Eur J Wildl Res (2005) 51: 108–116
DOI 10.1007/s10344-005-0085-0

ORIGINAL PAPER

Richard G. Hamrick · Tahir Pirgalioglu
Serife Gunduz · John P. Carroll

Feral donkey *Equus asinus* populations on the Karpaz peninsula, Cyprus

Received: 31 August 2004 / Accepted: 22 February 2005 / Published online: 30 April 2005

Abstract Numerous researchers have documented the adverse effects of feral donkeys *Equus asinus* introduced to semi-arid ecosystems. With the release of feral donkeys and potential increasing populations in natural habitats in northern Cyprus, there is concern for negative impacts on vegetation and native species. In the north of the island, there has been only one published study of feral donkey populations, and population estimators were relatively subjective. We estimated feral donkey populations on the Karpaz Peninsula using line transect surveys and quantitative distance sampling estimators. We stratified the sampling by using 11 sample units within the study area. We evaluated potential biases associated with habitat, topography, and perpendicular distance from the transect line and found that these variables did not bias donkey detections during our surveys. Using program DISTANCE, we found that a hazard rate cosine model was the best model that described our distance data based on model selection criterion (Akaike's Information Criteria adjusted for small sample bias). Estimated effective strip width was 280.19 m and detection probability was 0.47 with this model. Estimated donkey density was 6.7 donkeys/km^2, and estimated total abundance was 800 donkeys for the entire 132.5 km^2 study area. Of 95 donkey groups detected: 16% were detected in agricultural habitats with flat topography, 9% were detected in agricultural habitats with sloped topography, 24% were detected in shrub/forest habitats with flat topography, and 51% were detected in shrub/forest habitats with sloped topography. Of 102 behavioral observations recorded (multiple behaviors were detected in groups), frequencies of behaviors were 1% bedded, 70% standing, 22% grazing, 6% moving, and 2% other. Our estimated donkey population density in the Karpaz Peninsula was >2 times densities reported in arid regions of the United States and Australia, but slightly lower than earlier density estimates reported for the Karpaz region. These estimates of feral donkey populations in the Karpaz Peninsula provide a quantitative baseline from which to make population management decisions.

Keywords Abundance estimation · Cyprus · Density estimation · Distance sampling · *Equus asinus* · Feral donkeys · Karpaz Peninsula · Line transect

R. G. Hamrick · J. P. Carroll (✉)
Daniel B. Warnell School of Forest Resources,
University of Georgia, Athens, GA 30602, USA
E-mail: jcarroll@smokey.forestry.uga.edu
Tel.: +1-706-5425815
Fax: +1-706-5428356

Present address: R. G. Hamrick
Department of Wildlife and Fisheries, Mississippi State University,
Box 9690, Mississippi State, MS 39762, USA

T. Pirgalioglu
2, Ataturk Caddesi, Alaykoy, Lefkosa/Mersin, 10, Turkey

S. Gunduz
Environmental Education and Research Center,
Lefke European University, Mersin, 10, Turkey

Introduction

Studies of feral donkeys have focused on behavior (e.g., Rudman 1998), food habits (e.g., Woodward and Ohmart 1976), habitat use, population dynamics, and interactions with other species (e.g., Seegmiller and Ohmart 1981). Often, the purpose of these studies has been for evaluation of suspected adverse effects of feral donkeys on habitats where they were introduced.

Few definitive conclusions have been reached regarding what population level of feral donkeys could be considered acceptable (Hanley and Brady 1977; Wagner 1983), assuming that managers want to (or have to) maintain and regulate these populations.

During the war in Cyprus in 1974, large numbers of domestic donkeys and pigs were allowed to go feral. Most of these were subsequently captured, but feral populations of donkeys and pigs have persisted in the north of the island (e.g., the Karpaz Peninsula).

Population estimates are uncertain, and the local Department of Environmental Protection estimates the number of feral donkeys to be about 300. However, villagers complaining of agricultural damage estimate the population to be in the thousands. Besides these free-ranging populations, the government has been releasing additional donkeys captured and obtained in other parts of the region, in a fenced area on the Karpaz Peninsula. This has raised concerns about the impact of donkeys on native vegetation and wildlife.

