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Distance Sampling as a Technique to Monitor Pronghorn in Kansas

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DISTANCE SAMPLING AS A TECHNIQUE TO MONITOR

PRONGHORN IN KANSAS

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PREFACE

This thesis is written in the style of the Journal of Wildlife Management to which a portion of this thesis will be submitted for publication. My research protocol was approved by the Institutional Animal Care and Use Committee (FHSU 2013-006).

ABSTRACT

Accurate and precise estimates of abundance are crucial for wildlife management.

Wildlife agencies spend large amounts of time and money to obtain estimated abundance.

The Kansas Department of Wildlife Parks and Tourism (KDWPT) has conducted strip

transect (ST) counts biannually since 1963 to estimate pronghorn (*Antilocapra*

americana) abundance in Kansas. However, the accuracy and reliability of results are

questionable. Distance sampling (DS) is a method used to estimate abundance of a

biological population. All perpendicular distances of objects to the transect line are

recorded; however, there is no designated strip width and no assumption that all objects

are detected. I conducted DS surveys and ST surveys biannually between the summer of

2012 and the winter of 2014 in western Kansas. The objectives of the study were to: (1)

compare DS results to ST results from winter and summer, (2) compare DS results from

winter and summer, (3) evaluate the time and cost needed to complete both methods, and

(4) evaluate the feasibility of reducing to 1 DS survey per year. Results from the DS and

ST methods in the winter provided similar estimated abundance. Timing of flights had a

substantial effect on cluster size, fawn:doe ratios, and buck:doe ratios. Summer DS

surveys yielded larger sample sizes and more precise estimates than winter DS surveys.

Cluster size, side (of the plane pronghorn were detected), distance to road, and habitat

were the most influential covariates on detection probability. Detection probability was

higher in cropland than in rangeland. Because DS results indicated that pronghorn

avoided within 200 to 300 m of roads, I suggest that the DS transect placement be

changed to 1 of 3 options: (1) transects angled to roads, (2) randomly placed north-south

oriented transects, or (3) north-south oriented transects placed 800 m from roads. I

suggest that the KDWPT conduct 1 DS flight per year, in the summer, during a small

temporal window. Doing so would save the KDWPT time, money, and avoid risk from

unnecessary flight time, while still providing reliable population estimates.

ACKNOWLEDGMENTS

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INTRODUCTION

Pronghorn (*Antilocapra americana*) are endemic to North America and were once widespread across western North America (Seton 1909). Nelson (1925) suggested that 30 to 40 million pronghorn occupied North America prior to European settlement. By the early 1920s, the estimated abundance of pronghorn had dwindled to 30,326 pronghorn (Nelson 1925).

Some factors that contributed to the decline of pronghorn were: (1) conversion of land use to agriculture, (2) competition with domestic livestock, and (3) overharvesting of pronghorn (Allen 1962, McCabe et al. 2004, O'Gara and Yoakum 2004). Conservation efforts have restored pronghorn to some former ranges and pronghorn numbers have increased to an estimated 1.1 million pronghorn in 2008 (O'Gara and Yoakum 2004, Morton 2008).

Pronghorn are an economically important species. Pronghorn hunting is highly regarded in many areas and contributes money to local and state economies (Loft 1976, Lewis et al. 1998). In 2003, the Wyoming Game and Fish Department estimated the value of a pronghorn in Wyoming to be $3,000. Hunters in North Dakota spent nearly $3,000,000 during the 1996 hunting season (Lewis et al. 1998).

To restore pronghorn to former ranges in Kansas, the Kansas Department of Wildlife Parks and Tourism (KDWPT) began the Pronghorn Restoration Program in 1964 (Jensen 2001). Initially, landowners in western Kansas supported the Pronghorn Restoration Program. However, conflicts between landowners and pronghorn have become more frequent in recent years. Stakeholders have been skeptical of information about pronghorn provided by wildlife managers (Murphy and Noon 1991, Jensen 2001).

Additionally, demand for permits to hunt pronghorn in Kansas has steadily increased and nearly doubled over the last 20 years, from approximately 700 permits to over 1200 permits (Peek 2013).

Accurate and precise estimates of abundance are crucial for pronghorn management. Many management decisions are based from population size. Obtaining estimates of population size can be expensive. For example, Montana spent $1,700,000 in 1998 to survey big-game populations (Rabe et al. 2002). Conducting appropriate surveys of big-game populations can be a challenge. Surveys require careful planning, preparation, training, proper equipment, personnel, implementation, evaluation, and refinement of methods (Martin 2009). Therefore, it is imperative that wildlife agencies use effective methods to survey wildlife populations.

Throughout pronghorn range in North America, natural resource agencies have used many different methods to obtain estimated abundance of pronghorn populations, while some used multiple methods every year (Morton et. al 2008). These methods included helicopter, fixed-wing aircraft, and ground surveys. However, 10 out of the 18 natural resource agencies desired to improve survey methodology (Morton et al. 2008).

The KDWPT has conducted strip transect (ST) counts biannually since 1963 via fixed-wing aircraft. STs are long narrow quadrats. The ST method has the strong assumption that surveyor(s) detect all objects within the strip width (i.e., a census of the total strip area; Buckland et al. 1993). Given the simplicity of the method, ST surveys can be a favorable method for estimating abundance. However, there are several

perceived limitations of ST surveys for estimating pronghorn abundance in Kansas. These include:

1. Accuracy and reliability of data are questionable. A potentially large proportion of pronghorn are not detected during flights (Firchow et al. 1990, Pojar et al. 1995) and are consequently not included in estimated abundance.

2. The area covered during ST surveys is small in comparison to the overall range of pronghorn in Kansas.

3. Two flights are conducted every year in the same locations to obtain both estimated abundance in winter and ratio estimates (buck:doe and fawn:doe) in the summer. Ratio estimates are obtained only in the summer because bucks, does and fawns are not easily distinguishable in the winter (O'Gara and Yoakum 2004). Estimated abundance is more efficient to obtain in the winter because of larger cluster sizes (O'Gara and Yoakum 2004). Flight time should be decreased if possible to reduce risk associated with flights, as well as reduce time and money spent.

4. No measures of precision or uncertainty are obtained with ST survey results (e.g., confidence intervals, coefficients of variation, standard error etc.).

In the early 1930s, R.T. King recognized that during ST surveys not all ruffed grouse (*Bonasa umbellus*) within a designated strip width were observed. He devised a method that used an "effective strip width" to obtain estimated abundance. The effective strip width was the mean perpendicular distance of observed ruffed grouse from the transect line. He also recognized that the effective strip width varied with survey

conditions (R.T. King, University of Minnesota, unpublished data). Gates and Smith (1980) defined the current use of effective strip width (μ) as: the distance at which the number of undetected objects closer to the transect line than μ equals the number of detected objects at distances farther than μ.

Distance sampling (DS) is a survey method that estimates density and abundance of a biological population. DS differs from ST surveys because there is no assumption that all objects are detected, except for a narrow strip near the transect line (Buckland et al. 1993). DS has no designated strip width, rather perpendicular distances from the transect line are recorded for all detected objects. It is assumed that the detection probability of objects will decline as distance from the transect line increases.

The mathematical rationale for DS can be demonstrated by using data from Anderson and Pospahala (1970). Anderson and Pospahala (1970) recorded duck (*Anas spp.* and *Aythya* spp.) nests detected out to 8 feet (2.44m) in 1 foot (0.30m) distance intervals. If all nests were detected within the sample width, 8 feet (2.44m), you would assume a nearly uniform distribution of distances of nests from the transect line (Fig. 1a). However, Anderson and Pospahala (1970) demonstrated that some nests were undetected and that the number of undetected nests increased as distance from the transect line increased (Fig. 1b). The proportion of detected nests (Fig. 1c) was estimated by using a simple quadratic equation on the midpoints of each histogram class. The following equation was calculated from the data:

$$\text{frequency of duck nests} = 77.05 - 0.4039x^2$$

The calculated proportion of detected nests was 0.888 and they observed a total of 534 total nests. To estimate the total number of duck nests in the survey area (including undetected nests) they divided the total observed nests (534) by the proportion of observed nests (0.888); 534/0.888 = 601 estimated nests. Given that the transects surveyed 5.5% of the refuge, the total estimate of duck nests on the refuge was: 601/0.055 = 10,927 nests. The Anderson-Pospahala method is no longer recommended because there are now superior survey methods (Buckland et al. 1993). However, it demonstrates the underlying rationale of the DS method.

DS can be an effective method to estimate abundance of a population if several assumptions are met (Buckland et al. 1993):

1. Objects near the transect line are always detected (detection rate = 1).
2. Objects do not move before being detected (objects are detected at their original location).
3. Perpendicular distances of objects from the transect line are accurately measured.
4. Transects are placed randomly with respect to the distribution of objects.
5. Shape criterion; detection function should possess a shoulder (i.e., detection probability is nearly constant for some distance away from the transect line).

Furthermore, a minimum sample size of 60 to 100 objects (Burnham et al. 1980; Whittaker et al. 2003) is suggested to obtain reliable estimates. However, clustered populations generally require a larger sample size (number of clusters detected), because variability in cluster size (i.e., group size) increases the uncertainty in the population

estimates.

DS has several potential advantages when compared to ST surveys:

1. A potentially large proportion of pronghorn remain undetected during ST surveys. In Colorado, observers conducting ST surveys detected 55% of marked pronghorn in the winter and 63% of pronghorn in the summer (Firchow et al. 1990). DS incorporates the number of pronghorn that are detected and the estimated proportion not detected into the overall estimated abundance.

2. Using the DS method could reduce time, money, and risk associated with flying, because a ST survey is a census attempt in the area flown.

3. The area surveyed could be expanded into locations not previously flown with the ST method.

4. DS provides estimates of variance (i.e., standard error, confidence intervals, coefficient of variation) associated with population estimates. This provides a measure of confidence in population estimates that that are not available with ST surveys.

5. Analysis software, DISTANCE (DISTANCE 6.0, www.ruwpa.st-and.ac.uk/distance/, accessed 1 June 2012), provides increased flexibility for analyzing data.

However, there are also limitations associated with DS. It requires careful planning and extensive quality control (Guenzel 1997). Those measures need to ensure that the above-mentioned assumptions are met. This might include: proper equipment,

training of personnel, correct timing of surveys, appropriate analysis, evaluation of all processes, and adjustments as needed (Guenzel 1997).

Obtaining a sufficient sample size in areas with small populations, like pronghorn in Kansas (Morton et al. 2008), can also be a challenge (Guenzel 1997). An adequate sample size is needed in order to obtain reliable inferences. Additional survey effort might be needed to meet a minimum required sample size in areas with small populations.

The objectives of my study were to: (1) compare the DS results to the ST results from both summer and winter; (2) compare DS and ST results from summer and winter; (3) evaluate the time and cost needed to complete both methods; and (4) evaluate the feasibility of reducing to 1 survey per year, if DS is a more effective and efficient method.

STUDY AREA

The study areas (Fig. 2) were located in northwest Kansas in the pronghorn management unit 2 (Fig. 3). They were comprised of 2 main habitat types: rangeland and cropland. The center of the study area was predominately rangeland while the northern and southern portions were predominately cropland. The main crops grown in the study areas were winter wheat (*Triticum aestivum*), corn (*Zea mays*), soybeans (*Glycine max*) and sorghum (*Sorghum spp.*). Rangeland was comprised of both short-grass and mixed-grass prairies. More specifically, rangelands were comprised of northern grama-buffalograss prairie (*Bouteloua-Buchloë*) with western wheatgrass (*Pascopyrum smithii*) as a codominant species in the eastern portion, bluestem-grama prairie (*Andropogon-Bouteloua*), and chalkflat prairie (*Andropogon-Bouteloua-Distichlis*) (Küchler 1974). Compared to cropland, rangelands generally had more uneven terrain, were rockier, and contained more anthropogenic features (e.g., fence rows, water tanks, old farm equipment). The DS study area was comprised of 55% cropland and 45% rangeland. ST method area was comprised of 46% cropland and 54% rangeland. All other habitat types comprised < 1% of land area (State of Kansas GIS 2014).

In my study area, 2012 was the third driest year on record with 24.4 centimeters of precipitation and was the fourth warmest year on record with a mean temperature of 12.7° C (National Weather Service 2014). In 2013, there was 42.5 centimeters of precipitation with a mean temperature of 10.7° C (National Weather Service 2014). Due to drought conditions and associated restrictions being loosened, much of Conservation Reserve Program (CRP) land was either mowed or grazed (J. H. Oyster, Fort Hays State

University, personal observation). Therefore, I included CRP with rangeland for

analysis.

METHODS

I conducted ST and DS surveys biannually during a 2-year period: summer 2012 through winter 2014. I conducted ST surveys on: 18-19 July 2012; 4-5, 15 February 2013; 22-23 July 2013; and January 13-15 2014. I conducted DS surveys on: 13-14 August 2012; 14-15 January 2013; 29-30 July 2013; and 15-16, 22, 24 January 2014.

I overlaid transects for both methods onto National Agriculture Imagery Program (NAIP) images and uploaded them into the program CyberTracker (CyberTracker Version 3.263, www.cybertracker.org, accessed 27 Apr 2011). I recorded all data into CyberTracker on a Trimble Juno SB GPS receiver (Trimble Navigation, Ltd., Sunnyvale, California). CyberTracker displayed an interactive image on the GPS receiver, where the real-time location of the plane was shown relative to the transect line and the surrounding landscape. This allowed the pilot to remain near the transect line at all times and allowed the recorder to plot locations of pronghorn clusters more accurately in relation to landmarks (i.e., fencerows, field boundaries, farm ponds etc.) and the real-time position of the plane. The interactive image displayed all locations of previously detected pronghorn clusters, which helped prevent double-counting. The image also displayed the prior flight path by plotting a location point every 5 seconds, in a different color than locations of pronghorn clusters.

Flights were conducted in a fixed-wing aircraft, Cessna Skyhawk 172. The plane was flown at approximately 185 kilometers/hour at an above ground level between 120 to 150 m. A Cessna Stationair 206 was used to conduct ST surveys in the summer of 2012 and to finish a portion of the 2014 winter DS survey. This plane traveled at

approximately 240 kilometers/hour at the same above ground level. A team of 4 people

conducted every survey. The pilot sat in the front left seat of the plane. He was primarily

responsible for flight safety. He attempted to keep the plane on the transect line and

scanned for pronghorn the remainder of the time. The recorder sat in the front right seat.

He recorded all data, helped the pilot stay on the transect line, and scanned for pronghorn

the remainder of the time. Two observers sat in the back seats and were responsible for

scanning their respective side for pronghorn.

For the ST and DS method in the summer, I counted the number of bucks, does,

or fawns in each pronghorn cluster. Bucks, does, and fawns were not easily

distinguishable in the winter (O'Gara and Yoakum 2004), so I counted only a total

pronghorn number for each cluster. All observers attempted to obtain a total count of

pronghorn for each cluster, however; it was difficult to obtain an accurate pronghorn

count when large clusters were aggregated tightly. I recorded the mean count (whole

number) from all the observers if there was not a consensus count.

I recorded a GPS location for each pronghorn cluster. The majority of pronghorn

locations were recorded while flying over the cluster. I also recorded pronghorn

locations remotely, without leaving the transect line, by plotting it on the interactive

image on the GPS receiver. I did this if the pronghorn cluster was close to the plane and

small enough to count accurately.

ST Surveys

I used ST surveys from the winter to obtain estimated abundance, but not

buck:doe and fawn:doe ratios. Every winter I flew 39 transect lines (Fig. 3) directly over

section lines (spaced 1.6 km (1 mile) apart), which were usually roads, in a north-south direction. The transects totaled 2,102 kilometers and covered an area of 3,589 square kilometers. Observers searched for pronghorn in a strip width of 0.8 kilometers (0.5 miles). When an observer detected a pronghorn cluster, the pilot left the transect line, flew toward the cluster, and I recorded a total pronghorn count.

ST surveys from the summer were used to estimate buck:doe and fawn:doe ratios, but not estimated abundance. ST surveys from the summer were flown only in the center region of the winter study area. I continued until a minimum of 300 total pronghorn were counted. This was done to limit flight time, while still obtaining reliable buck:doe and fawn:doe ratios. Every year, summer surveys were conducted between 15 July and 15 August to estimate fawn survival, because fawn mortality is low after the first 3 weeks of life (Gregg et al. 2001; Van Vuren et al. 2013). Buck:doe ratios obtained during this period provided estimates of the number of bucks in the population prior to hunting season. When a pronghorn cluster was detected, the pilot flew close enough so that observers could identify the number of bucks, does or fawns in the cluster.

DS Surveys

Each season I flew 28 transects (Fig. 4) in a north-south direction. Transects were placed approximately 4.8 kilometers (3 miles) apart. There were 3 sets of transects that I flew at different distances in relation to section lines, which were usually roads: (1) 0 m (over top of road), (2) 400 m (0.25 miles) from roads, and (3) 800 m (0.5 miles) from roads. Transects did not always remain at the designated distance to road when flying over rangelands, where roads were not always present or oriented consistent with

surrounding roads. The transects totaled 1723 kilometers each season and covered an area of 8247 square kilometers, except for the summer of 2013. Because of equipment malfunction, I discarded a western portion of the summer 2013 survey and used data from 1493 kilometers of transect and a total area of 7262 square kilometers. The equipment malfunction occurred while I was attempting to implement surveys that used angled transects that were angled to roads, oriented in a northwest to southeast direction. Consequently, all data from those transects were discarded and not used in analysis.

