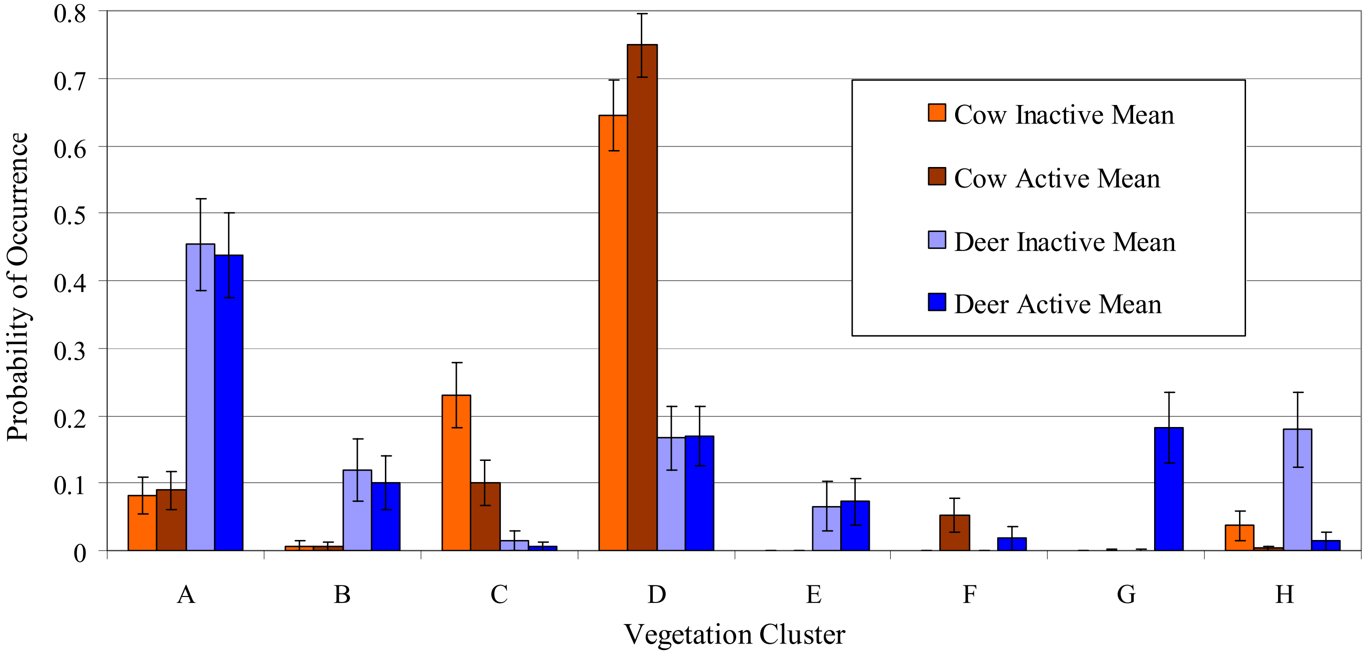

Fig. 3.23. Cattle and deer use of vegetation clusters in active and inactive periods during the spring of 2001 in a temperate savanna (bars represent standard error).

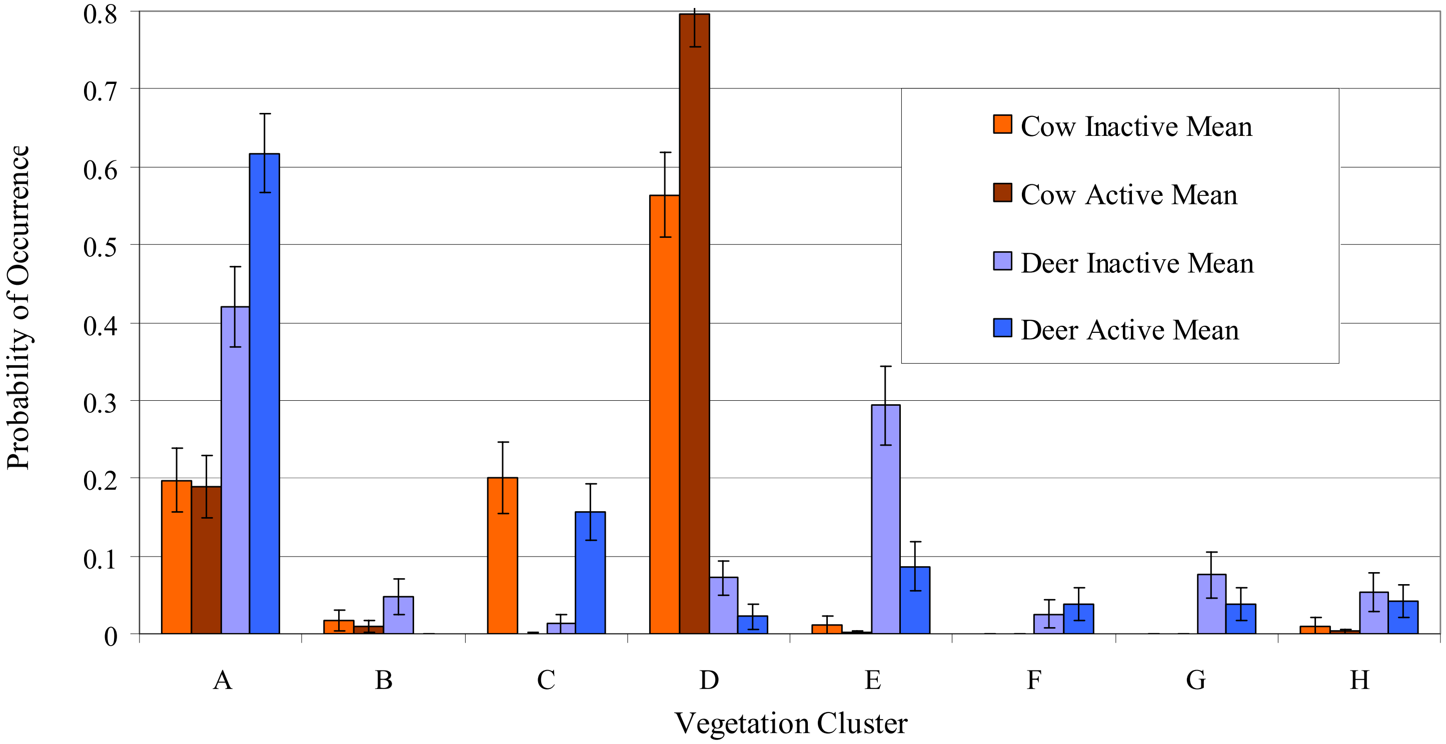

Fig. 3.24. Cattle and deer use of vegetation clusters in active and inactive periods during the summer of 2001 in a temperate savanna (bars represent standard error).