In northern Cyprus, there have been few studies designed to obtain quantitative estimates of feral donkey populations. To date, Reid et al. (1997) reported the only known, published estimates of donkey populations in the Karpaz region. Their study utilized modified capture-recapture (re-sightings) and other subjective estimators of donkey populations and estimated the feral donkey population to be 300–400 animals (8–10 animals per km^2). Although a 22-km^2 area of the Karpaz Peninsula was declared to be set aside for conservation purposes, neither organized leadership nor plan was ever set up for the area. The most recent decision was that this area be declared an archeological and biological protection area. Most of this area has been fenced to keep donkeys inside. However, this was not very successful as demonstrated by the donkey population found outside of the fenced area. It is not known if there is movement of donkeys across the fence or those outside represent animals that have simply not been captured.

Currently, little is known about how feral donkeys in the Karpaz Peninsula interact with the environment, although anecdotal evidence suggests they are adversely affecting native vegetation. Thus, there is a need for quality data on these donkey populations for directing long-term population and ecosystem management decisions. The primary goal of this research was to develop abundance estimation techniques and obtain reliable baseline estimates of these populations. We utilized line transect estimators because they are robust, quantitative estimators, and we believed feral donkeys in the Karpaz region satisfied the assumptions for line transect sampling. We also collected descriptive data on feral donkeys detected during line transect surveys (behavioral observations, age, sex, and reproductive status) in an effort to add to our knowledge of feral donkey population dynamics in the Karpaz Peninsula.

Study area

The study was conducted on a 132.5 km^2 study area in the Karpaz region of northern Cyprus. The survey area started at 34°20″ East and ended at the northeastern end of the peninsula. The survey area was characterized by low hills <200–250 m in elevation and running east to west in direction. These hills are dissected by, generally dry, river beds (only one river maintains some water during the dry season) in a northsouth direction. The hilly character of the region results in only narrow strips of land suitable for cultivating crops. The main agricultural crops in the region are barley and wheat, but tobacco is reemerging as an agricultural crop. In general, vegetable farming is very limited, although recent projects have been implemented to promote chickpea farming. There are small family farms that raise sheep, goats, cows, etc. Dominant vegetation in the hills is juniper forest, ranging from 1.5 m to 7 m in height, with some small pine *Pinus bruita* groups scattered throughout the area. Olive *Olea europea* and carob trees *Certonia siliqua* are also seen on the hills and plains. The remaining vegetation is comprised of brushy vegetation and perennial wild flowers. Climate in the Karpaz is semi-arid Mediterranean and generally the same as the rest of the island, but due to the narrow, strip shape and low hills the area receives more rain compared to the inside plains.

Methods

Data collection

The study area was stratified into 12 sample units, and line transects were sampled via walking on 11 of the 12 sample units during 2003 (Table 1). This was done because of a wide range of habitats and topographies

Table 1 Summary of line transect survey data used to estimate feral donkey populations in the Karpaz Peninsula, Cyprus during 2003

Sample unit	Sample unit area (km^2)	Transects surveyed	Total length of transects (m)	Individuals detected	Groups detected
1	13.5	3	13,000	6	3
2	13.0	0			
3	13.0	4	9,000	0	0
4	11.0	3	10,000	0	0
5	10.0	4	8,900	20	1
6	11.0	3	10,850	30	3
7	6.5	3	5,000	59	11
8	9.0	2	10,700	0	0
9	13.5	3	17,250	96	20
10	7.0	3	11,500	26	8
11	3.0	2	2,500	25	5
12[a]	22.0	5	21,500	202	44
Total	132.5	35	120,200	464	95

[a]Fenced area

throughout the area. Data were only collected from 11 of the sample units because vegetation was too dense in one sample unit to travel through and obtain visual observations. Due to limitations of area maps, the study area could not be stratified into completely equal sample units. The fenced area, referred to earlier, was deliberately left as a contiguous sample unit (Unit 12). The size of sample units surveyed ranged from 3 km^2 to 22 km^2 (mean = 10.86 km^2; median = 11 km^2) (Table 1). It was not possible to stratify line transects by habitat type or topography (transects traversed through varying habitats and topography), but habitat and topography were recorded when donkey groups were detected during line transect surveys. The topography of the region (see Study Area) does not facilitate transect surveys in a north-south direction, and we ran all transects in an eastwest direction. Within the constraints described above, transects were established randomly.