All personnel were familiar with the main assumptions of DS. The pilot and the recorder, who could view out the front window, attempted to detect all pronghorn that were near the transect line. Back-seat observers also tried to scan near the transect line to avoid missing pronghorn near the transect line; however, it was more difficult for them to view pronghorn that passed under the plane. It was more critical that pronghorn locations were recorded accurately during DS surveys than ST surveys. When an observer detected a pronghorn cluster, he then helped the recorder locate the pronghorn cluster, to ensure that the location was plotted in the original location before pronghorn moved. Then, the recorder notified the pilot that a pronghorn cluster was detected. If needed, the pilot left the transect line so pronghorn could be counted.

Eight additional variables were recorded for each pronghorn cluster: percent cloud cover, temperature, wind speed, side (of transect that the pronghorn cluster was detected), sun position, pronghorn behavior, and habitat. Although the method of collecting data for DS surveys and ST surveys was similar, the interpretation and analysis was quite different.

Analysis

Conventional DS models. — I calculated perpendicular distance of pronghorn cluster locations from the transect line, by using ArcGIS 9.3 and ArcGIS 10 (Environmental Systems Research Institute, Inc., Redlands, CA). I analyzed DS data in DISTANCE 6.0. All confidence intervals (CI) reported were at the 95% confidence level. Outliers (farthest observations from the transect line) provide little information about density and are difficult to model. Therefore, Buckland et al. (1993) recommend truncating 5 to 10% of the farthest observations before analysis. However, low sample sizes prevented me from applying the recommended truncation. I removed all observations beyond 950 m from the summer of 2012 (2 out of 65 observations), beyond 1500 m (1 out of 21 observations) from the winter 2013 survey, and I removed no observations during the summer 2013 or winter 2014 surveys.

With each analysis, I used 1 of 3 key functions (expected distributions of observations): uniform, half-normal, or hazard-rate. The uniform distribution has no estimated parameters, whereas half-normal has 1 parameter that is estimated from distance data, and hazard-rate has 2 parameters that are estimated. A series expansion (cosine, simple polynomial, or hermite polynomial) was used, if needed, to adjust each distribution to fit the model to the distance data. A series expansion might add 1 or 2 parameters to improve model fit. The key functions + series expansions that were compared with each analysis were: (1) half-normal + cosine, (2) half-normal + hermite polynomial, (3) uniform + cosine, (4) uniform + simple polynomial, and (5) hazard-rate + cosine (Buckland et al. 1993). The key function + series expansion with the lowest

Akaike information criterion (AIC) value was selected for each set of analyses and used to estimate abundance and density.

Occasionally, cluster size and distance from the transect line were correlated (i.e., size bias). If they were correlated, the larger clusters were usually easier to detect than smaller clusters farther from the transect line, i.e., positively correlated (Buckland et al. 1993). There was little evidence of a size bias during the summer of 2012, summer of 2013, or winter of 2014. Therefore, I used mean cluster size to estimate abundance and density during those seasons. There was a size bias during the winter of 2013 (Fig. 5); therefore, I used a size-biased regression (cluster size against estimated distance) to estimate expected cluster size.

Final model selection considered AIC, Chi-square goodness of fit test probability, and coefficient of variation (CV) of abundance. AIC was used to select the key function + series expansion that was best-supported by the data. Chi-square goodness of fit test assesses the model fit to the distance data. However, it has limited use because of lower power, but should be considered nonetheless (Buckland et al. 1993). After the key function + series expansion was selected using AIC values, I placed the most emphasis on CV of abundance when selecting the top model. I selected the model with the lowest CV of abundance as the top model every season.

Multiple covariate models. — I ran multiple covariate models every season to identify the variables that had the greatest effect on detection probability. The covariates that I included in those models were: distance to road (0m, 400 m, and 800 m), percent cloud cover, sun position (favorable, unfavorable or neutral), side (right or left side of

plane), habitat (rangeland or cropland), and cluster size. I did not include wind speed and temperature as covariates because they probably did not have a significant effect on detection probability. Pronghorn behavior was also not included because the variable was separated into 4 categories, resulting in sample sizes too small to model.

Analysis of multiple covariate models was similar to conventional DS models. DISTANCE selected from the same sets of key function + series expansion that were examined with conventional distance sampling models. The cluster size analysis that was used each season for conventional DS models also was used for all multiple covariate models during that season. However, cluster size was also analyzed as a covariate. I used forward step-wise selection to construct models. First, I ran each of the 6 covariates as a model by itself. I ranked these models by AIC value. The 2 covariates that had the lowest AIC value were included together in the next model. If the AIC value of the model with the 2 top covariates was not lower than the top covariate, then the top covariate was considered the top model. However, if the model with the 2 top covariates had a lower AIC value than the top covariate, then the covariate with the next lowest AIC value was added to the top model until the AIC value did not continue to lower.

Stratification of Covariates. — I further investigated 2 of the top covariates, by combining data from all survey periods and then analyzed the covariate by strata (e.g., habitat was stratified as rangeland and cropland). Distance to road and habitat were the covariates that I analyzed with all survey periods combined. Although side was one of the top covariates included in top models, I did not analyze it with all survey periods combined because observers changed throughout the study. Similarly, I did not analyze

cluster size with stratification because there were no set strata within the cluster size variable.

RESULTS

DS and ST method comparison

During the summer of 2012, I calculated a fawn:doe ratio of 14:100 and a buck:doe ratio of 51:100 with the ST method (Table 1). The mean cluster size was 3.98 pronghorn. With the DS method, I calculated a fawn:doe ratio of 23:100 and a buck:doe ratio of 37:100. The mean cluster size was 6.23 pronghorn.

During the summer of 2013, I calculated a fawn:doe ratio of 42:100 and a buck:doe ratio of 24:100 with the ST method. The mean cluster size was 5.03 pronghorn. With the DS method, I calculated a fawn:doe ratio of 45:100 and a buck:doe ratio of 20:100. The mean cluster size was 5.69 pronghorn.

During the winter of 2013, I counted 1,127 pronghorn with the ST method and calculated a density of 0.31 pronghorn per square kilometer (Table 2). I detected 93 pronghorn clusters, ranging from 1 to 47 pronghorn per cluster, with a mean cluster size of 12.1 pronghorn. When the results of the ST method were extrapolated to the study area of DS surveys, I obtained an estimated abundance of 2,590 pronghorn. From the DS data, I calculated an estimated abundance of 2,409 pronghorn and an estimated density of 0.29 pronghorn per square kilometer. I detected 21 pronghorn clusters, ranging from 1 to 84 pronghorn per cluster, with a mean cluster size of 36.1 pronghorn (SE = 4.5, CI = 27 - 46). With the size-bias regression, I obtained an expected cluster size of 28.1 pronghorn.

During the winter of 2014, I counted 1,103 pronghorn with the ST method, and calculated a density of 0.31 pronghorn per square kilometer. I detected 47 pronghorn clusters, ranging from 1 to 83 pronghorn per cluster, with a mean cluster size of 23.5

pronghorn. When the results of the ST method were extrapolated to the study area of DS surveys, I obtained an estimated abundance of 2,534 pronghorn. From the DS data, I calculated an estimated abundance of 2,241 pronghorn and an estimated density of 0.27 pronghorn per square kilometer. I detected 50 pronghorn clusters, ranging from 1 to 101 pronghorn per cluster, with a mean cluster size of 23.6 pronghorn.

Extrapolation of DS data. —

When I combined DS data from all survey periods and extrapolated the estimated abundance within the ST study area to the overall DS study area, the estimated abundance was 2,817 pronghorn. I obtained an estimated density of 0.34 pronghorn per square kilometer (SE = 0.06, CV = 0.18, CI = 0.24 – 0.49) within the ST study area and an estimated density of 0.32 pronghorn per square kilometer (SE = 0.05, CV = 0.17, CI = 0.23 – 0.44) outside the ST area.

Method cost comparison

ST surveys took approximately 12.2 hours to complete in the winter and 6.2 hours in the summer. ST surveys were completed with 2,102 transect kilometers in the winter and approximately 888 transect kilometers in the summer. The DS surveys took 12.4 hours to complete in the summer and 11.0 hours to complete during the winter. DS surveys were completed with 1,723 transect kilometers. One hour of flight time costs approximately $150 and when not flying (e.g., breaks), a pilot costs $40 per hour. The cost of flight time and 2 hour breaks between flights would be approximately $3,000 for the ST method (winter and summer) and $2,020 for 1 DS survey in the summer.

DS season comparison

The DS survey in the summer of 2012 produced an estimated abundance of 1,827 pronghorn (Table 3) and an estimated density of 0.22 pronghorn per square kilometer. I detected 65 clusters, for a total of 405 detected pronghorn, ranging from 1 to 17 pronghorn per cluster and a mean cluster size of 6.2 pronghorn. The effective strip width was 517.4 m. The summer 2013 DS survey produced an estimated abundance of 1,814 pronghorn and an estimated density of 0.25 pronghorn per square kilometer. I detected 67 clusters, for a total 381 detected pronghorn, ranging from 1 to 19 pronghorn per cluster and a mean cluster size of 5.6 pronghorn. The effective strip width was 504.1 m.

The DS survey from the winter of 2013 produced an estimated abundance of 2,409 pronghorn and an estimated density of 0.29 pronghorn per square kilometer. I detected 21 clusters, for a total of 758 detected pronghorn and a mean cluster size of 36.1 pronghorn (SE = 4.5, CI = 27 - 46). The estimated cluster size after the size-bias regression was 28.1 pronghorn. The effective strip width was 521.3 m. The DS survey from the winter of 2014 produced an estimated abundance of 2,241 pronghorn and an estimated density of 0.27 pronghorn per square kilometer. I detected 50 clusters with a mean cluster size of 23.6 pronghorn, totaling 1,179 detected pronghorn. The effective strip width was 1,266.2 m.

I combined data from all DS survey periods (Fig. 6) and obtained an estimated abundance of 2,355 pronghorn (SE = 317.6, CV = 0.13, CI = 1808 - 3067), a density estimate of 0.29 pronghorn per square kilometer (SE = 0.04, CV = 0.13, CI = 0.23 -

0.38), an mean cluster size of 12.4 pronghorn (SE = 1.1, CV = 0.09, CI = 10.4 - 14.8),

and an effective strip width of 602.4 m (SE = 32.6, CV = 0.05, CI = 541 - 670).

Multiple Covariate Models

The top model for each survey period included a different set of covariates.

Covariates in top models included: side twice, cluster size twice, distance to road once,

and habitat once. Side was the top covariate during 2 survey periods. None of the other

tested covariates were included in top models.

The top model from the summer 2012 survey included the covariates side and

cluster size, with side being the top covariate. Observers on the right side of the plane

(Fig. 7) seemingly missed pronghorn up to 200 to 300 m from the transect. Observers on

the left side of the plane (Fig. 8) detected pronghorn close to the transect line, but did not

detect pronghorn at distances as far as observers on the right side of the plane did.

Detection probability was greater for larger pronghorn clusters than for smaller clusters

for observers on the right side (Fig. 9) and left side (Fig. 10) of the plane. The estimated

abundance was 1,805 pronghorn (SE= 315.1, CV = 0.19, CI = 1170 - 2405), with a

density estimate of 0.22 pronghorn per square kilometer (SE = 0.04, CV = 0.19, CI =

0.14 - 0.29), a mean cluster size of 6.2 pronghorn (SE = 0.5, CV = 0.07, CI = 5.4 - 7.2),

and an effective strip width of 444.0 m (SE = 50.3, CV = 0.11, CI = 356 - 553).

The top model from the winter 2013 survey included the covariate cluster size.

Detection probability was greater for larger pronghorn clusters than for smaller ones (Fig.

11). The estimated abundance was 2,811 pronghorn (SE = 861.2, CV = 0.30, CI = 1452 -

4828), with a density of 0.34 pronghorn per square kilometer (SE = 0.10, CV = 0.30, CI =

0.17 - 0.59), an expected cluster size of 27.3 pronghorn (SE = 4.9, CV = 0.17, CI = 19.5 -

38.6), and an effective strip width of 433.1 m (SE = 96.4, CV = 0.22, CI = 272 - 688).

The top model for the summer 2013 survey included the covariate distance to

road. The detection function plot of the 0 m transect indicated evidence of pronghorn

avoiding areas within 200 to 300 m of roads (Fig. 12). The 400 m transect also had a

detection probability lower than 1 within 150 m of the transect (Fig. 13). The detection

function plot from the 800 m transect indicates a fairly uniform distribution out to 600 m

from the transect (Fig. 14). The estimated abundance was 1,826 pronghorn (SE = 309.3,

CV = 0.17, CI = 1309 - 2548), with an estimated density of 0.25 pronghorn per square

kilometer (SE = 0.04, CV = 0.17, CI = 0.18 - 0.35), and an effective strip width of 500.8

m (SE = 44.1, CV = 0.09, CI = 420.1 - 596.9).

The top model for the winter 2014 survey included side and habitat, with side

being the top covariate. The detection function plots (Figs. 15 and 16) suggested that

observers on both sides of the plane missed pronghorn near the transect line in the

rangeland habitat. However, detection function plots from cropland habitat (Figs. 17 and

18) from both sides resembled a half-normal distribution. The model produced an

estimated abundance of 2,259 pronghorn (SE = 569.6, CV = 0.25, CI = 1381 - 3695), an

estimated density of 0.27 pronghorn per square kilometer (SE = 0.07, CV = 0.25, CI =

0.17 - 0.45), a mean cluster size of 23.2 pronghorn (SE = 4.2, CV = 0.18, CI = 16.2 -

33.3), and an effective strip width of 1,237.8 m (SE = 152.5, CV = 0.12, CI = 967.0 -

1484.5).

Stratification of Covariates

When I combined distance to road data from all 4 survey periods, the detection function plots from the 3 distance to road transects displayed different distributions, produced different population estimates (Table 4), and estimates of variance. The detection function plot of the 0 m transects (Fig. 19) indicated evidence of pronghorn avoiding areas within 200 to 300 m of roads. The 0 m transects data were best-fit to the hazard-rate key function and used 2 estimated parameters. The model produced an estimated abundance of 2,161 pronghorn, an estimated density of 0.27 pronghorn per square kilometer, a mean cluster size of 11.0 pronghorn, and an effective strip width of 635.5 m.

The detection function plot of the 400 m transects (Fig. 20) indicated evidence of pronghorn avoiding between 200 to 700 m from the transect line (i.e., within 200 to 300 m of the road). The detection probability increases again between 700 and 900 m from the transect line. The 400 m transects were best-fit to the half-normal key function with a cosine series adjustment, for a total of 2 estimated parameters. The model produced an estimated abundance of 4,081 pronghorn, an estimated density of 0.51 pronghorn per square kilometer, a mean cluster size of 15.3 pronghorn, and an effective strip width of 441.6 m.

The detection function plot of the 800 m transects indicated high detection probability at distances out to 600 m from the transect line and a decline at distances farther than 600 m (Fig. 21). The data was best-fit to a uniform distribution with a cosine series adjustment for a total of 1 estimated parameter. The model produced an estimated

abundance of 1,870 pronghorn, an estimated density of 0.23 pronghorn per square kilometer, a mean cluster size of 10.4 pronghorn, and an estimated strip width of 516.8 m.

When combined across all survey periods, detection probability was higher at distances farther from the transect line in cropland (Fig. 22) than it was in rangeland (Fig. 23). Cropland also yielded higher population estimates than rangeland did. I detected 142 pronghorn clusters in croplands. From the cropland observations, I calculated an estimated abundance of 1,656 pronghorn (SE = 256.9, CV = 0.16, CI = 1173 - 2193), an estimated density of 0.21 pronghorn per square kilometer (SE = 0.03, CV = 0.16, CI = 0.15 - 0.28), a mean cluster size of 13.5 pronghorn (SE = 1.4, CV = 0.10, CI = 11.0 - 16.5), and an effective strip width of 659.6 m (SE = 39.7, CV = 0.06, CI = 585.6 - 742.9).

I detected 61 pronghorn clusters in rangelands. From the rangeland observations, I calculated an estimated abundance of 744 pronghorn (SE = 188.8, CV = 0.25, CI = 455 - 1218), an estimated density of 0.09 pronghorn per square kilometer (SE = 0.02, CV = 0.25, CI = 0.06 - 0.15), a mean cluster size of 11.1 pronghorn (SE = 1.8, CV = 0.17, CI = 8.0 - 15.5), and an effective strip width of 529.0 m (SE = 47.3, CV = 0.09, CI = 442.6 - 632.4).

DISCUSSION

DS and ST method comparison

The lower cluster sizes obtained from the ST method compared to the DS method during the summer of 2012 was probably due to a difference in the timing of surveys and not the methods. The increase in mean cluster size between 18-19 July 2012 (ST method) and 13-14 August 2012 (DS method) might be due to fawns joining their mothers in larger nursery clusters (White et al. 2012). Cluster size also increases between July and September as males begin to actively defend harems (groups of females) in preparation for the breeding season (White et al. 2012*).* The percentage of clusters that were harem clusters (1 male with 1 or more female) increased from 25% to 60% between July and August and there were more buck-only clusters in July (40%) than in August (29%). All of those factors combined probably resulted in the lowered detectability of bucks and increased detectability of fawns in August compared to July. Consequently this might have caused the decline in buck:doe ratio and the increase in fawn:doe ratio.