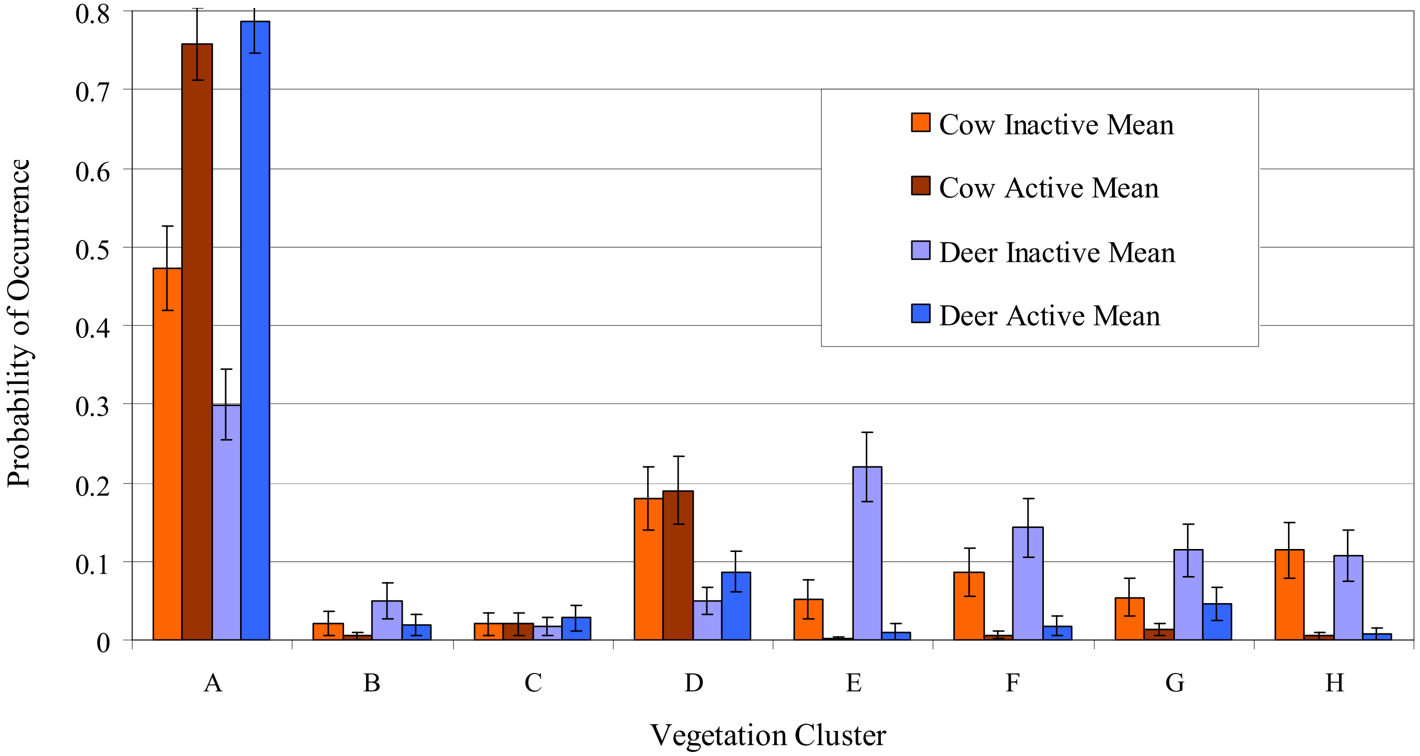

Fig. 3.25. Cattle and deer use of vegetation clusters in active and inactive periods during the winter of 2002 in a temperate savanna (bars represent standard error).

Discussion

Man-made structures have been shown to affect animal distributions in many different landscapes (Cook 1966, Roath and Krueger 1982, Owens et al. 1991). Although we can state that the spatial distribution for cows and white-tailed deer in a south Texas landscape was not randomly distributed with regard to man-made structures, the relationships were complex and varied with the animal species, the season of the year, and the type of man-made structure. To efficiently manage grazing animals, all of these factors must be considered.

Roads are undoubtedly one of the most common features of a landscape. In our 1100 ha landscape, there were more than 17 miles of roads resulting in a maximum distance from a road of about 600m. Even with such a high density of roads, cattle distributions within 100 meters of roads during the spring and summer were much greater than would be expected when compared to the random distributions. Only during the winter were the distributions of 4 of the 6 collared animals similar to a random distribution. Use of roads is not surprising in that least effort pathways offer more energy efficient travel and possibly function as corridors between grazing areas (Roath and Krueger 1982, Ganskopp et al. 2000) especially when areas adjacent to roads are cleared; however use of areas near roads has been shown to decrease when forage availability was limited (Owens et al. 1991). The random distribution during the winter could have occurred because of increased visibility and easier travel through brush when foliage was absent. Visual observations of roads in the study area indicate many cattle trails parallel them. Studying the distribution of white-tailed deer relative to roads has been an intractable problem of studying wild animals without interfering in their behavior. White-tailed deer used areas near roads more during the spring than in the summer and winter.