Before conducting surveys, observers were instructed in first aid, map reading, and global positioning system (GPS) use. Groups of observers were divided to conduct the transect surveys throughout a unit simultaneously. All transects were traversed at walking speed. To estimate perpendicular distances to observed donkeys, a GPS location was determined on the transect line at the sighting. Then a second was obtained 50–100 m further along the line. Triangulation was used to then determine the location of the donkey(s). This allowed perpendicular distance from the line to be calculated. When donkey groups were detected, observers recorded habitat and topography to evaluate habitat use. Observers also recorded sex, age, reproductive status, and behavior of animals to obtain ancillary data relative to feral donkey population dynamics.

Population estimates

We evaluated potential donkey group size bias (increasing or decreasing trends in individuals counted/group by perpendicular distance) by plotting and performing a simple linear regression analysis on group sizes by perpendicular distance of detection from the transect line. We used Program DISTANCE (Thomas et al. 2002) to estimate feral donkey density and abundance for the whole study area and each sample unit. There were not enough donkey groups detected to estimate a detection function for individual sample units, so the detection function was estimated for the entire study area. The encounter rate (number of observations/transect length) and mean group size was estimated for each sample unit. Population density for the entire study area was estimated as the mean density of survey sample units weighted by sample unit area. We evaluated four candidate models in Program DISTANCE for our line transect data analysis. We used uniform, half normal, and hazard rate key functions to estimate population size from line transect data. Cosine adjustments were used with the uniform and hazard rate key functions, simple polynomial adjustments were used with the uniform key function, and hermite polynomial adjustments were used with the half-normal key function (Buckland et al. 1993). Program DISTANCE uses an information-theoretic approach [refer to Chapter 3 of Buckland et al. (1993)] to assess fit of candidate models to the distribution of distance data for estimating population parameters. Program DISTANCE has several model selection options, but we used Akaike's Information Criteria adjusted for small sample bias (AICc) model selection option for our data. Program DISTANCE first determines the number of adjustment terms to use within each key function model. The number of adjustments for a key function that provide the best fit to the distance data is selected based on minimum AICc value. The program then calculates AICc values among the set of best key function + adjustments models, and the model which best describes the data relative to the set of candidate models is determined by minimum AICc value. Goodness-of-fit of the four key function models was assessed by χ^2 goodness-of-fit tests. Adequate fit was assumed if $P > 0.15$. Given adequate goodness-of-fit, the best key function + adjustments model based on minimum AICc was used for parameter estimation.

For analysis, distance data were first grouped into 50-m intervals and then into 100-m intervals for inspection of frequency of groups detected by perpendicular distance. We used spreadsheet software to develop these frequency histograms. We estimated density for ungrouped data, 50-m interval data grouping, and 100-m interval data grouping to evaluate estimator robustness to ungrouped and grouped data.

Other observations

Observers recorded habitat and topography where detections were made to evaluate habitat use. Observers also recorded sex, age, reproductive status, and behavior of animals to obtain ancillary data relative to feral donkey population dynamics. Habitat was classified as shrub, forest, or agricultural. Topography was classified as flat (estimated slope = 0–5°), sloped (estimated slope > 5–30°), or steep (estimated slope > 30°). Habitat and topography observations were summarized as frequencies of detections located within different habitat and slope classes. The number of males, females, foals, and unknowns in each feral donkey group were recorded during line transect surveys. The number of male, female, foal, and unknown donkeys were evaluated with simple summary statistics. Behavior of donkeys in groups detected during line transect surveys was also recorded. Behaviors were classified as bedded, standing, grazing, moving, and other activities. Behavioral activities were summarized as frequency of behaviors detected.

As exploratory analyses, we evaluated potential differences in detection and abundance among habitat and topography classes where donkeys were detected during line transect surveys. It was hypothesized that detection probability might have been greater in agricultural habitats and flat topography due to greater visibility. We treated these analyses as exploratory because there were not enough donkey groups detected among habitat and topography classes to accurately estimate parameters of interest. Shrub and forest habitats were pooled because there were few donkeys detected in forest habitats. The sloped and steep topography classes were pooled because of few steep topography detections. Thus, we could compare potential differences among relatively open, agricultural or forested habitats and flat or sloped topography. Despite relatively large errors associated with estimated parameters, we did believe these analyses would reveal some useful information about parameters of interest in an exploratory context. Separate analyses were performed for habitat and topography classes, and we used the same models described above with Program DISTANCE to obtain parameter estimates, only stratified by habitat or topography classes. Only results from the best fitting model (as described above) for habitat or topography classes were reported.