The same pattern was observed when I compared the ST method and DS method from the summer of 2013. Cluster size increased, buck:doe ratio decreased, and the fawn:doe ratio increased. However, the magnitude of change was less dramatic due to the closer timing between the 2 survey periods in the summer of 2013. A similar pattern (i.e., increasing or constant fawn: doe ratio and decreasing buck:doe ratio) of ST results was observed by firchow et al. (1990) between June estimates and August estimates.

The ST survey and DS survey conducted during the winter of 2013 produced similar estimates of abundance. However, the number of clusters detected during the DS

survey was much lower, while the mean cluster size was 3 times larger. Similar to the

summer method comparison, the difference in results probably was due to timing of

surveys and not the methods themselves. There was a long temporal gap between the 2

methods. The larger clusters during the DS survey probably was due to a snowstorm

(White et al. 2012) that preceded the DS flights, as well as colder temperatures during the

DS survey ($\bar{x} = -7.8°$ C) compared to the ST survey ($\bar{x} = 4.4°$ C). The ST method and

DS method from the winter of 2014 yielded similar mean cluster sizes and number of

clusters detected. DS and ST surveys from the winter of 2014 were completed within a

relatively short time frame and environmental conditions were more similar ($\bar{x} = -4.1°$ C

and $\bar{x} = 1.7°$ C, respectively), probably causing the results to be similar.

The estimated abundance of the ST method might be overestimated when

extrapolated to the DS area, given that the DS data suggests that pronghorn density is

higher in the ST area than outside the ST area. When the estimated abundances from

both methods were extrapolated from the ST study area, the estimated abundance of the

DS method was higher. During ST surveys, we probably detected a higher percentage of

pronghorn than Firchow et al. (1990) did (63%). Pronghorn were probably easier to

detect in my study area compared to the study area of Firchow et al. (1990) in southeast

Colorado for 2 potential reasons: (1) my study area is flatter and likely did not contain as

many trees and shrubs, and (2) they flew at a lower above ground level of 30 to 39

meters, which might have caused them to miss more pronghorn at distances farther from

the transect line.

Given the large effect that timing of surveys seemingly had on results, I suggest that future surveys be restricted to a small temporal window. Consequently, results from different years would be more comparable to one another. Regarding the timing of summer surveys, a July survey would probably provide a larger sample size and more precise estimates because of the smaller cluster sizes than are typical in August. A survey in August however, would probably yield a lower buck:doe ratio and a higher fawn:doe ratio.

I suggest that DS is a superior method to ST surveys for estimating the pronghorn population in Kansas for the following reasons:

1. DS results include the estimated number of undetected pronghorn with the detected portion of pronghorn, whereas the ST method only totals the number of detected pronghorn.

2. Area covered by DS can be expanded from the ST study area while spending less survey effort (flight time) to accomplish the survey. This would provide more information about the pronghorn population as a whole.

3. Estimates of variance are obtained with population estimates from DS, while they are not with ST surveys. The KDWPT can present those results to stakeholders interested in the pronghorn population.

4. DS data can be analyzed by using multiple covariate models. The top models from these analyses help to identify potential violations of assumptions, provide information about pronghorn biology, and to realize ways in which surveys can

continue to be improved. ST surveys provide little additional information beyond estimated abundance.

5. DS allows for greater flexibility when analyzing data. For example, if there is a size bias that makes using the mean cluster size inappropriate, there are 4 options to use a size-bias regression to estimate cluster size. There are also several ways to use a bootstrap method to estimate expected cluster size.

Method cost comparison

Using only 1 DS flight per year, in the summer, instead of the traditional 2 ST surveys would save 6 hours of flight time. This would save the KDWPT approximately $980 (6 hours of flight time + 2 hour break between flights). This does not include the additional cost of travel and lodging that might also be incurred by the KDWPT with extra flights.

DS season comparison

When comparing DS surveys from winter and summer, I obtained larger sample sizes during the summer because pronghorn were dispersed into smaller clusters. Consequently, population estimates from summer surveys were more precise. Durant et al. (2011), reported that coefficient of variation (CV) impacted the ability to detect changes in estimated abundance of a population. A CV of estimated abundance < 0.2 had a much higher probability of detecting small changes in estimated abundance than a CV of estimated abundance ≥ 0.2. Both summer surveys yielded CVs of < 0.2. The 2013 winter survey did not produce a CV of < 0.2, while the 2014 winter survey did.

Higher survey effort in the center of the DS study area and lower effort in the periphery of the study area (Buckland et al. 1993) could be used to increase sample size and consequently improve precision. This type of survey would be analyzed by strata (high density and low density) and a global estimate (all strata combined) would also be calculated. Estimates of density and encounter rate (pronghorn clusters/km) were slightly higher in the center of the study area. Therefore, higher survey effort in this area could increase sample size.

The winter DS surveys yielded higher population estimates than summer surveys although there was overlap in confidence intervals for all 4 DS surveys. Higher population estimates from winter DS surveys was probably due to larger cluster sizes which increased detection probabilities. Thus, we were able detect pronghorn clusters at distances farther from the transect line because they were easier to detect than small clusters. Vegetation in was either absent or shorter in the winter than in the summer, making pronghorn easier to detect. The effective strip width during the DS survey in the winter of 2014 was over twice the distance of all other surveys. This might be due to higher detection probability during winter surveys and observer experience. All other survey periods included at least 1 observer that was surveying pronghorn for the first time. All observers participating in the DS survey in the winter of 2014 had previous experience. This previous experience might have improved their abilities to detect pronghorn, especially at distances farther from the transect line.

I suggest that DS surveys are more appropriate to conduct in the summer than the winter for the following reasons:

1. Smaller cluster sizes in the summer make it easier to meet the minimum suggested sample size.

2. Smaller cluster size range and larger sample sizes in the summer improved the precision of population estimates.

3. Overall estimated abundance can be obtained, while also obtaining buck:doe and fawn:doe ratios that were not obtained from winter surveys.

4. Considering the above 3 reasons, the KDPWT can reduce to 1 survey a year instead of the traditional 2 surveys per year.

Multiple Covariate Models

The covariates side, cluster size, distance to road, and habitat affected detection probability the most. Other covariates had little effect on detection probability, were difficult to collect accurately, or were difficult to model.

There was evidence from multiple seasons, of observers missing pronghorn near the transect line. This is a violation of the most critical DS assumption (Buckland et al. 1993) and can make modeling of data difficult and influence accuracy of estimates. Observer bias could be ameliorated by standardized training of all observers. If observers lean close to the plane window instead of sitting upright in the seat, then more area below the plane becomes visible to the observer. Observers commonly scan distances farther from the plane and might miss pronghorn closer to the transect line. I suggest that an observer covariate replace the side covariate. Instead of each pronghorn detection being associated with a side of the plane, it would be associated with a specific observer. This would allow for recognition and accountability of bias associated with individual

observers instead of groups of observers. The position of each observer in the plane (pilot, recorder, back left, or back right) would be recorded before the survey begins.

Cluster size was a covariate in the top model for 50% of the survey periods. This bias can be reduced in 2 ways: (1) by using a size-bias regression instead of mean cluster size to obtain estimated abundance, (2) by liberal truncation of the farthest observations. Truncation of 5 to 10% of the farthest observations is suggested. Removing the farthest observations usually reduces the effect of the largest clusters, probably increasing accuracy of estimates (Buckland et al. 1993), and (3) manually stratify and analyze by cluster size, if there is a sufficient sample size. Each stratum should have a sample size of at least 20 clusters. For example, summer data could be stratified into 3 strata (1-3 pronghorn; 4-7 pronghorn; and 8+ pronghorn) and analyzed (Buckland et al. 1993).

Stratification of Covariates

When data were combined from all survey periods, there was evidence that pronghorn were avoiding areas within 200 to 300 m of roads. Gavin and Komers (2006) found that pronghorn exhibit increased vigilance within 300 m of roads, suggesting that pronghorn view roads as a potential risk. This is consistent with my results that suggest pronghorn avoid roads. Pronghorn avoidance of roads affects the detection function plots, population estimates, and estimates of variance of each distance to road transect.

The 0 m transect violated the assumption of a detection rate of 1 near the transect line. Pronghorn avoided between 200 to 700 m from the 400 m transects (i.e., avoided areas within 200 to 300 m of roads), resulting in a higher-than-expected detection probability (i.e., heaping) near the transect line. This distribution of observations violated

the shape criterion and no model in DISTANCE could accurately estimate density in this case (Buckland et al. 1993). Buckland et al. (1993) also stated that heaping near the transect line can result in serious overestimation of density. Consequently, the estimated abundance of the 400 m transects was approximately double that of 0m and 800m transects. To obtain reliable estimates, the detection function should have a shoulder. If detection probability drops sharply near the transect line, estimates tend to be poor (Buckland et al. 1993). Pronghorn likely avoided areas between 600 to 1000 m from 800 m transects. The 800 m transects produced a detection function with a shoulder. Consequently, the 800 m transects produced the most precise population estimates.

Throughout the study, rangelands probably supported fewer pronghorn than normal because of drought conditions. Vegetation in rangelands appeared desiccated and unpalatable, while vegetation in fertilized and recently-disturbed croplands was probably more palatable and nutritious (Vitousek et al. 1989). Detecting pronghorn in rangelands also was more of a challenge because of uneven terrain, fence lines, livestock, yucca plants (*Yucca glauca*), and other objects that were not common in croplands.

Transect placement

Aside from the equipment malfunction (GPS receiver did not record location points of the flight path) mentioned previously, I discontinued surveys with angled transects for the following reasons: (1) difficulty staying on the transect line, (2) loss of observer effort from the pilot and recorder because of time spent navigating to the transect line, and (3) difficulty accurately plotting pronghorn locations. Flying at an angle to roads made it more difficult to plot pronghorn clusters in relation to the transect

line because it was difficult to use roads or property lines as a reference to the location of the transect line.

KDWPT is faced with the choice of changing the transect locations every year or surveying the same transects every year. Surveys with transects in the same location every year will improve the ability of the KDWPT to compare population estimates from different years with more confidence because of increased consistency between years. However, because the majority of the study area would not be surveyed, results might consistently overestimate or underestimate population estimates. Conversely, surveying transects placed in different locations every year could produce results that better represent the true population (Buckland et al. 1993).

I suggest 3 possible options for transect placement of future flights:

Option 1. — Fly all transects at an angle to roads. This transect placement would be the least biased regarding the distribution of pronghorn. To be effective, this would require the KDWPT to invest in equipment that would allow the pilot to easily remain on the transect line (i.e,. auto pilot). This would allow the pilot and the recorder to have more observation effort instead of focusing on staying on the transect line. However, as previously mentioned, this transect placement introduces some challenge in accurately plotting pronghorn locations perpendicular to the transect line.

Option 2. — Fly randomly-placed north-south transects. This transect placement would be less biased than the current transect placement. This placement probably would produce similar population estimates and estimates of variance as the current transect placement. Combining data from all transects at random distances from roads is similar

to combining the current 0 m, 400 m, and 800 m transects. This transect placement would provide the KDWPT with a representative sample of pronghorn observations in relation to their distribution to roads. This placement would meet the DS assumption of transects being placed randomly with respect to the distribution of objects. However, transects should not run parallel to physical (e.g., roads, fence lines) or biological features (e.g., ridges, rivers) because they would likely yield unrepresentative samples (Buckland et al. 1993, Guthery 1988).

This option introduces the risk of violating the shape criterion assumption similar to the 0 m and 400 m transects. Violating this assumption could decrease the precision of estimates or could overestimate abundance similar to the 400 m transect (Buckland et al. 1993). Conversely, combining data from random transects might result in an appropriate detection function because bias across all transects would balance out; similar to combining the detection functions of the 0 m and 400 m transects would balance out to meet the shape criterion. This option would introduce challenges similar to those faced from surveys with angled transects, namely, difficulty staying on the transect line (because the pilot would not always fly over roads or section lines) and loss of observer effort from pilot and recorder.

Option 3. — Fly only 800 m transects. The 800 m transects produced an appropriate detection function and produced the most precise population estimates. This option probably would be the simplest to effectuate compared to the other options. Consistent transect placement probably would produce the most precise estimates (Buckland et al. 1993). However, this option would violate the assumption of random

placement of transects with respect to the distribution of objects. This option would also be placed parallel to roads, which would likely yield unrepresentative samples. Pronghorn avoidance occurred approximately 600 to 1000 m from the 800 m transect. The effective strip width was below 600 m for 3 out of the 4 DS surveys. Pronghorn avoidance beyond 600 m should not have a significant effect on model fit near the transect line, where it is most critical (Buckland et al. 1993). Nevertheless, the bias from roads would still be present.

Management implications

I suggest that the KDWPT change from the current transect placement and implement 1 of the 3 aforementioned options. All observers involved should be properly instructed on the theory, application and assumptions of DS before participating in surveys. I recommend that the KDWPT fly 1 DS flight per year, in the summer, during a small temporal window. By reducing to 1 flight per year, the KDWPT can save time, money, and diminish risk associated with unnecessary flight time.

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Table 1. Comparison of population estimates from the strip transect method and distance sampling method from summer surveys in western Kansas, 2012-2013.

	2012		2013	
	ST	DS	ST	DS
Fawn:doe ratio	14:100	23:100	42:100	45:100
Buck:doe ratio	51:100	37:100	24:100	20:100
Mean cluster size	3.98	6.23	5.03	5.69
SE	0.45	0.54	0.57	0.56
[a]LCL	3.09	5.27	3.92	4.61
[b]UCL	4.87	7.45	6.14	6.83
Clusters detected	83	65	64	67

[a]lower confidence limit (2.5%)

[b]upper confidence limit (97.5%)

Table 2. Comparison of population estimates from the strip transect method and distance sampling method from winter surveys in western Kansas, 2012-2013.

	2013		2014	
	ST	DS	ST	DS
Estimated abundance	2,590	2,409	2,534	2,241
Density (/square kilometer)	0.31	0.29	0.31	0.27
Mean cluster size	12.1	28.1	24.0	23.6
SE	1.3	5.1	2.8	2.8
[a]LCL	9.7	19.3	19.9	18.6
[b]UCL	14.6	41.1	27.1	29.9
Range	1 - 47	1 - 84	1 - 83	1 - 101
Clusters detected	93	21	47	50

[a]lower confidence limit (2.5%)

[b]upper confidence limit (97.5%)

Table 3. Results from distance sampling surveys from summer and winter in western Kansas, 2012-2014.

	2012	2013		2014
	Summer	Winter	Summer	Winter
Estimated abundance	1,827	2,409	1,814	2,241
CV	0.18	0.32	0.16	0.19
SE	336.0	770.9	291.8	425.0
[a]LCL	1268	1285	1321	1543
[b]UCL	2632	4516	2491	3255
Density (/square kilometer)	0.22	0.29	0.25	0.27
CV	0.18	0.32	0.04	0.19
SE	0.04	0.09	0.16	0.05
LCL	0.18	0.16	0.18	0.19
UCL	0.34	0.55	0.34	0.39
Mean cluster size	6.2	28.1	5.6	23.6
CV	0.09	0.18	0.10	0.12
SE	0.54	5.1	0.56	2.8
LCL	5.3	19.3	4.6	18.6
UCL	7.5	41.1	6.8	29.9
Range	1 - 17	1 - 84	1 - 19	1 - 101
Effective strip width (m)	517.4	521.3	504.1	1,266.2
CV	0.06	0.14	0.07	0.08
SE	33.4	75.2	35.4	100.3
LCL	455	386	438	1080
UCL	589	704	580	1485
Clusters detected	65	21	67	50

[a]lower confidence limit (2.5%)

[b]upper confidence limit (97.5%)

Table 4. Results from the distance to road covariate when stratified by 0 m, 400m and 800 m transects from western Kansas, 2012-2014.