Water influences on pasture utilization have also been well documented with varying pasture use away from water sources ranging <1600m depending on grazing pressure and forage availability (Roath and Krueger 1982, Owens et al. 1991, Hart et al.

1991). Distance to water was also significant for every season and for both species. Cattle used areas around watering sites during spring and summer trials, but showed less dependence on areas close to permanent water sources during the winter. Precipitation could have created temporary alternate watering sites, however animal dependence on areas around water in times of thermal stress has been observed in the region. In the semi-arid landscapes of south Texas, permanent water locations are closely associated with trees such as mesquite and live oak, so animals could be drawn to the water locations during mid-day periods to relieve thermal stress. Deer did not show a use of the pasture based on water and actually had a distribution that was skewed away from water during the summer and winter trials, indicating more time spent in areas away from water sources. This result is important in that deer are not concentrated in areas solely on water presence. It is possible that these free ranging deer could have been watering at points outside the study pasture or at temporary puddles after rain. Another possibility is that deer could have been using areas near water for short periods of time and moving off before animal locations were collected

Fences affected cattle distribution in the pasture in both the spring and summer trial. This follows closely to the results for both water and roads. This result could be due to the fact that in the study pasture water sources are located near fences. Roads are also in close proximity to fence locations and create a confounding factor. Results from the winter trial however, indicated a trend towards pasture use not based on proximity to fence locations. This may indicate that water is the driving factor in pasture selection for cattle in spring and summer. Roads and fences would still have a positive effect on distributions if travel patterns were the driving force in pasture selection throughout the year. Although not measured in this study, herbaceous vegetation patterns could also play a role in animal distributions across seasons (Owens et al. 1991). Fences did not have the same effect on deer locations. Areas within 300 meters of fences were used more than would be expected under a random distribution during the spring, but we had exactly the opposite result for the summer and winter. Deer locations within 300m of the fences were much lower than expected under an assumption of random distribution during the latter 2 seasons.

Feeder use has become wide spread in many areas, and nutritional supplements have been studied extensively with varying opinions (Kroll 1991), however little work has been done to quantify feeder use in free ranging deer. Use of feeders was not supported by findings in this study. Two feeders were found inside the perimeter of the study pasture and 1 feeder outside the pasture was included because of proximity to the pasture and deer did have access to it. Only points within the pasture were used for the distance analysis and visual interpretation of complete deer locations did show some locations around the outside feeder. Although these points could have elevated the results for use around areas with feeders, the feeder proximity to a nearby water location would prohibit any solid conclusion from those locations. Overall, summer and winter trials showed similar to random at best and possible avoidance of feeder locations when distributions were compared visually. No conclusions could be drawn from the spring trial because all collared deer exhibited different patterns of use when compared to the random distribution. Although not explored, home range and individual deer preference for supplemental feed could have affected these results. Another possible factor is that animal locations were taken on an hourly basis and deer could have used the feeder and moved on to a different location between fixes however this should still lead to a trend of locations being located closer to feeders than other areas of the pasture.

Vegetation composition was also important to animal selection of areas when animals were active and inactive. Cattle spent a majority of both active and inactive periods in vegetation group D during the spring and summer. Vegetation group D consisted of 47% bare ground/herbaceous, 40 percent mixed brush vegetation types (mesquite complex and blackbrush, guajillo, Texas persimmon), and 8% oak/shrub complex. The percentage of time spent in vegetation cluster D could possibly be attributed to the diversity found in the group. A relatively large amount of bare ground/herbaceous with mixed brush interspersed could account for cattle use as well as areas of oak/shrub complex interspersed to provide cover during thermal stress. During the winter trial, cattle spent almost 80 percent of their active time in vegetation group A that consisted of 44% bare ground/herbaceous; 45% blackbrush, guajillo, and Texas persimmon; and 6% mesquite, whitebrush, Texas Persimmon, and guajillo. Use of vegetation group A during the winter trial could have been facilitated by less visual obstruction due to less shrub foliage or by more time spent seeking areas containing new growth. Both classes used heavily by cattle contained >40 bare ground/herbaceous and at least 40% mixed shrub communities.

Deer selection of available habitat also showed a trend towards areas with >40% bare ground/herbaceous cover during active periods. Bello et al. (2001) also observed increased use of comparatively open habitats within their study area in northern Mexico. Deer spent the largest amount of their active periods in vegetation group A (described above). During the summer and winter trials, deer spent more than 20 percent of inactive periods in vegetation group E that consists of 15% bare ground/herbaceous, and 82% mixed brush communities (mesquite, Texas persimmon, blackbrush, whitebrush, guajillo). This indicates deer chose resting and loafing areas at least part of the time with high brush canopy during these periods. Deer also showed a trend in all trials of spending inactive periods in the same vegetation groups as in active periods. This trend indicates deer used the same areas for both foraging and resting activities in this study.

Cattle and deer interactions were also interesting across all seasons. Deer were at least twice as likely to be found in cluster A in the spring and summer compared to cattle, while in the winter cattle and deer use of cluster A during active time periods showed similar trends (76% vs. 79%). Cattle shift in habitat use to a shrubbier habitat during the winter might be attributed to less dependence on thermal cover. Another possible explanation for increased use of cluster A could be the increased visibility due to loss of leaves by the shrub species. The high use of cluster A by both species was not expected since concentration of cattle presence is thought to have an adverse effect on deer selection of habitat (Cohen et al. 1989). Cattle use of cluster D for active periods during the spring (75%) and summer (80%) eclipsed deer use of the same group respectively (17 and 2%). Deer were more likely to use the vegetation groups in a more even manner across all seasons when compared to more concentrated cattle use. Although deer and cattle used areas with around 45% bare ground and herbaceous vegetation during active periods, deer used areas containing more shrubs (blackbrush, guajillo, and Texas persimmon) whereas cattle used areas with a higher percentage of larger trees (mesquite and live oak) during the spring and summer.