Results

Data examination

There were 95 donkey groups and 464 individuals detected, collectively, during the study. The number of donkey groups detected/sample unit ranged from 1 to 44, and the number of individuals detected/sample unit ranged from 6 to 202 (Table 1). Evaluation of the plot and linear regression of group sizes by perpendicular distance of detection from the transect line did not reveal any group size bias (Fig. 1). Based on our evaluation of histograms, we concluded that observations beyond 600 m ($n=2$) would provide little information for estimating the detection function, therefore, we truncated the data >600 m. The 50-m interval data grouping appeared slightly more bimodal than the 100-m interval data grouping, and the 100-m interval grouping had a more distinct shoulder at the first interval than the 50-m interval grouping (Fig. 2). Thus, it was concluded that the 100-m interval grouping was best. However, we estimated density for ungrouped data, 50-m interval data grouping, and 100-m interval data grouping, and the results were approximately the same for ungrouped and grouped data (Table 2), indicating estimators were relatively robust to data grouping.

Population estimates

Population estimates obtained with Program DISTANCE were from data grouped into 100-m intervals in which observations ≥600 m were truncated. There were 93 donkey group detections used in the analysis after truncation. Evaluation of goodness-of-fit statistics for the four models used by Program DISTANCE indicated that only the hazard rate cosine and uniform simple polynomial models had adequate fit (Table 3). Model selection criteria indicated that the hazard rate cosine model best fit our distance data (Table 3). Population estimates from the four models were all similar

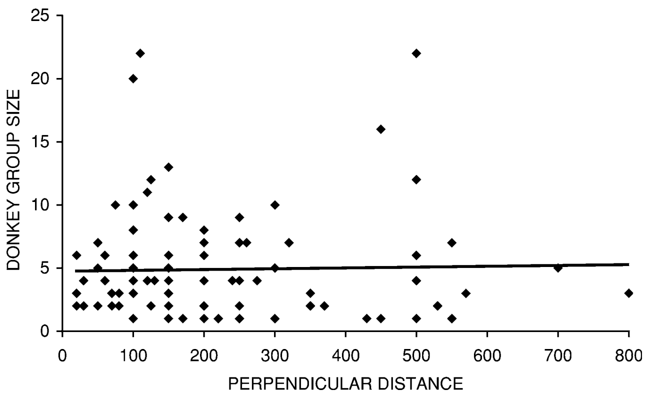

Fig. 1 Plot of feral donkey group sizes detected by perpendicular distance (m) from transect line. Linear regression analysis revealed no significant relationship among perpendicular distance and group sizes detected ($F=0.06$, df$=1$, $P=0.8105$). Data were from line transect surveys in the Karpaz Peninsula, Cyprus during 2003