	0 m	400 m	800 m
Estimated abundance	2,161	4,081	1,870
CV	0.24	0.26	0.23
SE	514.5	1063.9	422.9
[a]LCL	1358	2459	1201
[b]UCL	3439	6774	2912
Density (/square kilometer)	0.27	0.51	0.23
CV	0.24	0.26	0.23
SE	0.06	0.13	0.05
LCL	0.17	0.31	0.15
UCL	0.43	0.85	0.36
Mean cluster size	11.0	15.3	10.4
CV	0.15	0.15	0.16
SE	1.7	2.3	1.7
LCL	8.1	11.3	7.6
UCL	14.9	20.8	14.4
Effective strip width (m)	635.5	441.6	516.8
CV	0.11	0.15	0.05
SE	67.1	65.8	25.3
LCL	515	329	469
UCL	784	594	570
Clusters detected	67	62	56

[a]lower confidence limit (2.5%)

[b]upper confidence limit (97.5%)
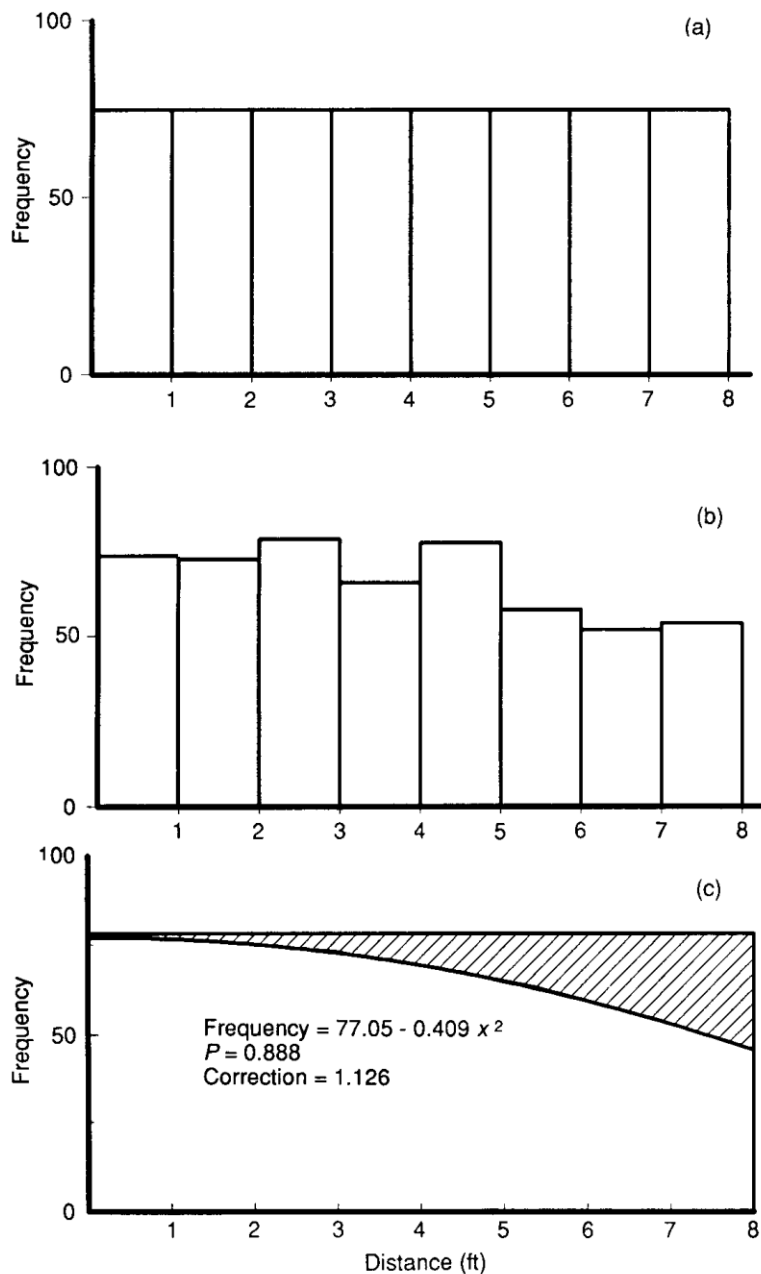
Figure 1. Mathematical rationale for distance sampling: (a) the expected distribution if all objects were detected; (b) the actual distribution of objects where the number of detections decline with increasing distance from the transect; and (c) the estimated portion of detected and undetected objects (Adapted from Buckland et al. 1993).
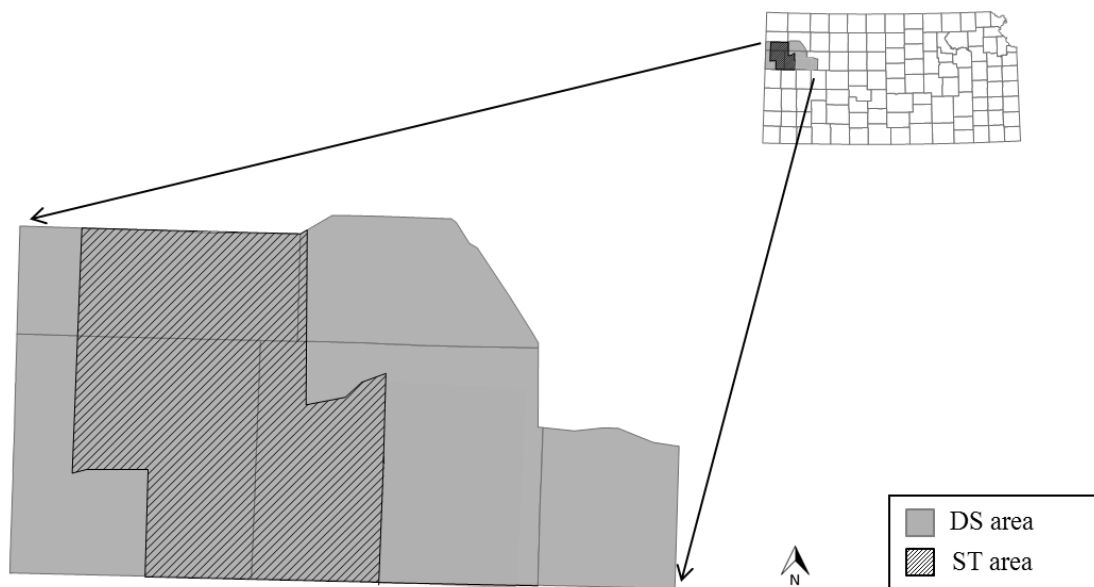
Figure 2. Study areas of Distance sampling (DS) surveys and strip transect

surveys (ST) in western Kansas, 2012-2014.
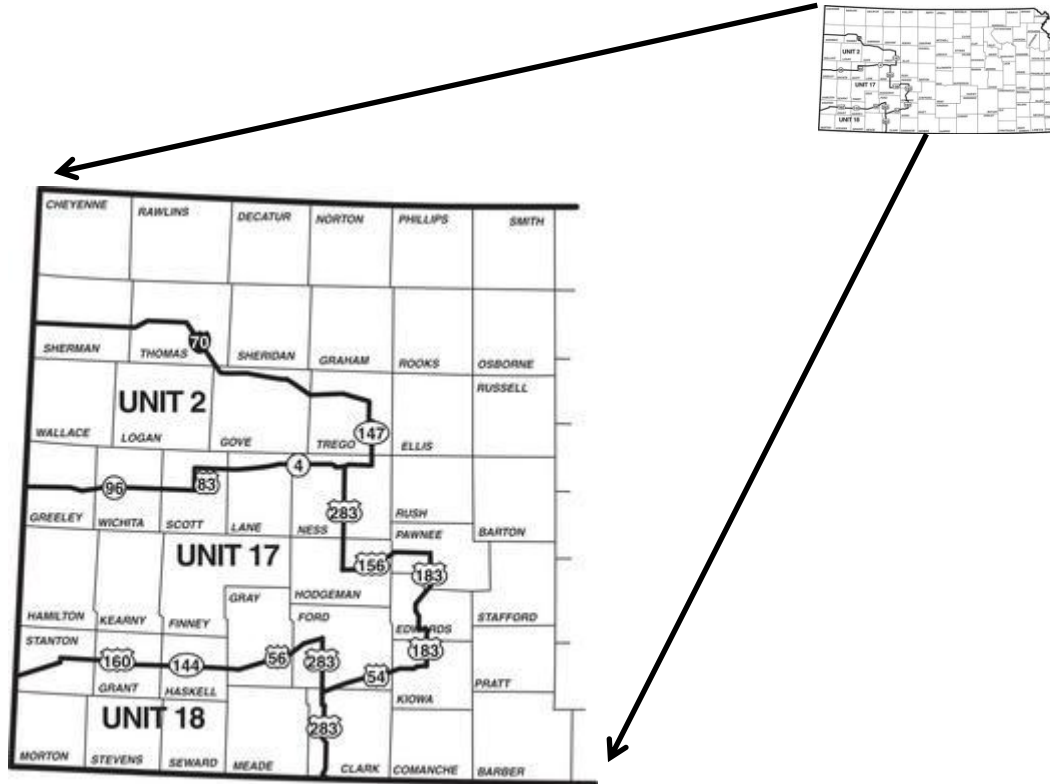
Figure 3. Pronghorn management units in western Kansas.
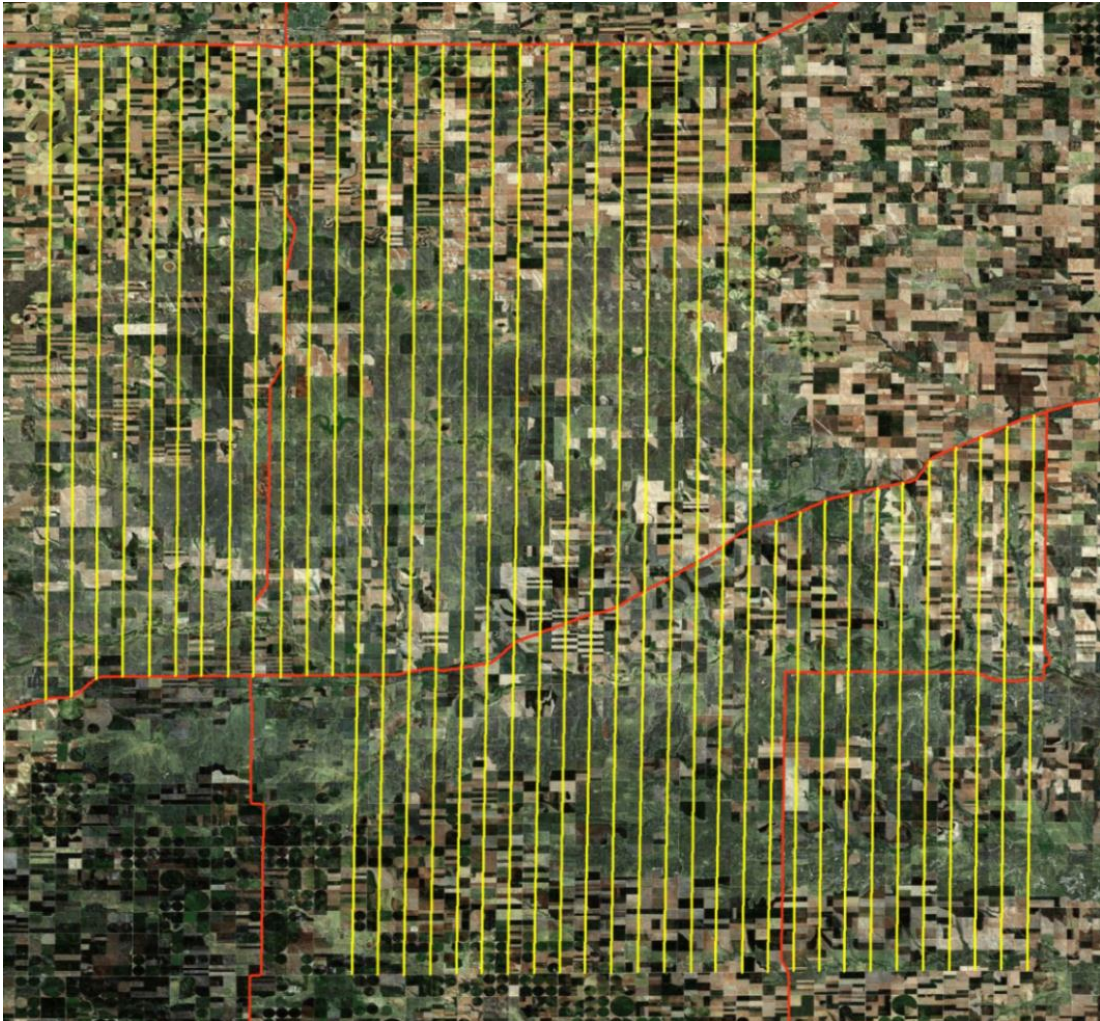
Figure 4. Transects spaced 1.6 km (1 mile) apart from one another, in a north-south

direction, for the strip transect method in Sherman, Wallace, and Gove county, Kansas,