Conclusion

Factors affecting pasture use by cattle and white-tailed deer were a complex mixture of physical attributes and habitat characteristics of the pasture. Cattle use was affected by distance to water and roads during the spring and summer. Cattle also spent a disproportionate amount of time in the habitat containing low growing mixed brush species and the live oak and mesquite complexes that offer thermal cover and were located near water locations. White-tailed deer distributions were primarily effected by vegetation composition more than physical attributes. Deer heavily used areas with blackbrush, guajillo, and Texas persimmon interspersed with more bare ground than was expected.

CHAPTER IV

SHRUB ATTRIBUTES AFFECTING CATTLE AND WHITE-TAILED DEER TRAVEL VELOCITY AND PATH TORTUOSITY

How species perceive their habitat has seen renewed interest in the past 20 years (Dicke and Burrough 1988, Wiens et al. 1989, Johnson et al. 1992, With 1994b, Gross et al. 1995). Studies have focused on how season (Beier and McCullough 1990), habitat attributes (Owens et al. 1991, Pollock et al. 1994, Pastor et al. 1997), species competition (Cohen et al. 1989, Loft et al. 1991, Kie et al. 1991), and juxtaposition of micro-habitats (Etzenhouser et al. 1998) affect grazing animals.

Insects and small mammals allow better observation during experiments since travel distances are generally limited. Dividers method fractal dimension has been used to compare insect species and how they travel through their environments (Dicke and Burrough 1988, With 1994b, Wiens et al. 1995). Methods developed for these studies can be adapted to larger species (Etzenhouser et al. 1998) but require that animals be observed in confined conditions that could possibly alter behavioral patterns. Radio telemetry has often been used to track larger animals over periods of time to determine travel patterns and habitat use (Bello et al. 2001). Accuracy of radio telemetry is questionable and revolves around triangulation error. These errors may occur when different users take directional data, terrain is broken or has sound reflective properties, animals are moving, or time lapses occur between data collection at different geographical locations (Samuel and Fuller 1996). Global positioning systems (GPS) have been adapted to animal collars and allow animal movements to be monitored without interference.

We used the latest technology to address how small scale habitat affected white-tailed deer and cattle movement. Travel velocity and path tortuosity were used to determine effects of shrub association characteristics on animal movements in south Texas during the spring, summer, and winter.

Objectives of this study were to: 1. Determine if differences in mean travel velocity and path tortuosity exist between seasons and animal species, and 2. Determine the affects of shrub association characteristics on mean travel velocity and mean path fractal dimension.

Materials and Methods

Movement Paths

Animal positions were collected using Lotek Wireless GPS (Global Positioning System) collars described in Chapter II. Animal locations for this study were collected in the Prairie pasture of the Harris Ranch (29º 15’ .020’’ N, 100º 5’ 54.01’’ W) near Uvalde TX. Shrub vegetation characteristics were described in detail in Chapter II. Animal locations were collected over a 40 day period with an intense sampling period (5 minute interval) for 3 days followed by 5 days of hourly sampling. This sampling scheme minimized auto-correlation between intense sampling periods and allowed for longer trial periods. Three cows were collared for all three trials (spring, summer, and winter). Three deer were collared for the spring trial and 4 deer were collared for the summer and winter trial; however, one collar was lost during the winter trial resulting in 3 useable collars being analyzed. Only data from the 5 minute sampling periods were used for path analysis. Animal positions were differentially corrected using Lotek Inc. software (Lotek Inc.) and correction data from the United States Coast Guard station located at Port Aransas, TX . Once corrected, the animal location data were imported into Arcview 3.2a (Environmental Systems Research Institute) for analysis preparation.

Cattle paths were determined by using only continuous active periods. Periods were considered active if the horizontal movement sensor of the collar registered over 130 movements per 4 minute time period. At least 7 out of 8 continuous periods had to be over 130 to be considered a path. White-tailed deer paths were drawn from time periods when deer were active. Time periods were determined by plotting the trial averages of the horizontal activity sensor for each hour. These time periods were from

2000-0600 (military time) for the spring trial, 1800-0700 for the summer trial, and 1800-2100 as well as 2300-0900 for the winter trial. The winter trial showed a drop in activity for the 2200 time period, so these were excluded from the analysis. After the ranges of active periods were defined, visual interpretations of our data sets were used to determine continuous animal locations with heightened activity. Heightened activity levels were separated by horizontal activity data and were derived for each individual collar depending on the range of activity for each collar. Paths were created using Animal Movements extension and Arcview 3.2a. Individual points were connected, and then adjacent distances were calculated. Mean travel velocity was determined for each path by summing the complete path distance and dividing by the number of path segments yielding distance (meters)/4 minutes.

Fractal dimensions were calculated using the Fractal Mean estimator as described by Nams (2003). The Fractal Mean estimator calculates a series of distances along the movement path at different spatial scales to determine an overall fractal D for each movement path. This estimator is based on the Dividers Method fractal D that has been used in previous path tortuosity studies (Dicke and Burrough 1988, With 1994b, Wiens et al. 1995, Etzenhouser et al. 1998). The advantage of this estimator over the original fractal D is that it truncates and estimates the final segment for each divider instead of throwing the final measurement out of the analysis hence the method eliminates possible over estimation of fractal d. The fractal value for each movement path is between 1 and 2 with values closer to 1 indicating straighter movement paths and values approaching 2 indicating paths with plane filling characteristics. This measurement gives a quantified indication of how animals travel through their habitat.

Vegetation Analysis

Vegetation associations were analyzed to determine effects on animal movement path characteristics. A complete description of the associations and how they were derived can be found in Chapter II. Seven classes of vegetation and 1 class representing bare ground/herbaceous were used for this analysis. The class representing bare ground/herbaceous was representative of interspaces between areas dominated by shrub canopy cover.