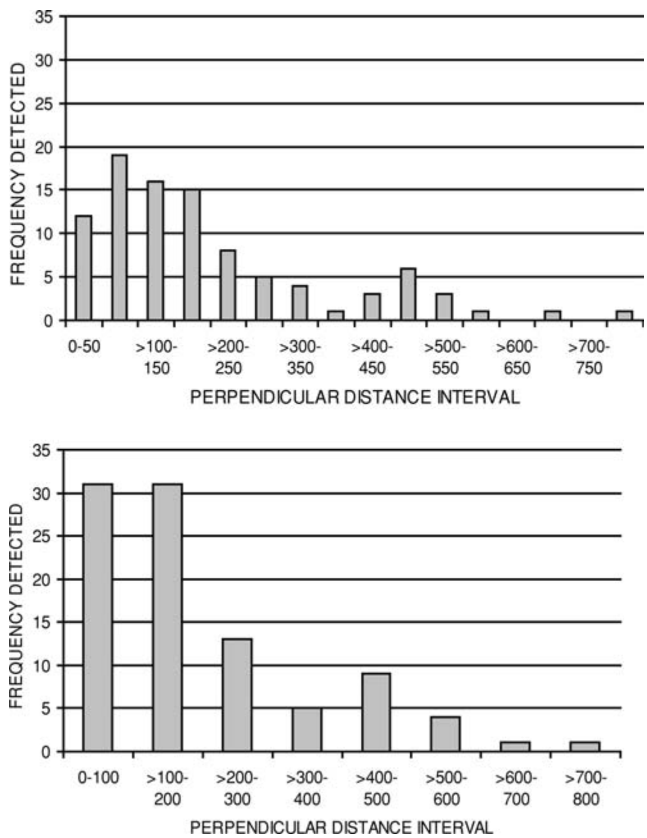

Fig. 2 Histogram of feral donkey groups detected by 50-m and 100-m perpendicular distance intervals from transect line. Data were from line transect surveys in the Karpaz Peninsula, Cyprus during 2003

Table 2 Comparison of density estimates of feral donkeys for 132.5 km^2 study area estimated from line transect surveys in the Karpaz Peninsula, Cyprus during 2003

Model	Ungrouped data			50-m interval data grouping			100-m interval data grouping		
	Donkeys/km^2	95% CI		Donkeys/km^2	95% CI		Donkeys/km^2	95% CI	
		Lower	Upper		Lower	Upper		Lower	Upper
Hazard rate cosine	5.76	2.98	11.17	6.58	3.32	13.04	6.70	3.37	13.33
Uniform simple polynomial	5.23	2.73	10.00	7.00	3.57	13.73	7.23	3.69	14.18
Uniform cosine	5.67	2.96	10.87	6.77	3.45	13.27	6.77	3.45	13.29
Half-normal hermite polynomial	5.54	2.89	10.62	6.07	3.10	11.86	6.09	3.11	11.92

Data were analyzed with no grouping, 50-m interval grouping, and 100-m interval grouping relative to perpendicular distance of observations to the transect line. Models were used with Program DISTANCE to derive these estimates (93 donkey group detections were used for estimation)

Table 3 Model selection criteria, estimated effective strip width, and estimated detection probability for models used with Program DISTANCE to estimate feral donkey population parameters from line transect surveys in the Karpaz Peninsula, Cyprus

Model	χ^2 (*P*-value)	Log-likelihood	AICc	Delta AICc	*K*	Effective strip width (m)	Detection probability	95% CI for detection probability	
								Lower	Upper
Hazard rate cosine	4.80, 3 df (0.19)	−144.310	292.753	0.000	2	280.19	0.47	0.35	0.62
Uniform simple polynomial	2.84, 2 df (0.24)	−143.357	292.984	0.232	3	259.61	0.43	0.36	0.52
Uniform cosine	5.81, 3 df (0.12)	−144.772	293.678	0.925	2	277.08	0.46	0.38	0.56
Half-normal hermite polynomial	8.60, 4 df (0.07)	−146.601	295.247	2.494	1	307.99	0.51	0.43	0.61

χ^2 Chi-square goodness-of-fit statistic for initial evaluation of individual model fit to the data, *AICc* Akaike’s information criteria with small sample bias adjustment; Delta AICc = $AICc_m$ − minimum AICc, where *m* model, *K* number of parameters; Effective strip width (ESW) = width of transect × detection probability; Detection probability = probability of observing donkey groups within the transect area

Table 4 Density and abundance (number of donkeys) of feral donkeys for 132.5 km^2 study area estimated from line transect surveys in the Karpaz Peninsula, Cyprus during 2003

Model	Donkeys/km^2	95% CI for individual density		Donkey groups/km^2	95% CI for group density		Donkey abundance	95% CI for abundance	
		Lower	Upper		Lower	Upper		Lower	Upper
Hazard rate cosine	6.70	3.37	13.33	1.35	0.66	2.77	800	402	1,592
Uniform simple polynomial	7.23	3.69	14.18	1.45	0.71	2.98	864	440	1,694
Uniform cosine	6.77	3.45	13.29	1.36	0.67	2.79	809	412	1,588
Half-normal hermite polynomial	6.09	3.11	11.92	1.23	0.60	2.51	728	372	1,424

Models were used with Program DISTANCE to derive these estimates (93 donkey group detections were used for estimation)

(Table 4). Densities for the entire study area estimated from the hazard rate cosine model were 6.70 (3.37, 13.33; 95% CI) donkeys/km^2 and 1.35 (0.66, 2.77; 95% CI) groups/km^2 (Table 4). Estimated abundance for the entire study area was 800 (402, 1592; 95% CI) donkeys (Table 4). Within sample units density estimates ranged from 0.00 donkeys/km^2 to 16.05 donkeys/km^2 (Table 5), with greatest density inside the 22 km^2 fenced area.