2012-2014.
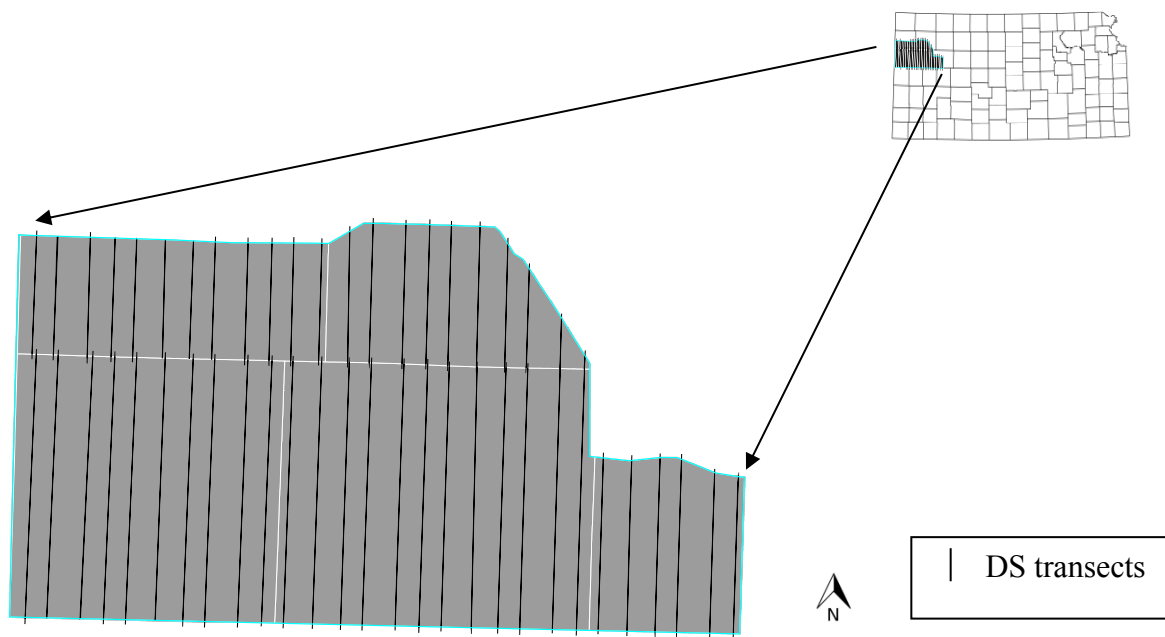
Figure 5. Distance sampling (DS) transects in western Kansas, 2012-2014.
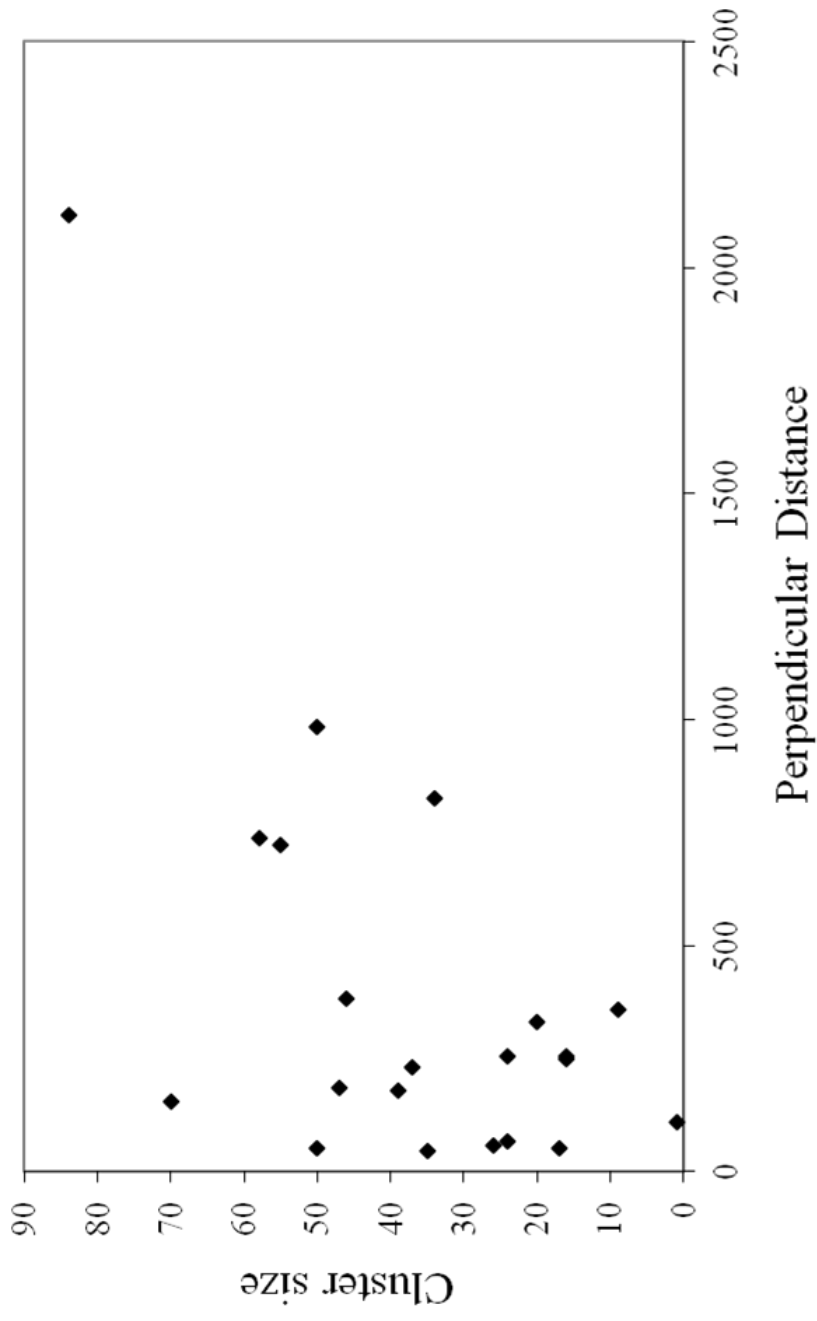
Figure 6. Scatterplot showing the size-bias of cluster size and perpendicular distance, from the distance sampling survey in western Kansas, winter 2013.
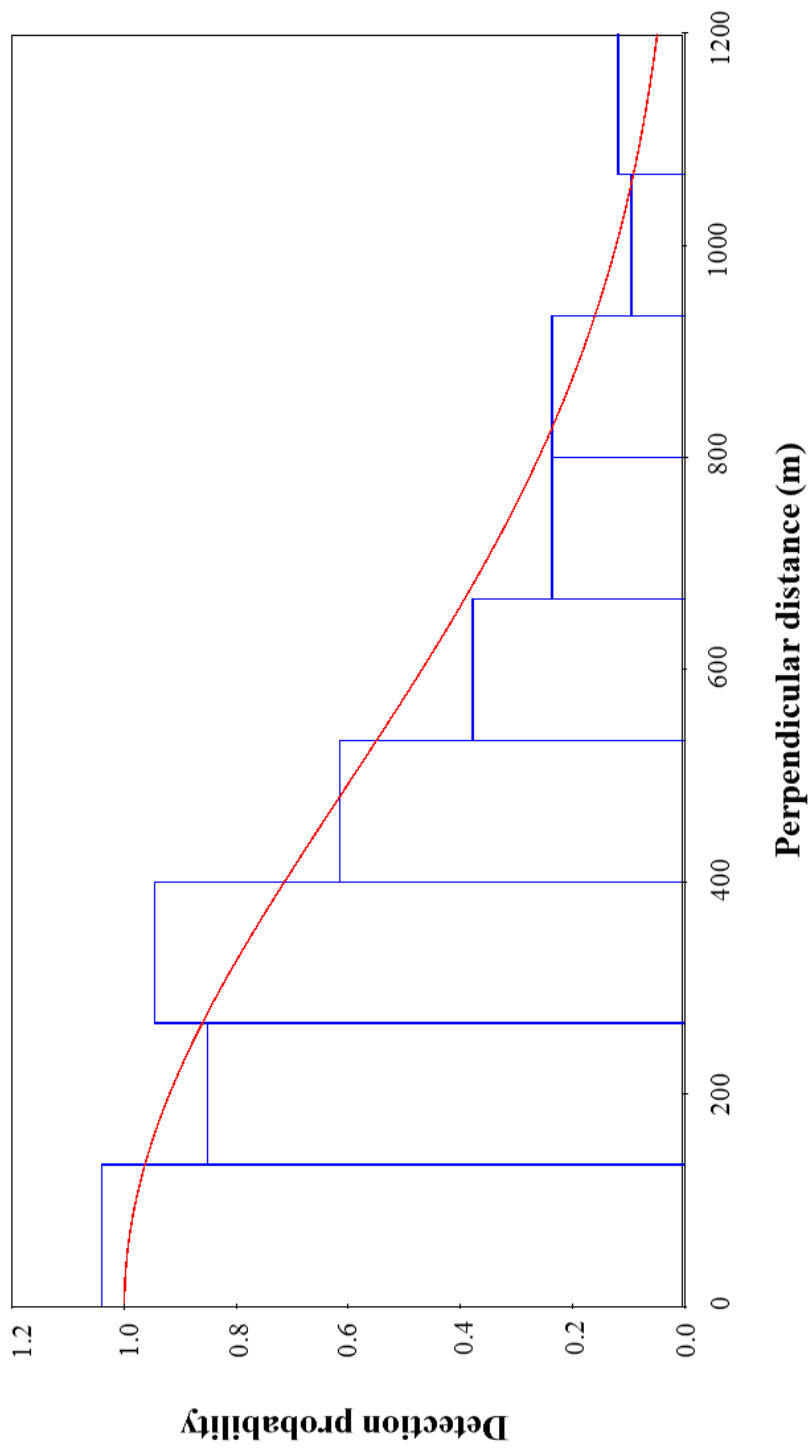
Figure 7. Detection function plot from all distance sampling surveys combined in western Kansas, 2012-2014.
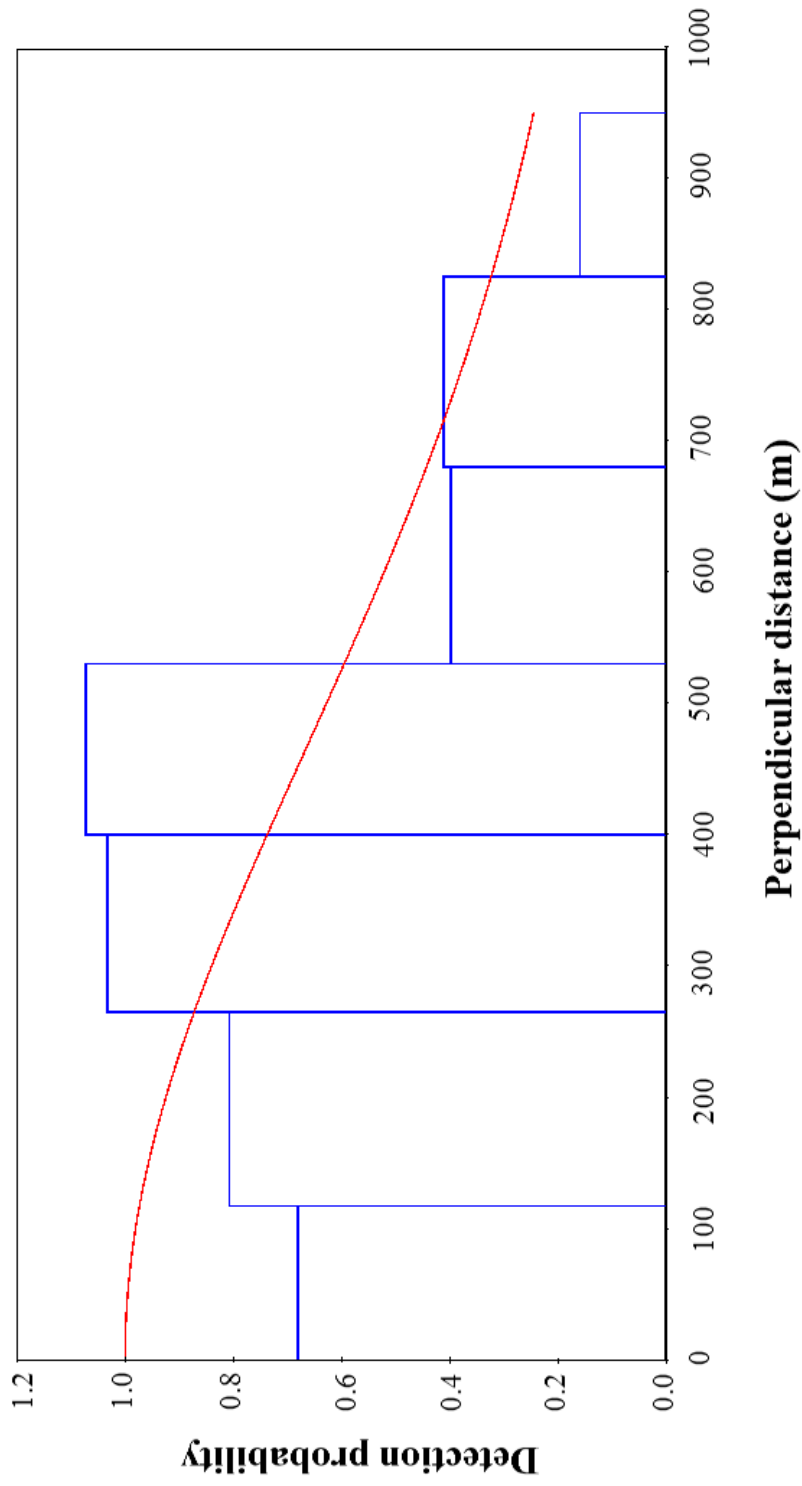
Figure 8. Detection function plot from observers on the right side of the plane (pooled over cluster size) from the distance sampling survey in western Kansas, summer 2012.
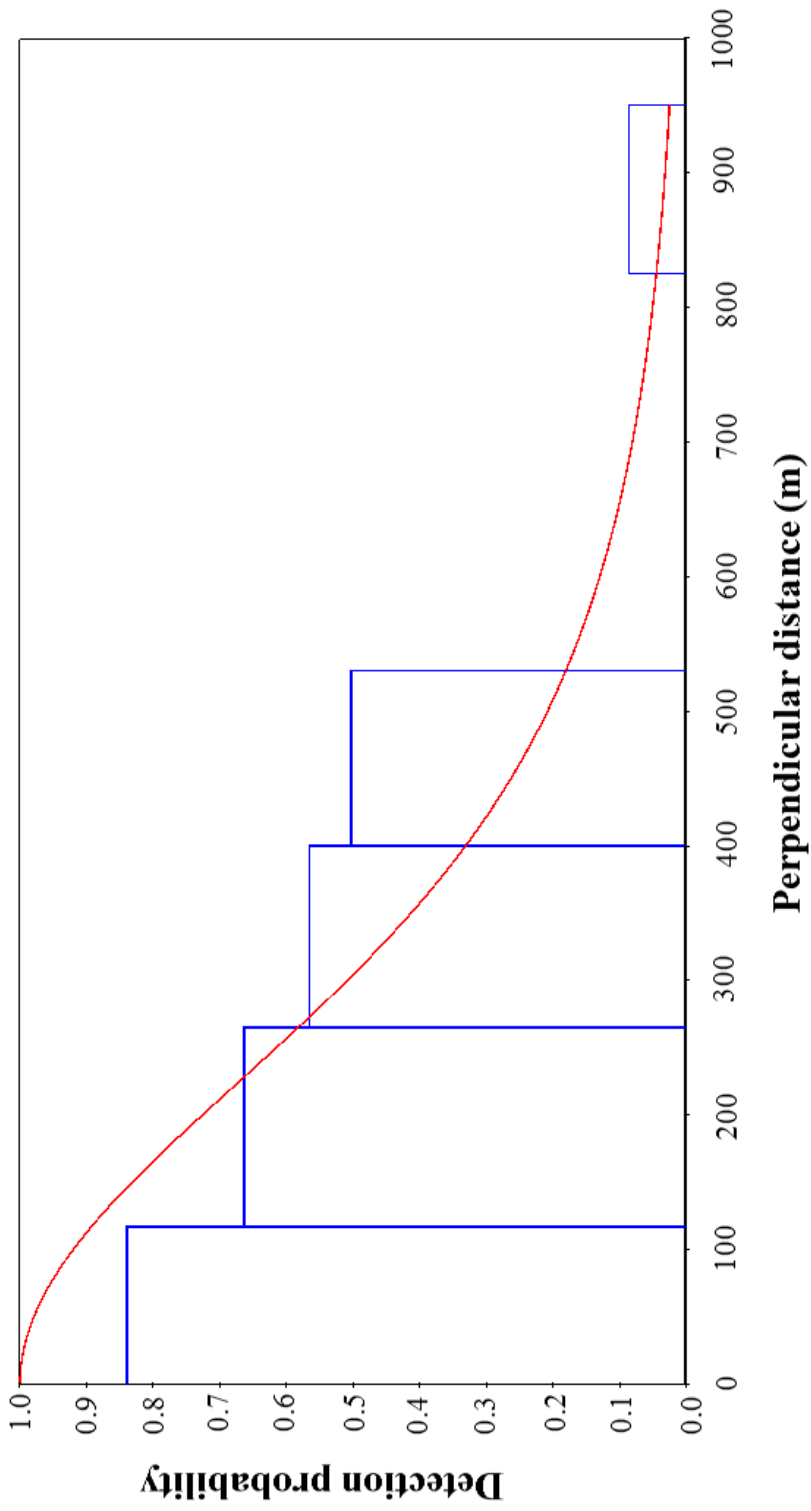
Figure 9. Detection function plot of observers on the left side of plane (pooled over

cluster size) from the distance sampling survey in western Kansas, summer 2012.
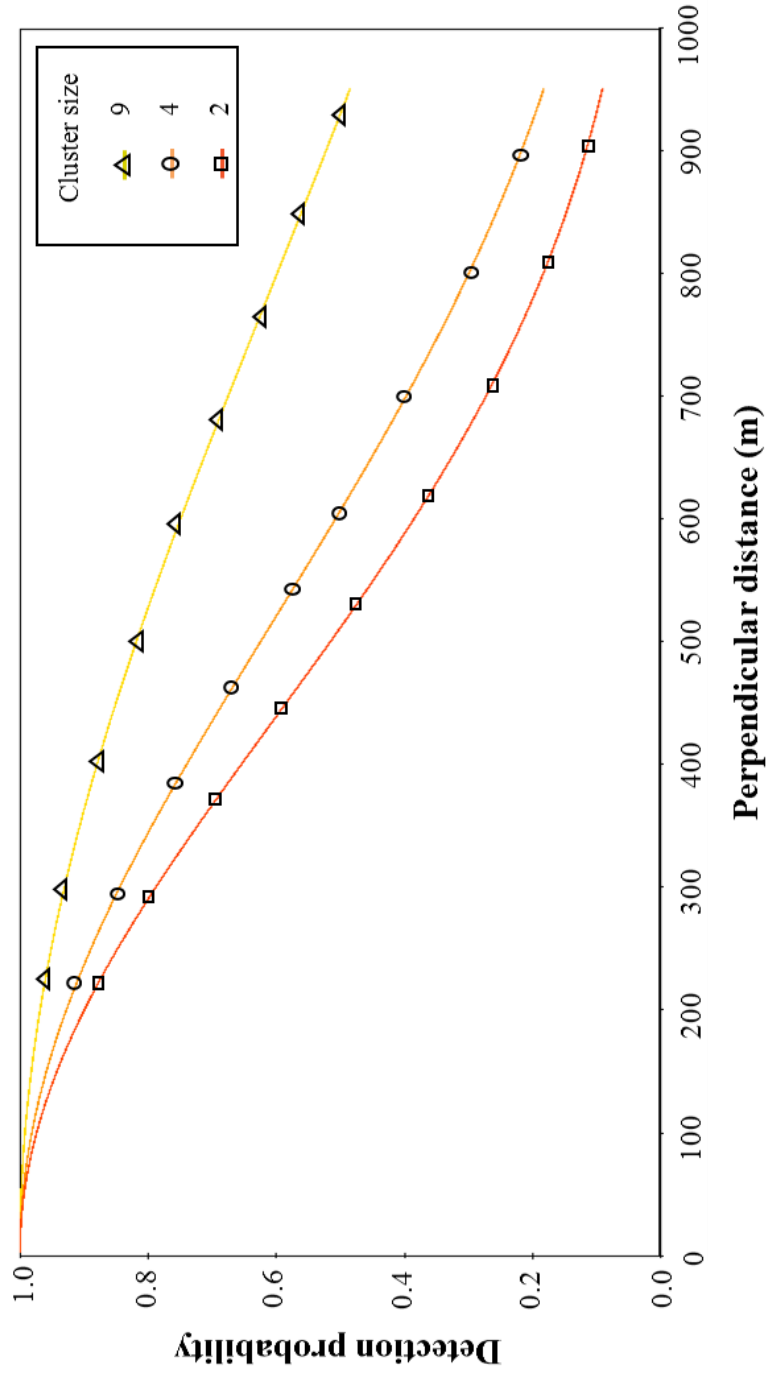
Figure 10. Detection function plot of covariates cluster size and side (right), showing the

declining detection probability of different cluster sizes from the distance sampling survey

in western Kansas, summer 2012.