A 5 meter buffer for each individual path was created to represent the habitat that the animal was using. Five meter visibility has been accepted as a probable view shed for deer in this area (Cooper, personal comm.) The vegetation characteristics within the buffered path (10 m wide and a variable length) were calculated using the Patch Analyst from ArcView 3.2a. The attributes generated for each path were: number of patches (NP), mean patch size (MPS), patch size standard deviation (PSSD), mean patch fractal dimension (MPFD), and area weighted mean patch fractal dimension (AWMPFD). Number of patches and mean patch size give indications of the heterogeneity of the landscape while the mean patch fractal dimension gives a measure of the complexity of vegetation patches found in the landscape.

Statistical Analysis

Path movements were analyzed using the GLM procedure in Statistical Analysis Software (SAS version 6.3 1988). Season (spring, summer, or winter) and animal species (deer or cow) were used as independent variables and mean path fractal dimension and mean path velocity were used as dependent variables in a complete factorial analysis of variance. Each of the dependent variables was analyzed separately and the individual animals were used as replications for the analysis. Significance levels were set at $\alpha=0.10$ for both tests.

The impact of vegetation characteristics on path tortuosity and travel velocity were assessed using step-wise multiple regression (SAS 1988). Mean path fractal dimension (tortuosity) and mean path velocity were used as dependent variables in separate analyses. Independent variables included all of the vegetation characteristics described above for each of the 8 vegetation assemblages. The independent variables were included in the forward-selection model only if $\alpha<0.10$.

Results

Mean travel velocity and mean path fractal dimension

Mean travel velocity (meters/ 4 minutes) for cattle and white-tailed deer was not significantly different in this mixed shrub ecosystem ($p=0.57$) (Fig. 4.1). Mean travel velocity was different between the spring (mean= 30.85, $\sigma^2=3.69$) and the summer and winter trials (mean=43.97, $\sigma^2=5.37$ and mean=44.81, $\sigma^2=4.4$) for white-tailed deer ($P=0.065$). Deer and cattle travel velocity was also different within the spring trial (deer mean= 30.85, $\sigma^2=3.69$ and cattle mean= 44.19, $\sigma^2= 3.7$) although season and species interaction was not significant ($p=0.71$).

Foraging paths of cows and white-tailed deer showed seasonal variation ($p=0.01$) when both species were combined (Fig. 4.2). Season and species interaction indicated an increase in path tortuosity by cattle during the summer trial (mean= 1.14, $\sigma^2= .027$) ($p= 0.068$) compared to cattle in the spring (mean= 1.082, $\sigma^2= 0.013$) and winter trials (mean= 1.072, $\sigma^2= 0.01$). Fractal dimension increases as the path becomes more tortuous, therefore values closer to 2 represent paths that are crooked whereas values closer to 1 represent straighter paths. During the summer trial cows also had more tortuous paths than deer (mean= 1.085, $\sigma^2= 0.011$). Overall, paths for both species were less tortuous than was expected ($FD<1.2$).

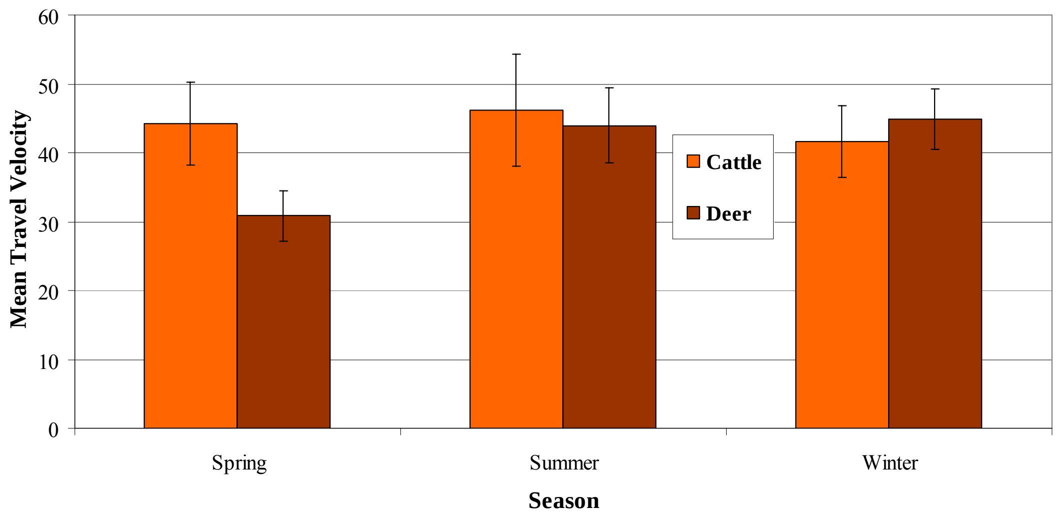

Fig. 4.1. Mean travel velocity expressed in meters/ 4minutes for cattle and white-tailed deer during active periods across 3 seasons in a temperate savanna (bars represent standard error).