Other observations

Of 95 donkey groups detected: 25% were detected in agricultural habitats and 75% were detected in shrub/forest habitats (7% from forest), while 40% were detected on flat topography and 60% were detected on sloped topography (9% from steep class). Of the 95 groups detected: 16% were detected in agricultural habitats with flat topography, 9% were detected in

Table 5 Density and abundance (number of donkeys) of feral donkeys for individual sample units within the study area estimated using a hazard rate cosine model with Program DISTANCE

Sample unit	Donkeys/km^2	95% CI for individual density		Donkey groups/km^2	95% CI for group density		Donkey abundance	95% CI for abundance	
		Lower	Upper		Lower	Upper		Lower	Upper
1	0.442	0.024	8.306	0.295	0.011	7.998	6	0	112
3	0.000	0.000	0.000	0.000	0.000	0.000	0	0	0
4	0.000	0.000	0.000	0.000	0.000	0.000	0	0	0
5	3.569	0.229	55.658	0.178	0.011	2.783	36	2	557
6	5.606	0.537	58.524	0.561	0.032	9.822	62	6	644
7	14.623	2.918	73.282	2.726	0.455	16.341	95	19	476
8	0.000	0.000	0.000	0.000	0.000	0.000	0	0	0
9	12.281	7.505	20.094	2.559	1.657	3.951	166	101	271
10	4.218	0.307	57.988	1.298	0.061	27.393	30	2	406
11	17.845	3.123	101.980	3.569	0.130	97.849	54	9	306
12[a]	16.053	3.902	66.033	3.504	0.837	14.660	353	86	1,453

Data were from line transect surveys in the Karpaz Peninsula, Cyprus during 2003
[a]Fenced area

agricultural habitats with sloped topography, 24% were detected in shrub/forest habitats with flat topography, and 51% were detected in shrub/forest habitats with sloped topography.

There were a total of 464 donkeys in 95 groups encountered during line transect surveys. Of donkeys positively identified, 34% were males, 49% were females, and 17% were foals. Using 95% CI's, mean number of males ($\bar{x} = 0.85, \mathrm{SE} = 0.11$) did not differ from mean number of females ($\bar{x} = 1.21, \mathrm{SE} = 0.18$), but mean number of foals ($\bar{x} = 0.41, \mathrm{SE} = 0.09$) differed from mean number of both males and females (Fig. 3). Of donkeys positively identified, the ratio of males to females was 1 male:1.42 females, the ratio of foals to females was 1 foal:2.95 females, and the ratio of foals to adults was 1 foal:5.03 adults. Of 115 females identified, 12% ($n = 14$) were identified as pregnant.

There were 102 behavioral observations recorded from 95 donkey groups encountered during line transect surveys (multiple behaviors could be detected in a group). The frequencies of behaviors recorded were 1% bedded, 70% standing, 22% grazing, 6% moving, and 2% other. All observations from the "other" behavioral category were of mating donkeys.

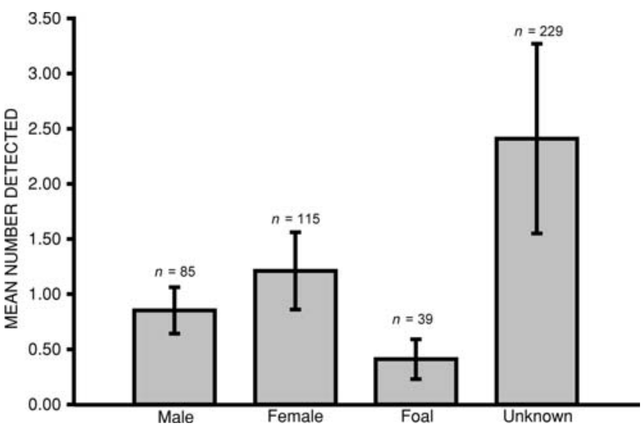

Fig. 3 Mean (±95% CI) number of male, female, foal, and unknown feral donkeys detected during line transect surveys in the Karpaz Peninsula, Cyprus during 2003