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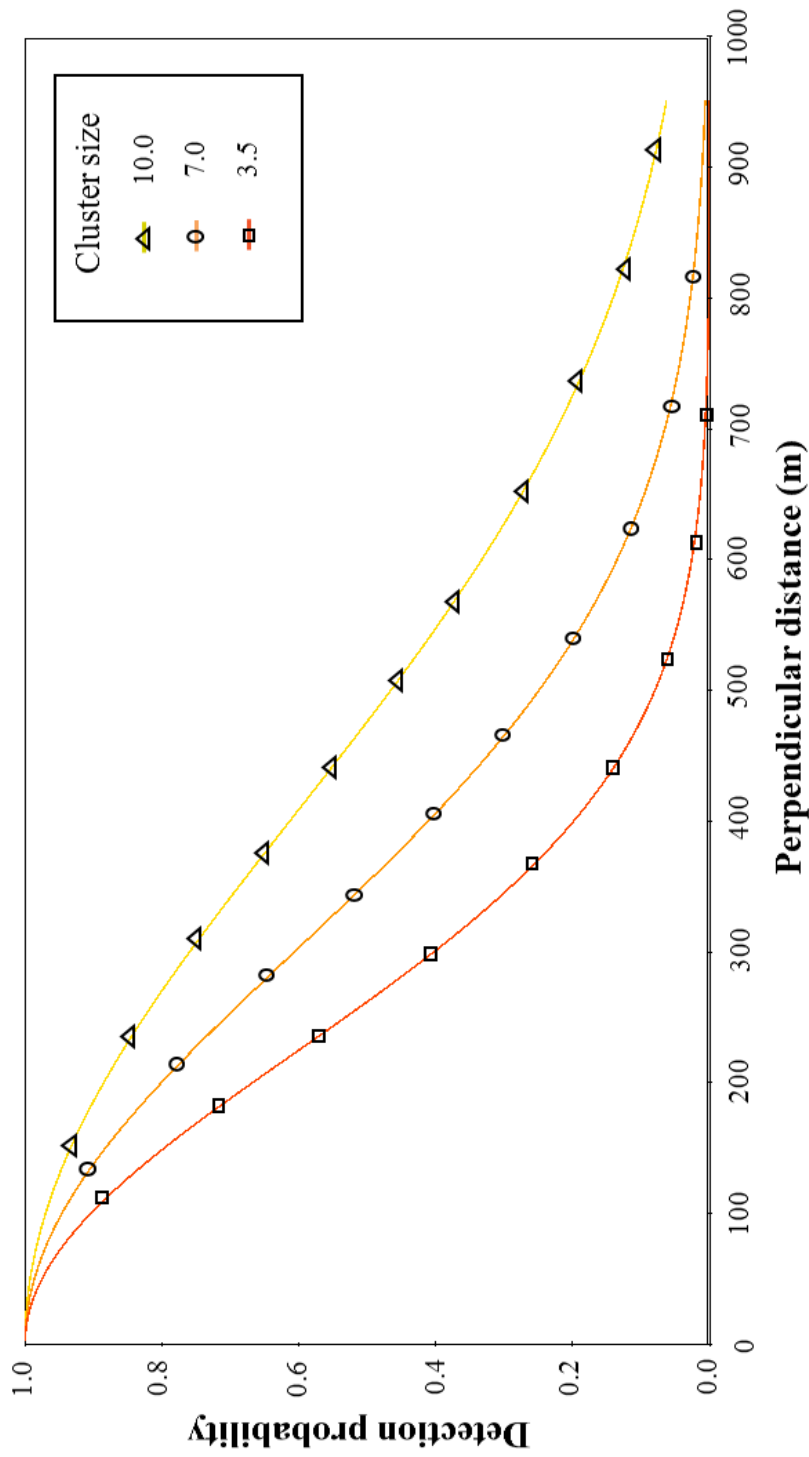
Figure 11. Detection function plot of covariates cluster size and side (left), showing the

declining detection probability of different cluster sizes from the distance survey in western
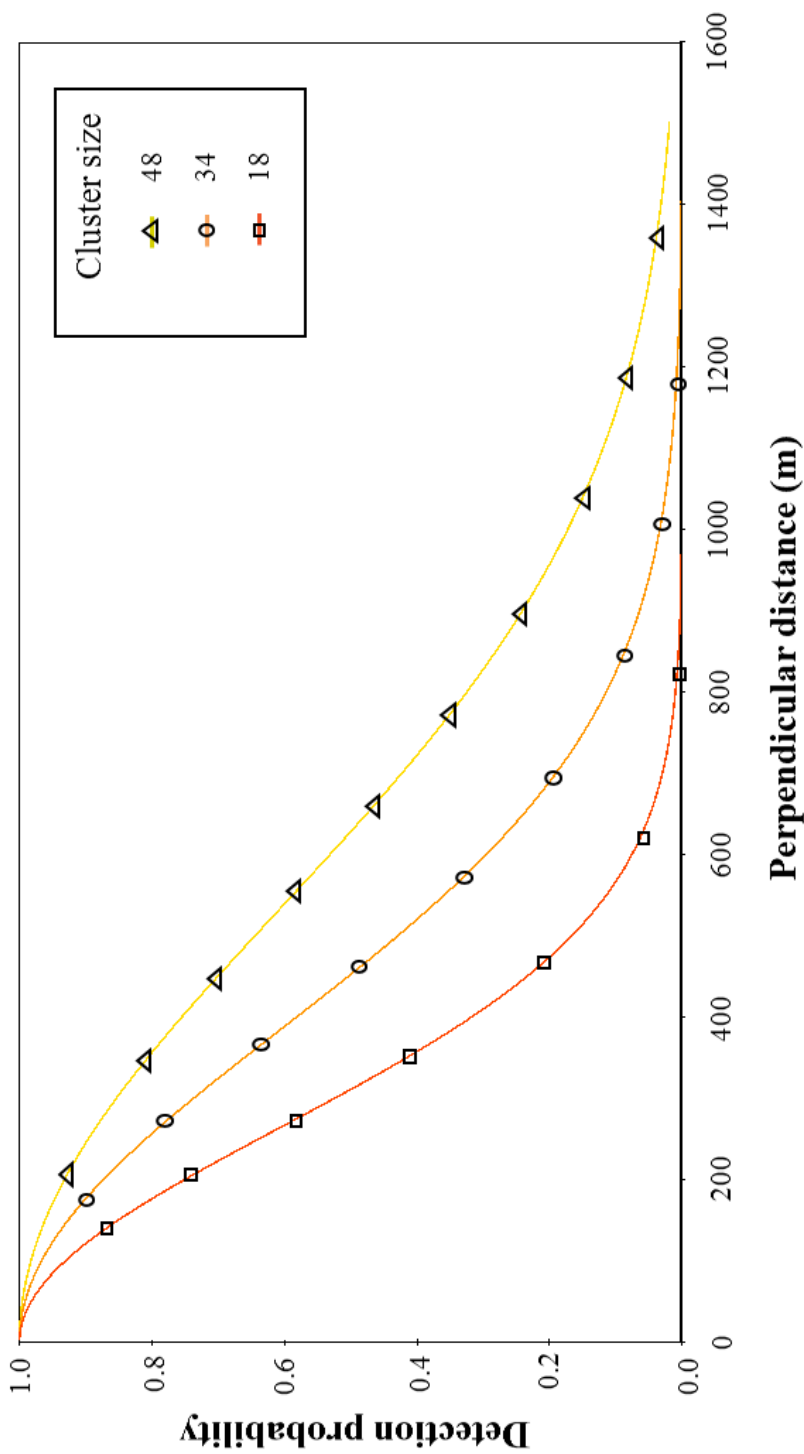
Kansas, summer 2012.

Figure 12. Detection function plot of covariate cluster size from the distance sampling survey in western Kansas, winter 2013.
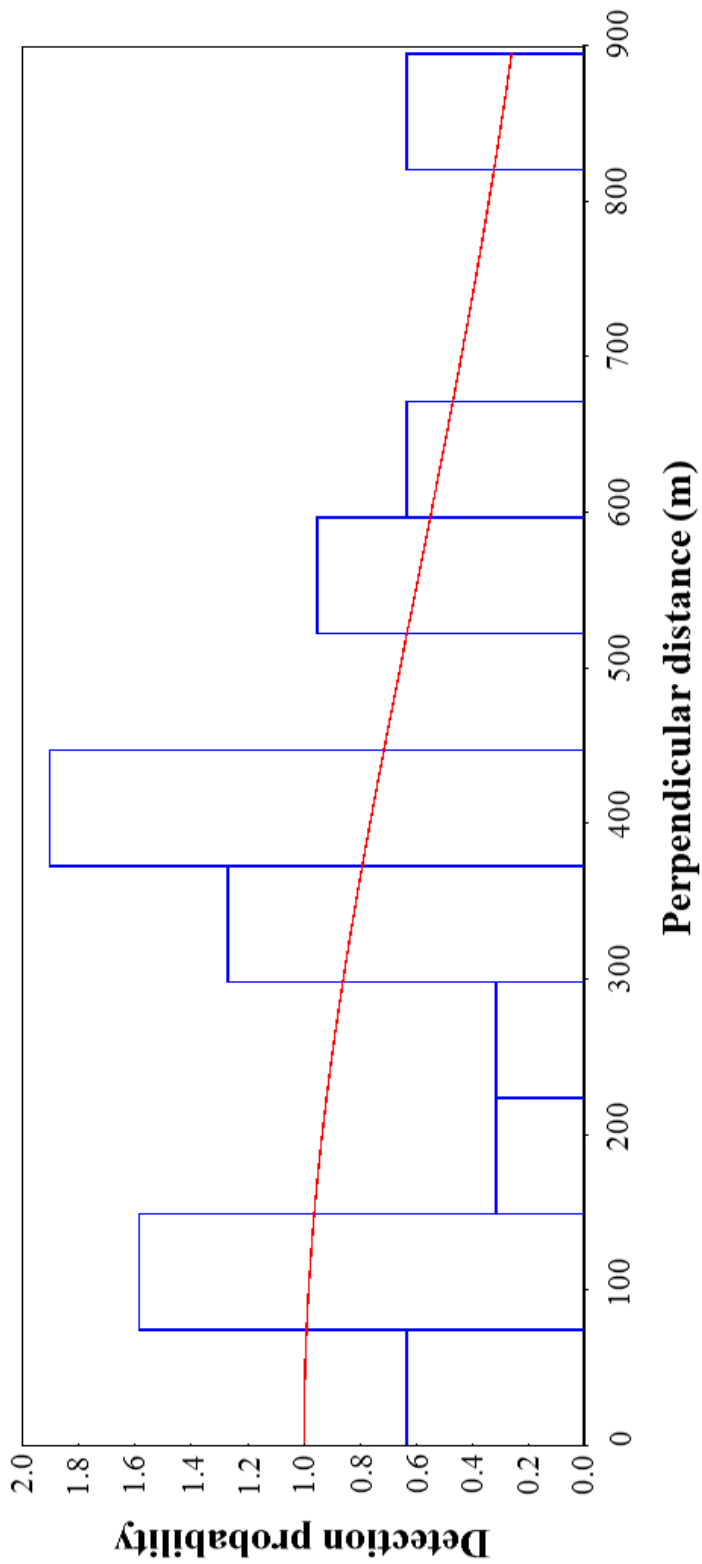
Figure 13. Detection function plot of the 0 m transect from the distance sampling survey in western Kansas, summer 2013.
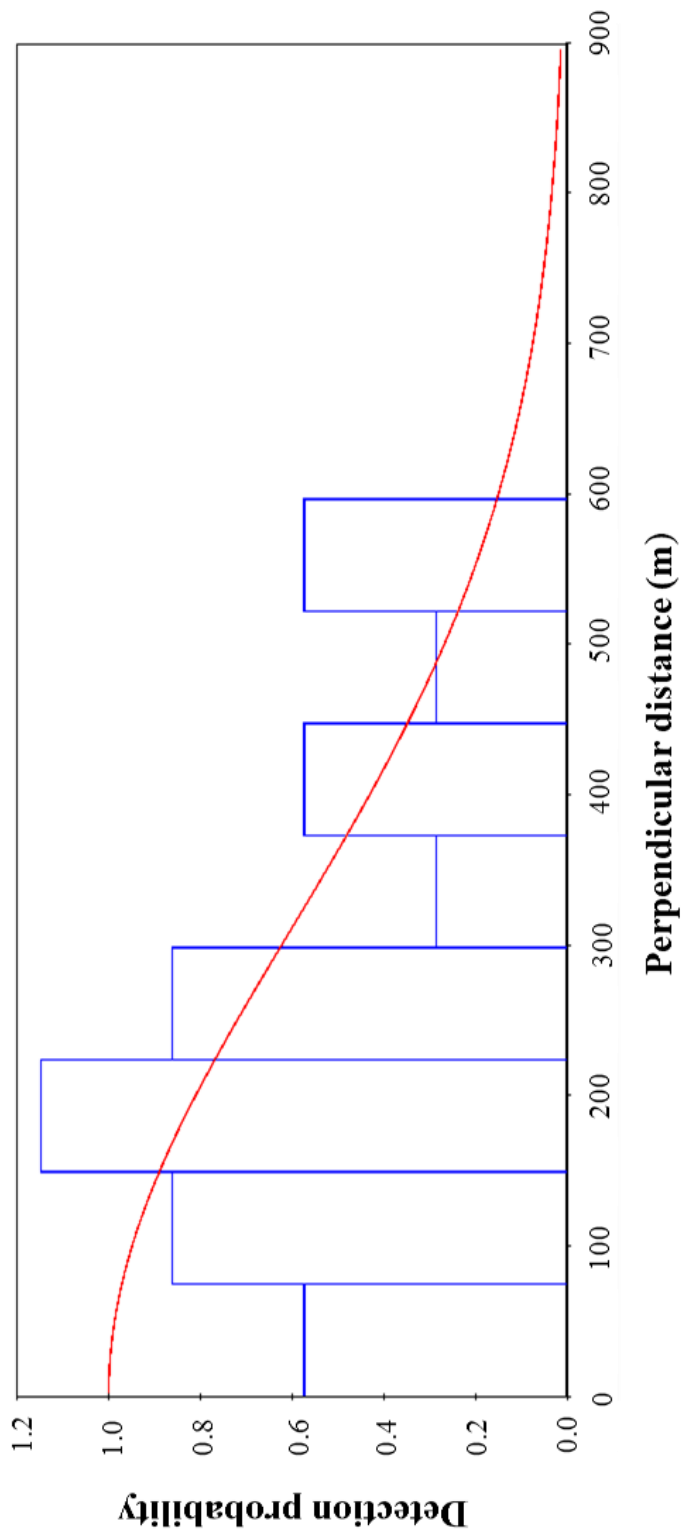
Figure 14. Detection function plot of the 400 m transect from the distance sampling survey in