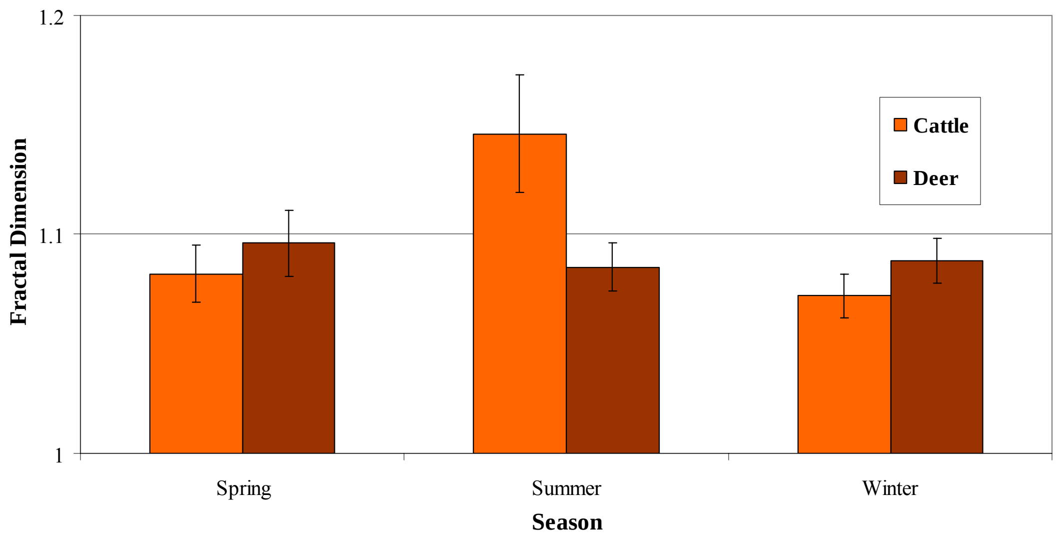

Fig. 4.2. Path tortuosity expressed as fractal dimension for cattle and white-tailed deer during active periods across 3 seasons in a temperate savanna (bars represent standard error).

Effects of shrub association attributes on animal movements

During the summer trial, 64% of the variation in the path tortuosity of the cattle was explained by 5 shrub association attributes (Table 4.1). Patch area and mean patch size of *A. berlandieri* and *C. texensis* explained 28.5% of the variation with mean patch size and patch fractal dimension of *A. berlandieri, L. frutescans*, and *A. gratissima* explaining another 20%. The vegetation association containing *Q. virginiana* and *A. gratissima* also explained 16% of the variation. Only mean patch fractal dimension and mean patch size of the shrub association containing *P. glandulosa, A. gratissima, D. texana*, and *A. berlandieri* explained any variation in the cattle path fractal dimension model during the spring (MPFD $r^2 = 0.33$) and winter trials (MPS $r^2 = 0.10$) (Table 4.1). White-tailed deer path fractal dimension model showed mean patch size of the *A. rigidula*, *A. berlandieri*, and *D. texana* shrub association to be the only attribute to explain path tortuosity during the spring trial. ($r^2=0.2144$). The summer trial was characterized by 5 shrub characteristics from 3 different shrub associations (Table 4.2). No shrub association attributes were significant for the winter trial.

Cattle travel velocity during the spring trial was characterized by the patch size fractal dimension of the shrub association containing *P. glandulosa*, *A. gratissima*, *D. texana*, and *A. berlandieri* ($r^2= 0.098$, Table 4.3). The summer trial was explained by the patch area (PA) and the patch fractal dimension of the shrub association containing *A. berlandieri*, *L. frutescens*, and *A. gratissima* ($r^2= 0.50$). Fifty five percent of the variation in the winter trial was explained by the MPS and the NP of *A. rigidula* and *A. berlandieri*. Bareground/herbaceous vegetation only accounted for 5% of the variation in all of the trials for cattle and 0% of the variation for white-tailed deer (Table 4.4). The *A. rigidula* and *A. berlandieri* shrub association accounted for 27% of the variation of white-tailed deer mean travel velocity during the spring trial. Another 25% was attributed to the PA and the MPFD of *P. glandulosa*, *A. gratissima*, *D. texana*, and *A. berlandieri*. The summer trial indicated travel velocity was related to MPFD of *P. glandulosa*, *A. gratissima*, *D. texana*, and *A. berlandieri* ($r^2= 0.11$) and the NP and PA of

A. rigidula, *A. berlandieri*, and *D. texana* (r^2= 0.17, Table 4.4). Only 11% of the variation was explained in the winter trial by NP of *P. glandulosa*, *A. gratissima*, *D. texana*, and *A. berlandieri*.

Table 4.1. Shrub association attributes and influence on variability in cattle mean path fractal dimension model

Shrub community attribute	**Shrub association***	**Coefficient**	**R^2**	**Pr>F**
Spring trial				
Patch Fractal Dimension	*P. glandulosa, A. gratissima, D. texana, A. berlandieri*	-0.078	0.3295	0.001
Total R-Square			0.3295	
Summer Trial				
Patch Area	*A. berlandieri, C. texensis*	0.0012	0.195	0.011
Patch Area	*Q. virginiana, A. gratissima, D. texana*	0.00011	0.1572	0.037
Mean Patch Size	*A. berlandieri, L. frutescens, A. gratissima*	-0.023	0.13	0.01
Mean Patch Size	*A. berlandieri, C. texensis*	-0.037	0.0891	0.062
Patch Fractal dimension	*A. berlandieri, L. frutescens, A. gratissima*	0.35	0.0676	0.088
Total R-Square			0.6389	
Winter Trial				
Mean Patch Size	*P. glandulosa, A. gratissima, D. texana, A. berlandieri*	0.0014	0.1013	0.086
Total R-Square			0.1013	

* Shrub associations are described in depth in Chapter II.

Table 4.2. Shrub association attributes and influence on path tortuosity in the white-tailed deer mean path fractal dimension model

Shrub association attribute	**Shrub association***	**coefficient**	**R^2**	**Pr>F**
Spring trial				
Mean Patch size	*A. rigidula, A. berlandieri, D. texana*	0.00067	0.2144	0.01
Total R-Square			0.2144	
Summer Trial				
Number of Patches	*A. rigidula, A. berlandieri, D. texana*	0.00033	0.1676	0.0146
Number of Patches	*P. glandulosa, A. gratissima, D. texana, A. berlandieri*	-0.0013	0.1568	0.0103
Number of Patches	*A. berlandieri, C. texensis*	0.0044	0.1247	0.0126
Patch Area	*A. rigidula, A. berlandieri, D. texana*	0.00002	0.0815	0.0297
Patch Fractal dimension	*A. berlandieri, C. texensis*	-0.096	0.0533	0.0638
Total R-Square			0.5839	
Winter Trial				
No variable was significant at α=0.10		0	0	0
Total R-Square			0	

* Shrub associations are described in detail in Chapter II.