There were 23 and 70 donkey group detections from agricultural and shrub/forest habitats, respectively, used in the exploratory habitat analysis after truncation. There were 37 and 56 donkey group detections from flat and sloped topography, respectively, used in the exploratory topography analysis after truncation. Our exploratory analyses suggested detection probabilities were similar among agricultural and forested habitats and flat and sloped topography. The estimated detection probabilities were 0.39 (0.19, 0.83; 95% CI) for agricultural and 0.47 (0.34, 0.65; 95% CI) for forested habitats (Table 6). The estimated detection probabilities were 0.40 (0.31, 0.52; 95% CI) for flat and 0.56 (0.45, 0.70; 95% CI) for sloped topography (Table 7). Population estimates from our exploratory analysis suggested that there might have been some differences in donkey density among open and forested habitats. Estimated donkey densities were 2.04 (0.65, 6.44; 95% CI) for agricultural and 4.84 (2.51, 9.34; 95% CI) for forested habitats (Table 6). Population estimates from our exploratory analysis among topography classes did not suggest any noticeable differences in donkey density. Estimated donkey densities were 2.96 (0.11, 8.00; 95% CI) for flat and 3.71 (2.00, 6.90; 95% CI) for sloped topography (Table 7).

Discussion

There was no evidence suggesting that sizes of donkey groups detected differed by perpendicular distance from the transect line. There was no way to know if some groups might have been completely missed due to obscurity by habitat, topography, or behavioral responses by the animals (e.g., fleeing before detection). Double sampling with a radio-marked sample may be

Table 6 Exploratory analysis evaluating potential differences in detection and abundance among habitat classes (agricultural and forest) where donkeys were detected during line transect surveys in the Karpaz Peninsula, Cyprus during 2003

	Agricultural			Forest		
	Estimate	95% CI		Estimate	95% CI	
		Lower	Upper		Lower	Upper
Detection probability	0.39	0.19	0.83	0.47	0.34	0.65
Effective strip width	234.97	110.98	497.51	281.58	202.21	392.10
Mean group size	4.83	3.11	7.48	5.02	4.03	6.24
Group density (km^2)	0.42	0.14	1.26	0.97	0.52	1.80
Individual density (km^2)	2.04	0.65	6.44	4.84	2.51	9.34
Abundance	244	77	769	579	300	1,116

A hazard rate cosine model (four parameters) was selected for parameter estimation with Program DISTANCE

Table 7 Exploratory analysis evaluating potential differences in detection and abundance among topography classes (flat and sloped) where donkeys were detected during line transect surveys in the Karpaz Peninsula, Cyprus during 2003

	Flat			Sloped		
	Estimate	95% CI		Estimate	95% CI	
		Lower	Upper		Lower	Upper
Detection probability	0.40	0.31	0.52	0.56	0.45	0.70
Effective strip width	240.13	186.49	309.19	337.03	268.96	422.33
Group size	4.58	3.42	6.15	5.18	4.08	6.57
Group density	0.65	0.25	1.69	0.72	0.40	1.28
Individual density	2.96	0.11	8.00	3.71	2.00	6.9
Abundance	354	131	956	444	239	825

A half-normal hermite polynomial model (two parameters) was selected for parameter estimation with Program DISTANCE

the only direct way to estimate such potential biases. In the absence of more specific data, we assumed no donkeys fled before detection. Our exploratory analysis did not reveal any definitive differences in detection probabilities among open or forested habitats and flat or sloped topography given low precision of these estimates. Contrary to expectation, detection probabilities were not greater for donkey groups in agricultural habitats or flat topography. The relative similarity in detection probabilities among habitat and topography classes suggested that using a single detection function was adequate to estimate population parameters in our primary data analysis.

Population estimates

Although it is uncertain exactly what constitutes an ecologically excessive population density of feral donkeys, comparison with other studies describing high-density donkey populations or populations causing adverse habitat effects suggest that the population in the Karpaz Peninsula was a relatively high-density population. Our estimates of approximately 7 donkeys/km^2 were higher than estimates of about 1–3 donkeys/km^2 reported by Seegmiller and Ohmart (1981; cumulative counts of distinguishable individuals and ratio estimators) and Johnson et al. (1987; removal and capture estimators) in the southwestern United States and about 1–3 donkeys/km^2 reported by Choquenot (1990, 1991; aerial transect surveys) in northern Australia. Our estimates were slightly lower than Reid et al.'s (1997; modified capture-recapture techniques) estimates of about 8 donkeys/km^2 in the Karpaz Peninsula.