western Kansas, summer 2013.
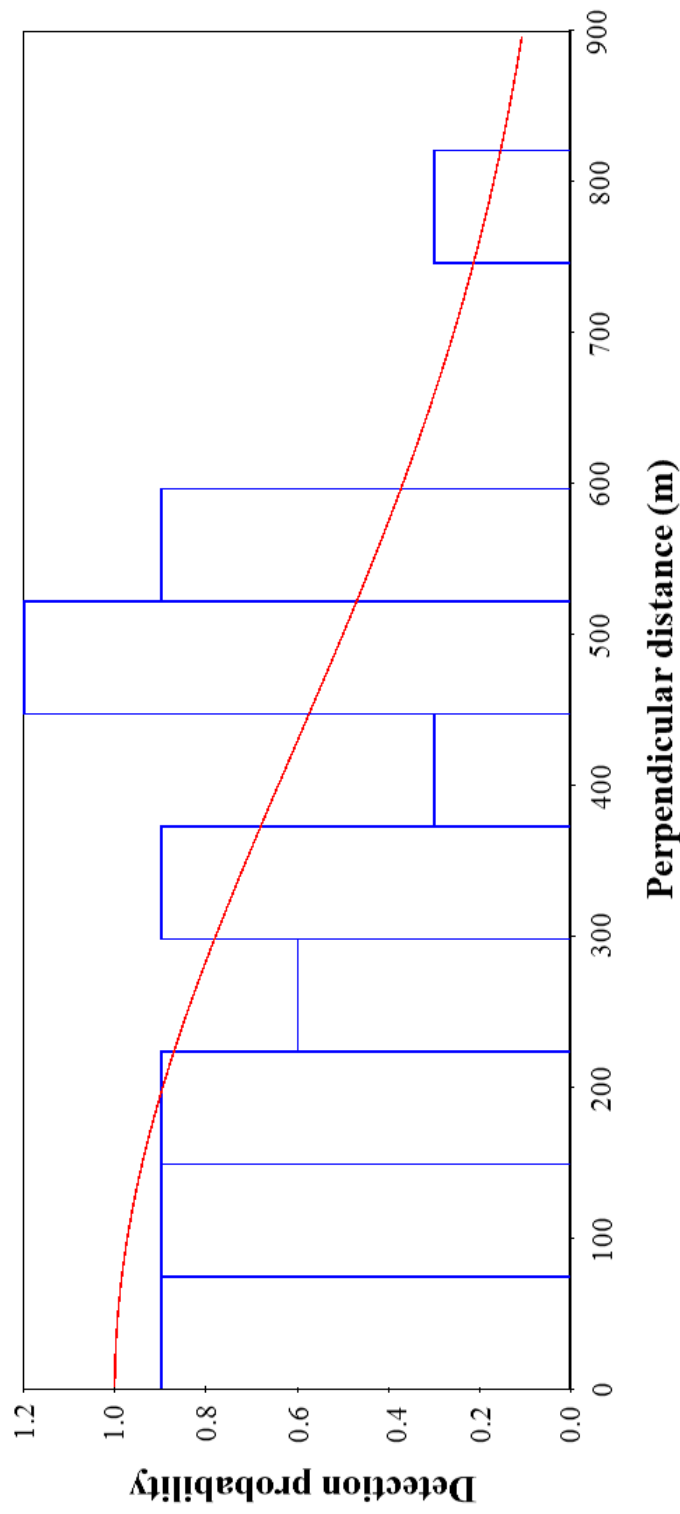
Figure 15. Detection function plot of the 800 m transect from the DS survey in western Kansas, summer 2013.
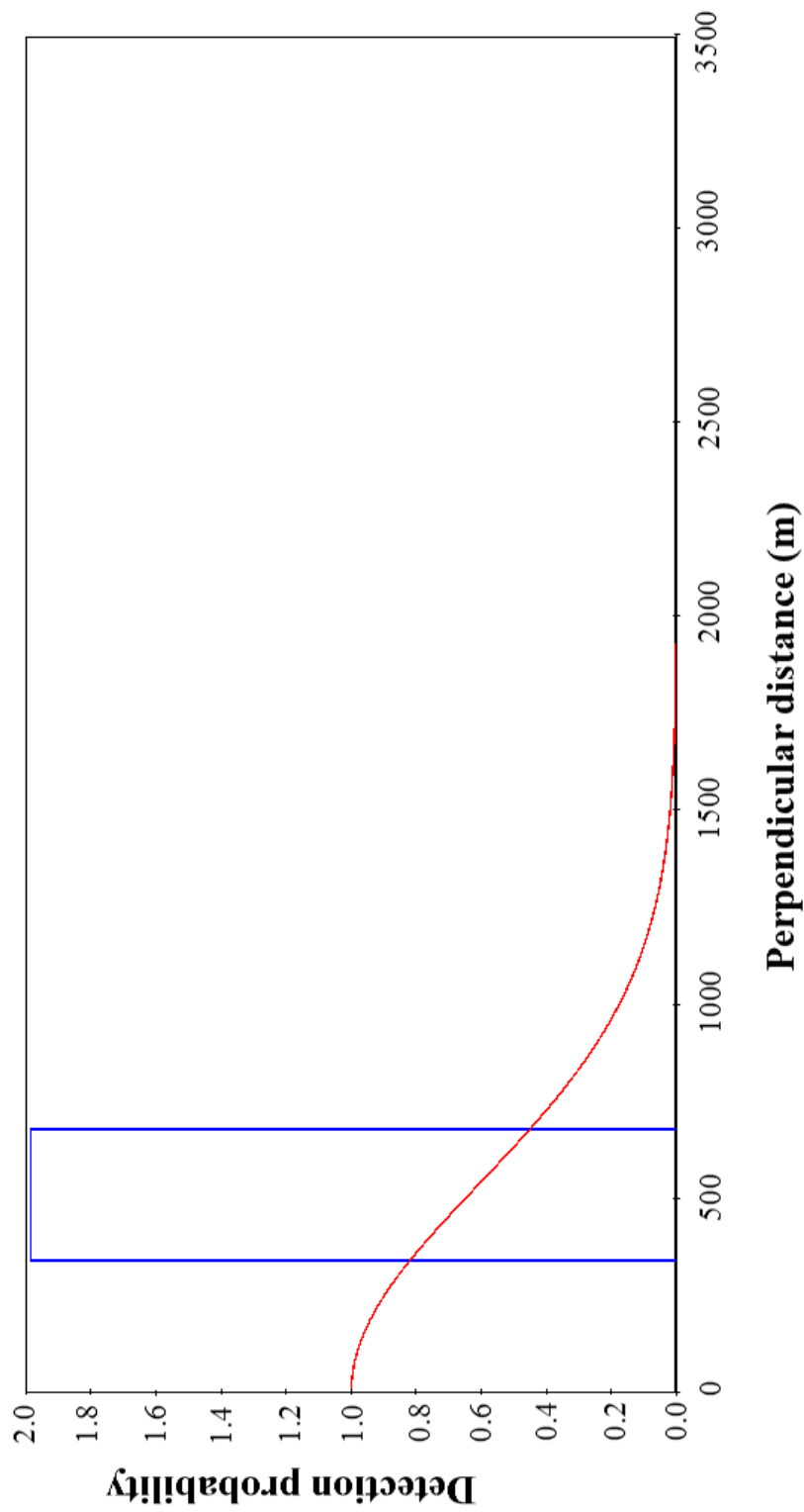
Figure 16. Detection function plot of observers from the left side of the plane in rangeland habitat during the distance sampling survey in western Kansas, winter 2014.
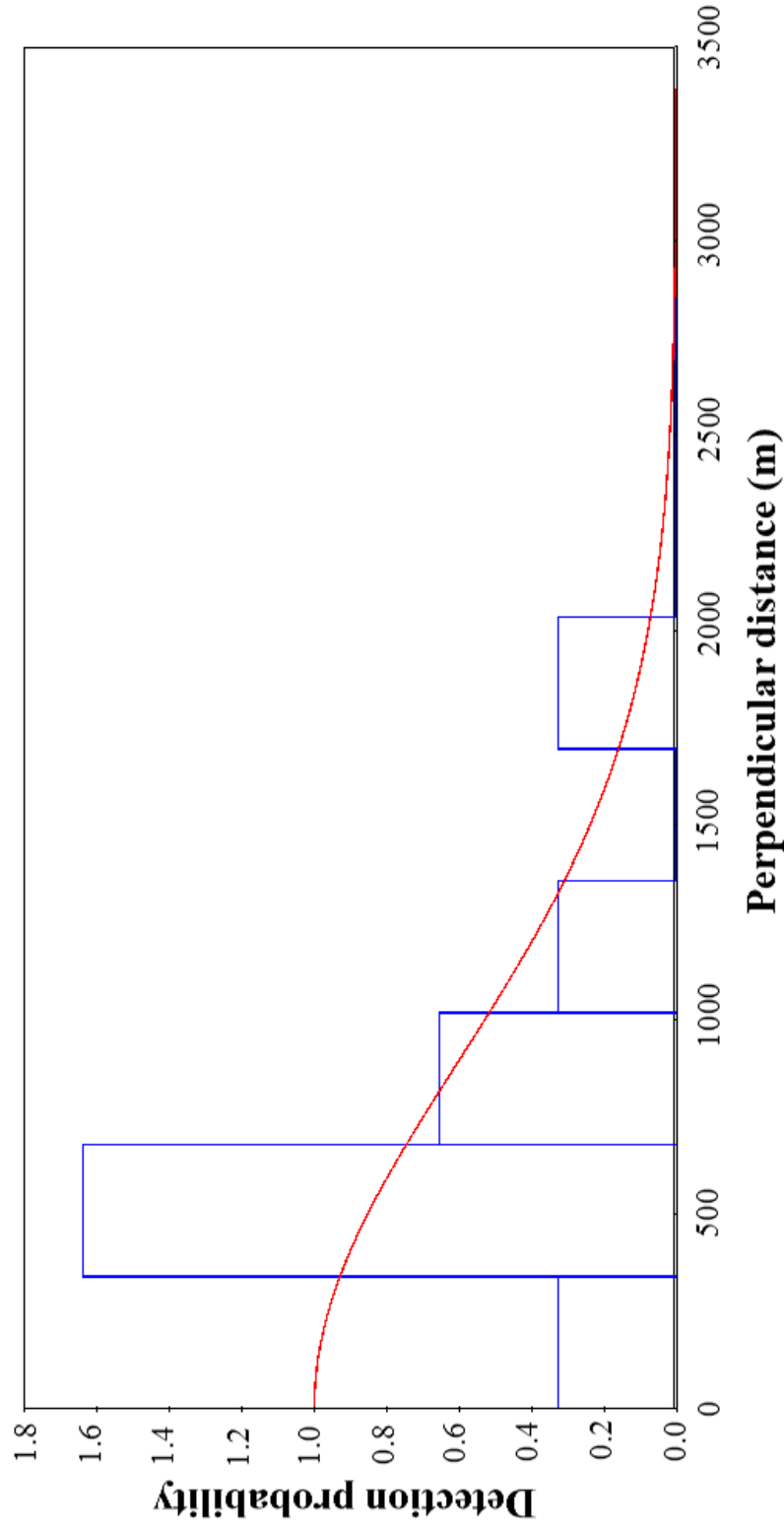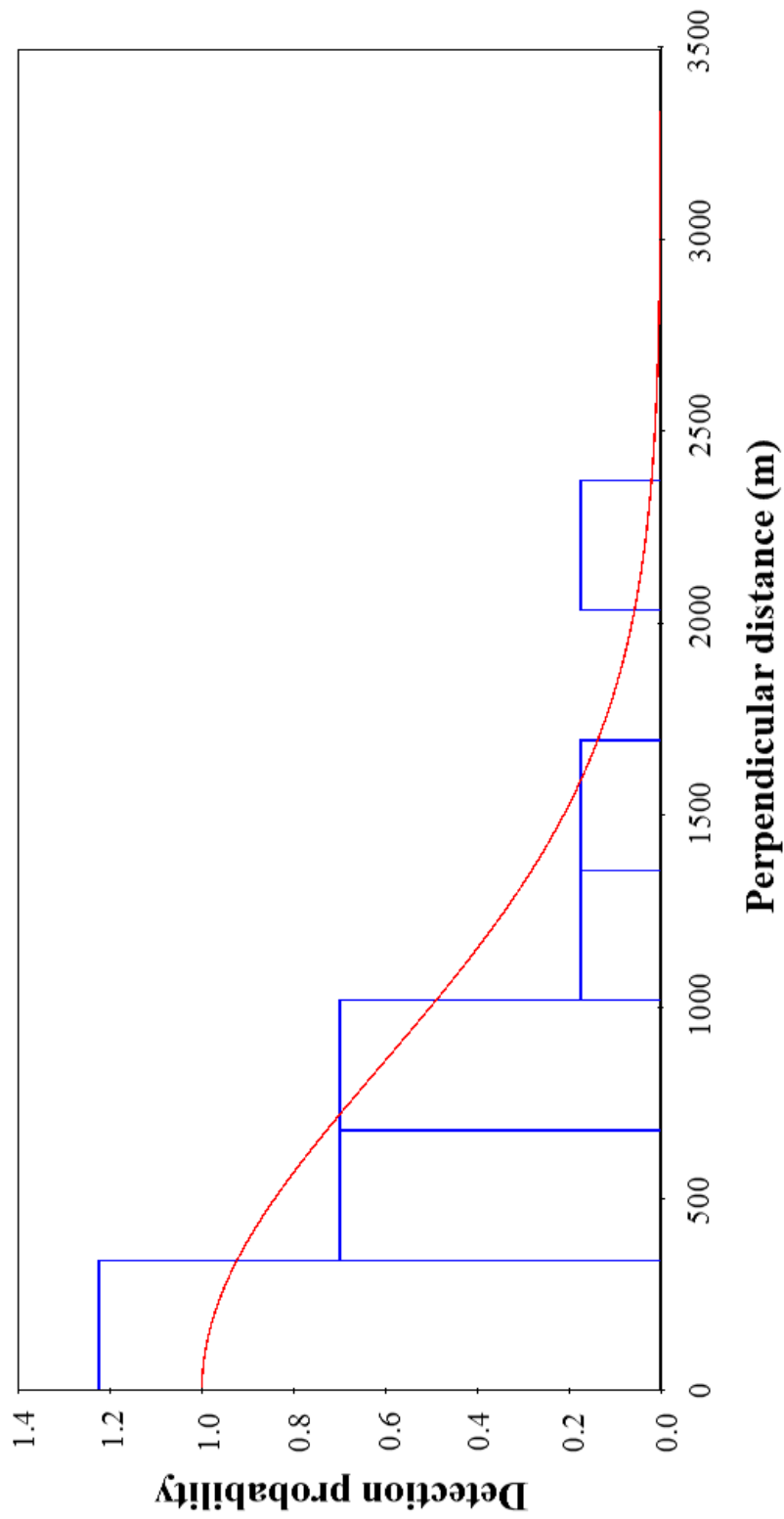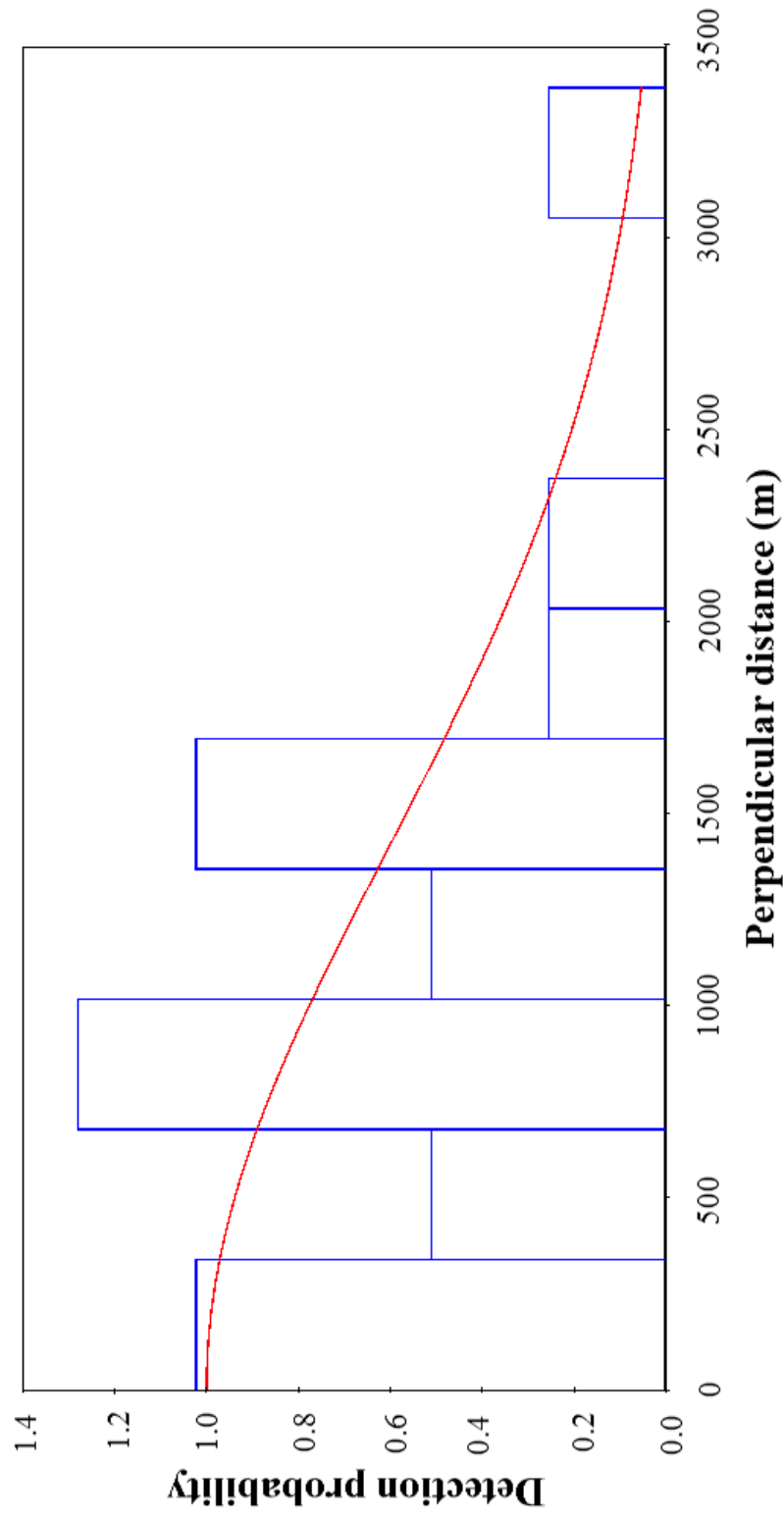
Figure 17. Detection function plot of observers from the right side of the plane in rangeland habitat during the distance sampling survey in western Kansas, winter 2014.
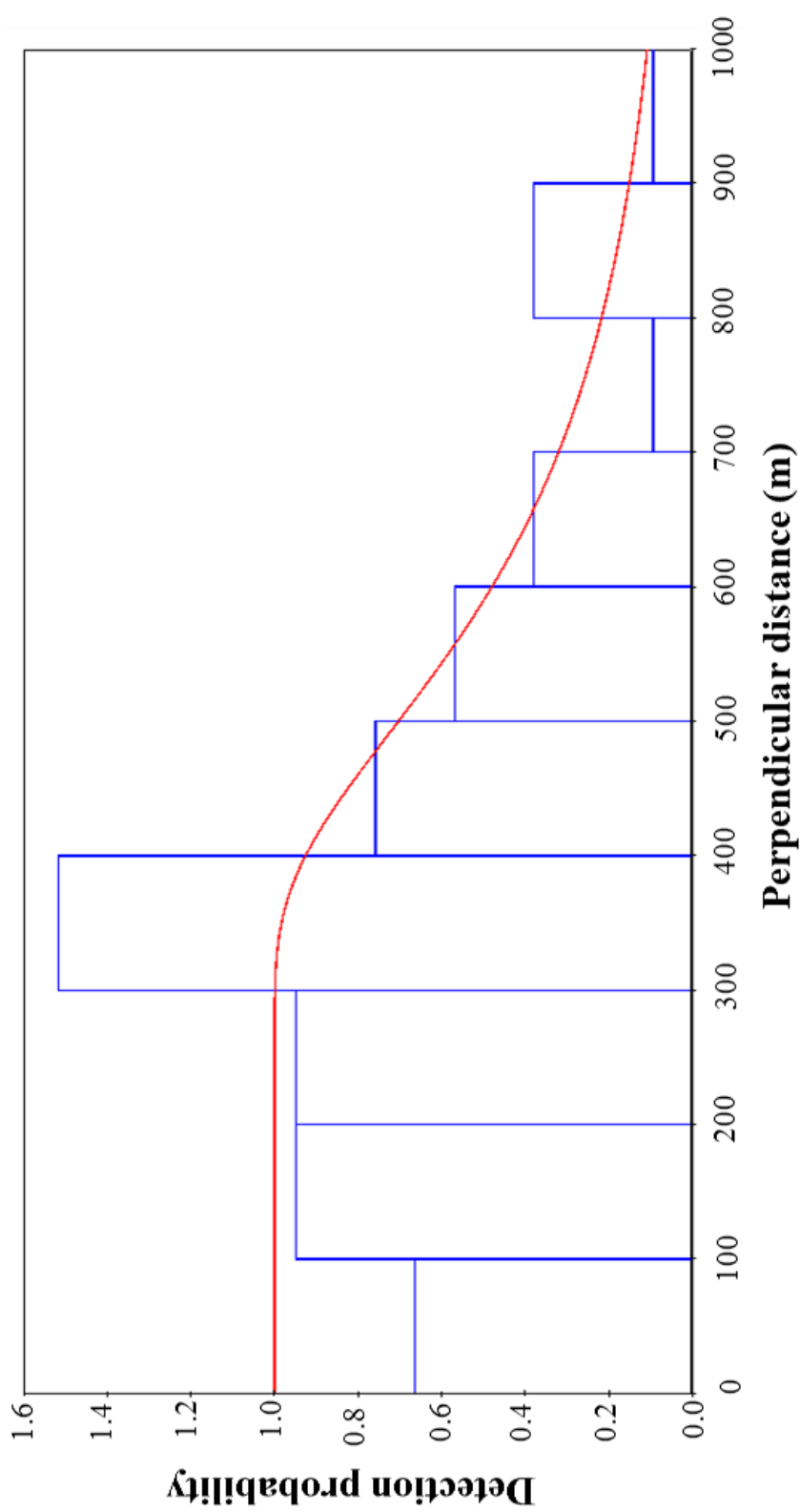
Figure 18. Detection function plot of observers from the left side of the plane in cropland habitat during the distance sampling survey in western Kanas, winter 2014.