Table 4.3. Shrub association attributes and influence on cattle mean travel velocity model

Shrub association attribute	Shrub association*	Coefficient	R^2	Pr>F
Spring trial				
Patch Fractal Dimension	*P. glandulosa, A. gratissima, D. texana, A. berlandieri*	19.76	0.0988	0.0967
Total R-Square			0.0988	
Summer Trial				
Patch Area	*A. berlandieri, L. frutescens, A. gratissima*	0.036	0.397	0.0003
Patch Fractal Dimension	*A. berlandieri, L. frutescens, A. gratissima*	-30.04	0.108	0.0282
Total R-Square			0.5044	
Winter Trial				
Mean Patch Size	A. *rigidula, A. berlandieri*	0.832	0.314	0.0013
Number of Patches	A. *rigidula, A. berlandieri*	0.049	0.239	0.0008
Number of Patches	*A. rigidula, A. berlandieri, D. texana*	-0.95	0.061	0.0522
Mean Patch Size	Bareground	0.108	0.052	0.0586
Total R-Square			0.67	

* Shrub associations are described in detail in Chapter II.

Table 4.4. Shrub association attributes and influence on white-tailed deer mean travel velocity model

Shrub association attribute	Shrub association	Coefficient	R^2	Pr>F
Spring trial				
Number of Patches	*A. rigidula, A. berlandieri*	7.13	0.268	0.0034
Patch Area	*P. glandulosa, A. gratissima, D. texana, A. berlandieri*	0.011	0.1303	0.0227
Patch Fractal Dimension	*P. glandulosa, A. gratissima, C. linearis*	28.88	0.123	0.016
Number of Patches	*Q. virginiana, A. gratissima, D. texana*	0.44	0.0695	0.05
Total R-Square			0.59	
Summer Trial				
Patch Fractal Dimension	*P. glandulosa, A. gratissima, D. texana, A. berlandieri*	25.89	0.108	0.054
Number of Patches	*A. rigidula, A. berlandieri, D. texana*	0.131	0.0874	0.0621
Patch Area	*A. rigidula, A. berlandieri, D. texana*	-0.01	0.0814	0.0825
Total R-Square			0.277	
Winter Trial				
Number of Patches	*P. glandulosa, A. gratissima, D. texana, A. berlandieri*	0.147	0.1064	0.0841
Total R-Square			0.1064	

* Shrub associations are described in detail in Chapter II.

Discussion

Mean path tortuosity for deer (FD= 1.09, σ^2=0.012) over all seasons was less than previously reported FD= 1.27 (Etzenhouser et al. 1998). A slightly different fractal estimator that reduces overestimation was used in this study and could have contributed to the results. The previous study also had greater precision in calculation since animal locations were collected in a grid system within a confined area of 1 ha and every animal movement was recorded, not movements based on a time interval (5 minutes). This study had at best a precision of within 5 meters of the animal's location after Global Positioning System (GPS) locations were differentially corrected. For deer, only the summer trial variation was explained by the shrub attributes tested (58%) with only the patch fractal dimension of *A. berlandieri* and *C. texensis* having a strong negative effect (coefficient= -0.10.)

Cattle movement path tortuosity has not been previously reported, but the range in our values (FD 1.072-1.15) indicated very straight travel paths for cattle. One possible explanation for this could be the distance between feeding stations and time spent at each feeding station. The 5 minute time step could encompass a feeding station so small scale movements, which would affect path tortuosity, could not be recorded. The increased path tortuosity observed for cattle during the summer correlates primarily with the patch area of *A. berlandieri* and *C. texensis* , as well as the patch area of *Q. virginiana*, *A. gratissima*, and *D. texana*. These 2 vegetation types occur in and adjacent to the draws in the study pasture. As the total patch area increased and the mean patch size decreased, path tortuosity increased (Table 4.1). In communities with many, isolated shrubs (high total area, low patch size) the animals may have been able to follow gaps in the shrub cover, resulting in a high path tortuosity. Conversely, when shrub cover was more continuous (high total area, high mean patch size), animals may not have been able to penetrate the thicket and traveling paths could be much straighter. Two of the 3 watering locations occur adjacent to these vegetation types and cattle dependence on areas near water during periods of thermal stress has been well documented (Roath and Krueger 1982, Owens et al. 1991, Chapter II). These 2 shrub community characteristics coupled with patch fractal dimension of *A. berlandieri*, *L. frutescens*, and *A. gratissima* explained 64% of the variability in the model. Tortuosity of cattle movements in the spring and winter was not well explained by the shrub attributes tested in this study with only 33% of the variation being explained by the patch fractal dimension of *P. glandulosa* vegetation group that had a negative effect on the fractal dimension of the movement paths during the spring. As the patches became more complex, the animal paths became more crooked.

Both cattle and deer path tortuosity compares interestingly to previous research conducted on insects. Studies on grasshoppers, beetles, and mites had mean path fractal dimensions ranging from 1.09-1.20 (Dicke and Burrough 1988, Crist et al. 1992, With 1994a). This result is not surprising in that one of the tenets of fractal theory is self similar replicating patterns at different scales (Dicke and Burrough 1988). The findings in this study lead to interesting questions of how species of vastly different body sizes have similar path tortuosity. An interesting study would be exact replica's of habitat spatial organization scaled to match several species of different body sizes to determine if animal step length truly makes a difference in observed path characteristics.

Cattle and deer travel velocity was similar during the summer and winter trials. This would be expected since herbivores of different sizes exhibit similar travel velocities (Shipley et al. 1996). The difference between travel velocities in the spring trial could possibly be attributed to the distance between foraging stations, although this was not tested in this study. Another possible explanation could be the availability of preferred forage, animals may have moved farther and at a faster pace to encounter areas with preferred or more abundant forage. Shipley et al. (1996) saw a 10 fold increase in travel velocity when foraging encounters were farther apart. None of the vegetation patch characteristics had a negative affect on mean travel velocity in the spring therefore an unexplored external factor led to the reduced mean travel velocity. Vegetation patches containing *A. berlandieri* also had less impact on deer travel velocity in this study than in previous studies. *A. berlandieri* had explained as much as 79% of the variation in white-tailed deer foraging velocity (Etzenhouser et al. 1998) whereas multiple shrub attributes explained at most 59% of the variability for deer in this travel velocity model. Mean travel velocity was also greater for deer in this study (>30 m 4minutes^{-1}) than the previous study (extrapolated= 24 m 4minutes^{-1}).

Conclusion

Cattle and white-tailed deer paths were similar across 3 seasons. Path fractal dimension for cattle was higher during the summer trial, but may be attributed to the shrub communities found close to water. Path tortuosity was lower than expected for both species. Travel velocity on the other hand was even across seasons for cattle with shrub community characteristics explaining 67% of the variability in the winter trial. Travel velocity for white-tailed deer was less during the spring trial, but was not explained by the variables in this analysis. Shrub association characteristics were important for white-tailed deer during the spring trial where 59% of the variability was explained.

CHAPTER V

CONCLUSION

Ikonos satellite imagery was suitable for small scale habitat studies of white-tailed deer and cattle. Final classification accuracy results were derived by a modification of standard accuracy testing that allowed for the highly heterogeneous landscape of southwest Texas. Although the standard accuracy minimum of 85% was not reached, 83.6% was close enough for the purpose of this study. Further research should be conducted on accuracy assessment for high resolution imagery. When 1 meter imagery is used, available GPS units used may not have enough precision to accurately find ground control points and user error in navigating to points may become more critical. In this study printed copies of the image were used to navigate as close as possible to the ground control points.

Pasture attributes were critical to cattle distribution across the study area. Roads and water locations had a higher incidence of animal locations than the random distribution would suggest. Deer distributions across the study site did not follow any clear patterns based on physical attributes. Two possibilities could account for this with the first being that the attribute that does affect deer distributions was not measured in this study or that vegetation characteristics had more effect on pasture usage.

Both cattle and deer showed specific trends in habitat selection. White-tailed deer used areas with more bare ground present than was expected. Since bare ground/ herbaceous in this study represented interspaces in shrub patches, this trend could be a result of patchy shrub canopy cover. Deer were found in areas that contained more shrub species such as guajillo, blackbrush, and whitebrush. Cattle however used habitats with larger tree species during the spring and summer trials, and shifted to shrubbier habitats during the winter trial.

Cattle and white-tailed deer paths were similar across 3 seasons. Path fractal dimension for cattle was higher during the summer trial, but might be attributed to the shrub communities found close to water. Path tortuosity was lower than expected for both species. Travel velocity on the other hand was even across seasons for cattle with shrub community characteristics explaining 67% of the variability in the winter trial. Travel velocity for white-tailed deer was less during the spring trial, but was not explained by the variables in this analysis. Shrub association characteristics were important for white-tailed deer during the spring trial where 59% of the variability was explained.

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APPENDIX A

CHI-SQUARE VALUES FOR CATTLE DISTRIBUTIONS RELATED TO PHYSICAL ATTRIBUTES

Trial and Attribute	Collar number	Chi-Square Value	Critical x^2
Spring			
Water	87	5316.24	30.14
	490	1224.23	30.14
	491	2824.78	30.14
Roads	87	149.59	9.348
	490	86.84	9.348
	491	179.87	9.348
Fences	87	288.58	19.68
	490	83.58	19.68
	491	313.43	19.68
Summer			
Water	380	4210.51	30.14
	490	2650.02	30.14
	491	2685.37	30.14
Roads	380	176.69	9.348
	490	94.28	9.348
	491	132.53	9.348
Fences	380	171.28	19.68
	490	120.6	19.68
	491	163.2	19.68
Winter			
Water	87	218.68	30.14
	88	133.82	30.14
	380	121.17	30.14
	381	85.66	30.14
	490	94.16	30.14
	491	45.61	30.14

Roads	87	56.27	9.348
	88	7.75**	9.348
	380	10.31	9.348
	381	22.16	9.348
	490	10.91	9.348
	491	11.3	9.348
Fences	87	770.2	19.68
	88	675.68	19.68
	380	278.59	19.68
	381	69.77	19.68
	490	30.25	19.68
	491	58.98	19.68

APPENDIX B

CHI-SQUARE VALUES FOR DEER DISTRIBUTIONS RELATED TO PHYSICAL ATTRIBUTES

Trial and Attribute	Collar number	Chi-Square Value	Critical x^2
Spring			
Water	487	170.35	30.14
	488	535.64	30.14
	489	891.74	30.14
Roads	487	109.8	9.348
	488	42.77	9.348
	489	60.83	9.348
Fences	487	139.91	19.68
	488	221.81	19.68
	489	189.37	19.68
Supplemental Feeders	487	209.66	31.41
	488	827.8	31.41
	489	1323.07	31.41
Summer			
Water	487	366.72	30.14
	488	358.34	30.14
	489	152.65	30.14
	528	112.88	30.14
Roads	487	23.42	9.348
	488	198.59	9.348
	489	10.72	9.348
	528	16.98	
Fences	487	176.15	19.68
	488	100.52	19.68
	489	171.42	19.68
	528	175.66	19.68

Supplemental Feeders	487	348.86	31.41
	488	1408.41	31.41
	489	104.21	31.41
	528	55.7	31.41
Winter			
Water	487	250.97	30.14
	489	227.68	30.14
	528	281.3	30.14
Roads	487	46.08	9.348
	488	150.35	9.348
	489	49.74	9.348
Fences	487	450.51	19.68
	489	1005.39	19.68
	528	101.75	19.68
Supplemental Feeders	487	279.25	31.41
	488	222.73	31.41
	489	454.34	31.41

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