Figure 19. Detection function plot of observers from the right side of the plane in cropland habitat during the distance sampling survey in western Kansas, winter 2014.

Figures 20. Detection function plot of the 0 m transect from all distance sampling survey periods combined in western Kansas, 2012-2014.
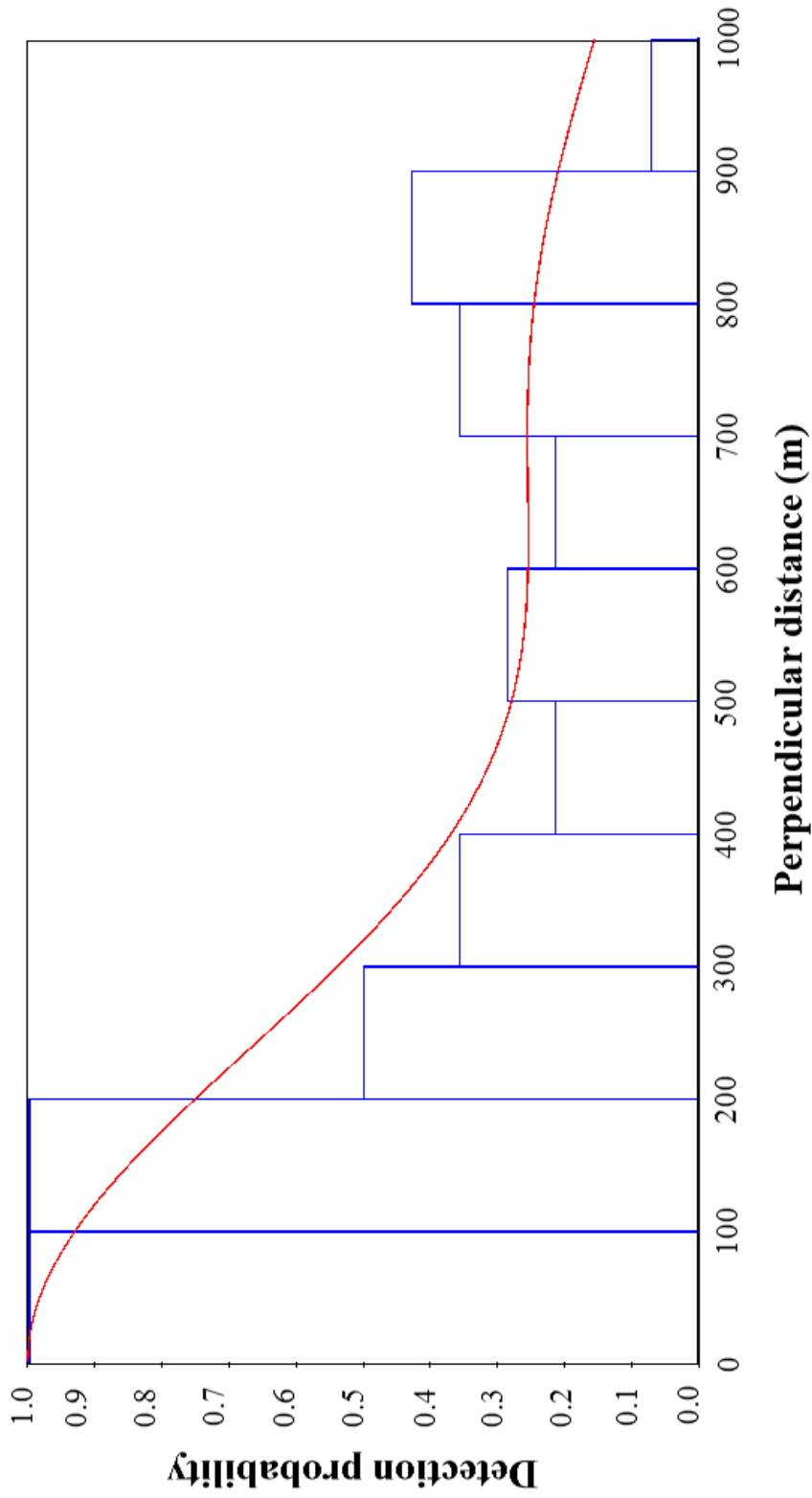
Figure 21. Detection function plot of the 400 m transect from all distance sampling

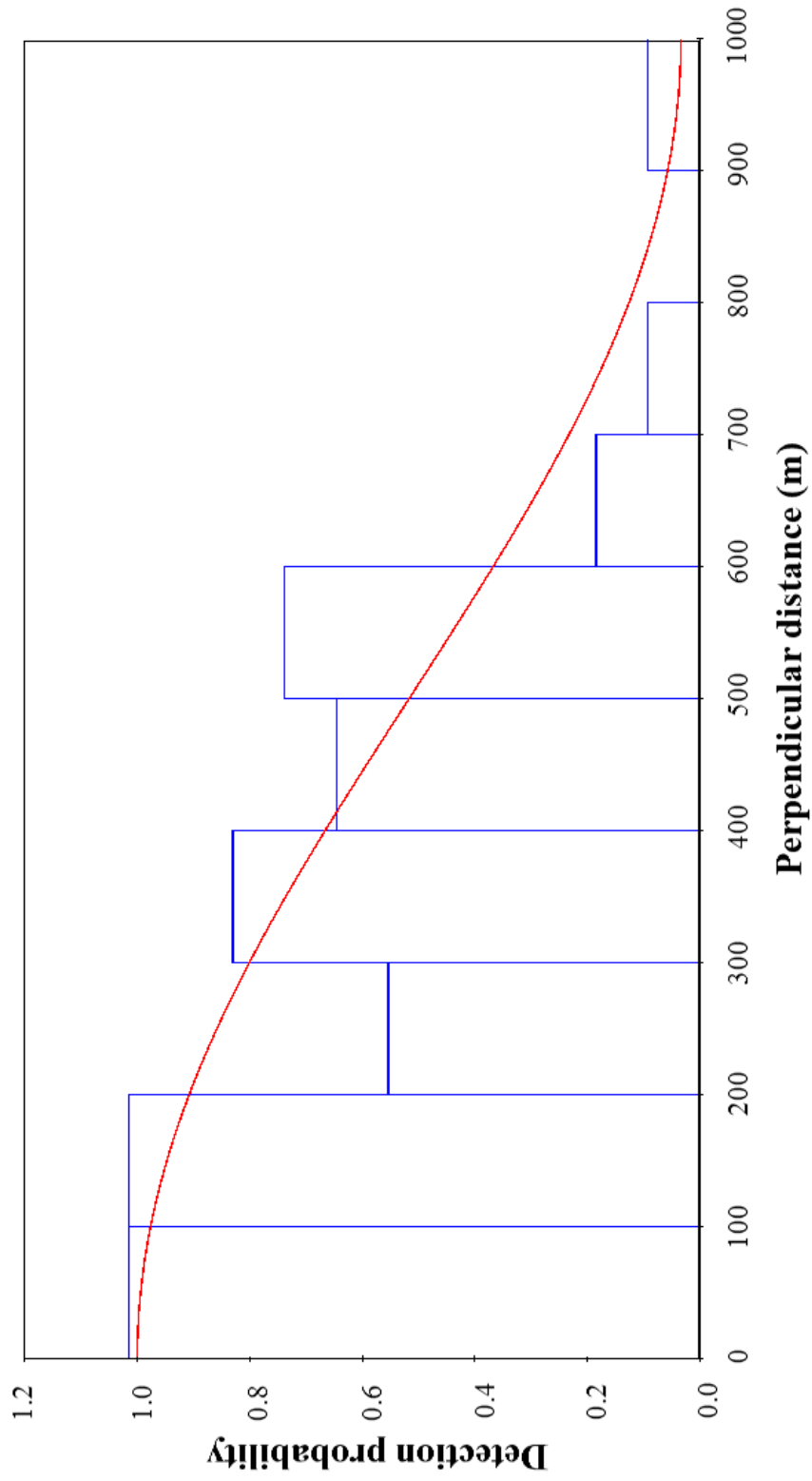survey periods combined in western Kansas, 2012-2014.

Figure 22. Detection function plot of the 800 m transect from all distance sampling survey periods combined in western Kansas, 2012-2014.
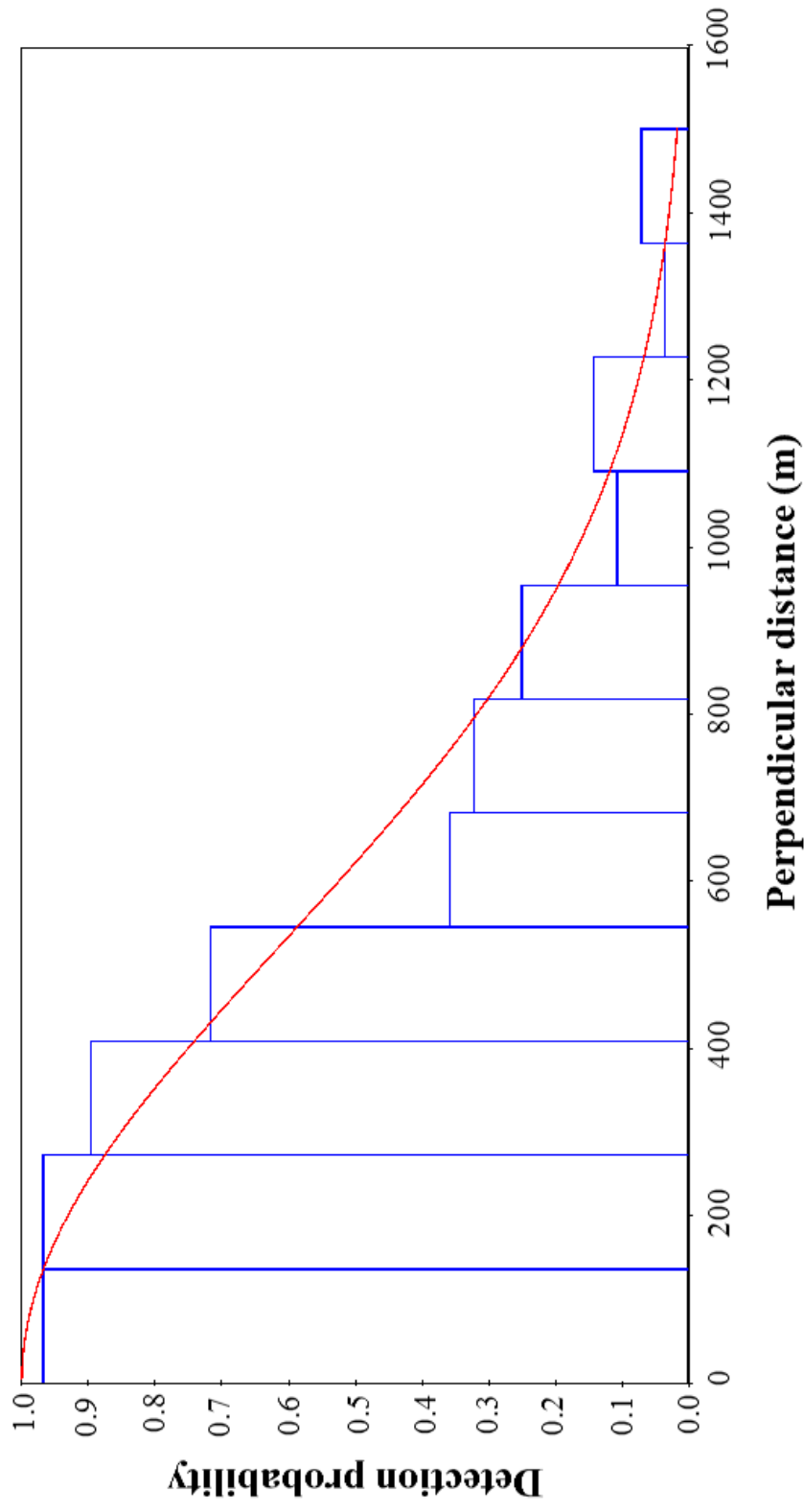
Figure 23. Detection function plot of cropland observations from all distance sampling survey periods combined in western Kansas, 2012-2014.
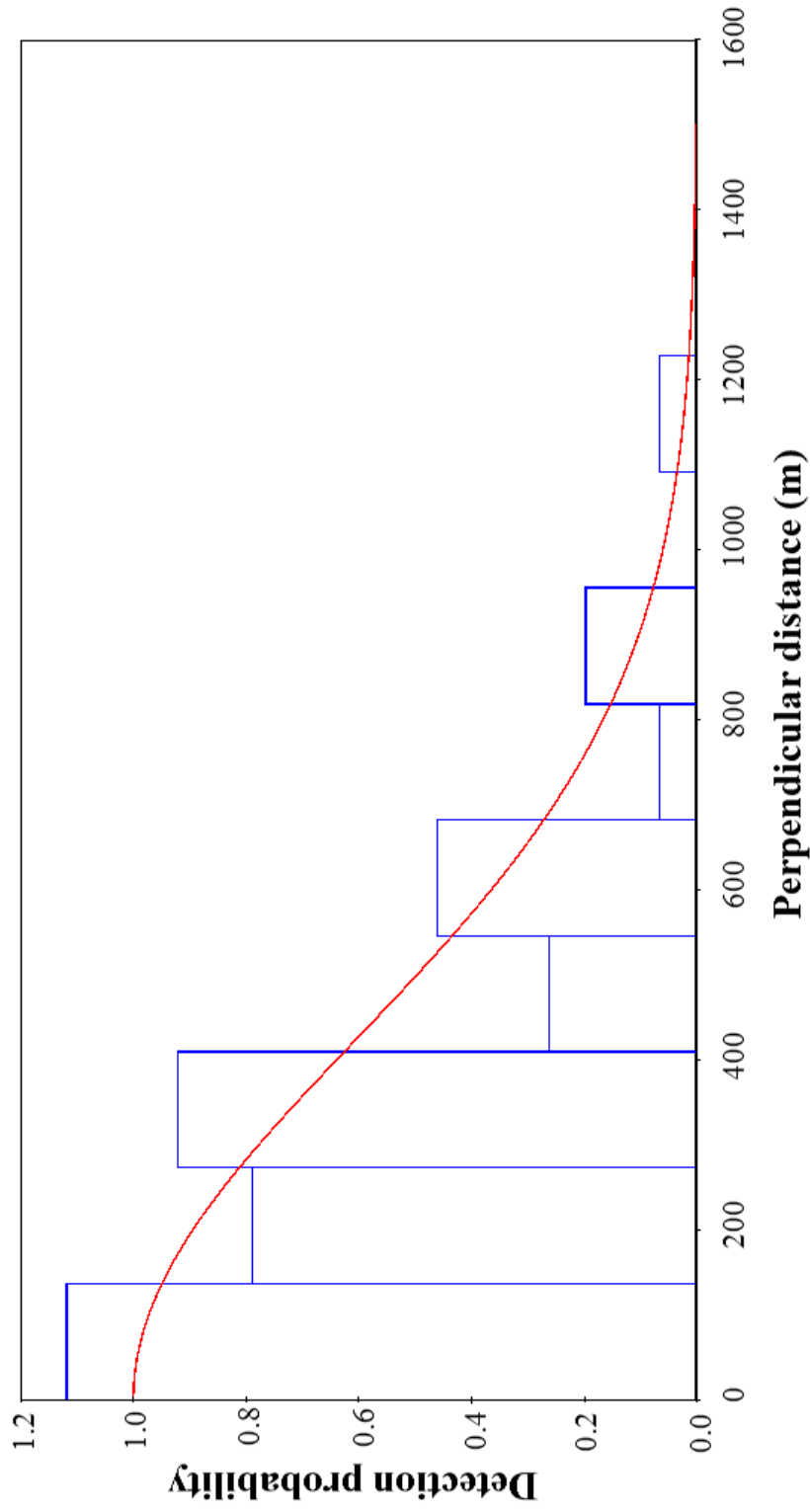
Figure 24. Detection function plot of rangeland observations from all distance sampling survey periods combined in western Kansas, 2012-2014.

y_kobayashi@fhsu.edu
To: lpaige@fhsu.edu
Cc: efinck@fhsu.edu
Re: IACUC Protocol (13-006)

April 23, 2013 4:03 PM

Leslie:

Please indicate in the record and also in the minute as an addendum that
proper correction was made on the protocol FHSU 2013-006 and that the chair
is satisfied with the action taken by the PI to address concerns of the
committee. Therefore, please note that the protocol FHSU 2013-006 is
approved and that the study can proceed.

Dr. Yass Kobayashi
Molecular and reproductive endocrinologist
Department of Biological Sciences
Fort Hays State University
600 Park St.
Hays, KS 67601
Tel: 785-628-5835
Fax: 785-628-4153

From: Elmer Finck/FHSU
To: Yasuhiro Kobayashi/FHSU
Cc: Leslie Paige/FHSU
Date: 04/23/2013 02:24 PM
Subject: IACUC Protocol (13-006)

Dr. Kobayashi -- As per your request The protocol should indicate the
number , or an estimate of the number of animals. If the number is unknown
or estimated, please provide justification. The number estimated for each
survey period is 1400 pronghorn (Antilocapra americana) This estimate is
based on long term record from surveys by personnel with the Kansas
Department of Wildlife, Parks, and Tourism. Please let me know if you
need additional information. Saludos y nos vemos más tarde, EJF

Elmer J. Finck
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cell: (785) 650-1057

The greatest gift you could give yourself is a job you enjoy.
In Tribute to Jerry R. Choate 1943 - 2009