Although our data were sufficient to estimate donkey density in individual sample units, these generally had very large associated errors due to lower sample sizes. However, this might result in enough pooled data to get adequate estimator precision. Careful consideration should be given to ecologically relevant groupings of sample units for future sampling. For example, perhaps several groups of sample units were located in the same type of landscape and could be pooled based on similar habitats, land use, etc. What is evident from our data is that donkeys are not uniformly distributed across the Karpaz Peninsula, suggesting that our pooled population density may underestimate concentrations of donkeys on portions of the study area. This could result in the perceived notion among policy makers that there is not an urgent need to address serious overpopulation problems in some sample units. For example, our pooled estimates do not reflect how much greater the density at several of our sample units (units 7, 9, 11, and 12) were than those that have been reported elsewhere.

Other observations

Feral donkeys in the Karpas region appeared to be more abundant in shrub/forest habitats with sloped topography (51% of all detections were from this combination of habitat and topography), at least during times in which these surveys were conducted. The second most number of detections (24%) was in shrub/forest habitats with flat topography. Our exploratory analysis evaluating potential differences in habitat classes suggested that donkey densities might have been 2.5 times higher in shrub/forest habitats than in agricultural habitats. Donkeys may have felt more secure in these forested and shrub habitats due to greater cover. These areas may have also provided more browse vegetation on which donkeys are adapted to eat. The remaining 25% of detections were from more open (agricultural) habitats with flat or sloped topography. These habitats may have been used primarily as short-term feeding areas, and thus donkeys were not as abundant in agricultural habitats during daylight survey hours.

Provided that estimated sex ratios adequately represent the entire population, the ratio of males to females (1:1.42) was similar to several other studies on feral donkeys (McCool et al. 1981; Seegmiller and Ohmart 1981; Johnson et al. 1987). Without more accurate estimates of age structure, it is difficult to make inferences about recruitment and productivity. The ratio of foals to adults (1:5) suggests that this population had a relatively high rate of production. However, the overall age structure of the population was not known, and thus whether the population had a "younger" or "older" age structure could not be precisely determined. Other studies of feral donkey populations have reported ≥20% of populations being foals, and these populations often appeared to exhibit increasing population trends (McCool et al. 1981; Johnson et al. 1987). Thus, it might be assumed from our ancillary data that the feral donkey population in our study area is increasing.

Behavioral results suggested that the majority of donkeys detected were in an upright position (standing, grazing, or moving). There could have been some behavioral response by donkeys to approaching observers (e.g., bedded animals stood up upon awareness of human presence) or observers could have potentially missed more bedded animals. It was unknown whether there were behavioral responses by donkeys to approaching observers or observer biases. If feral donkeys generally do not flee approaching observers before being detected, then there should be minimal biases in population estimators. McCool et al.'s (1981) account of feral donkey behavior in their study suggested that donkeys exhibited some flight behavior when approached by groups of shooters conducting removals for population control (although some of this was probably due to conditioned responses to persistent shooting efforts). There was no aggressive removal of donkeys during this study. Seegmiller and Ohmart (1981) reported that feral donkeys in their study "stared intently or fled" when alerted to the presence of human observers. Reid et al. (1997) described feral donkey behavior when approached by "non-donkey intruders", and indicated that some donkey groups fled when approached. Neither Seegmiller and Ohmart (1981) nor Reid et al. (1997) reported whether there appeared to be a threshold distance at which donkeys typically fled from intruders, or the proportion of donkeys that actually fled as opposed to simply taking an alarm stance until intruders moved a sufficient distance away from the group. We assumed that (in general) donkey behavior was relatively unaffected by the presence of line transect observers since the majority of detections were from animals in an upright position. These animals are neither harassed nor hunted, and therefore, human presence should have minimal impact on behavior from the distances most donkeys were observed.

Management implications

Based on this preliminary study, it appears that line transect surveys were a viable method to estimate feral donkey populations because of the robust nature of distance sampling estimators, and we believed feral donkeys in the Karpaz region satisfied the assumptions for line transect sampling. We suggest that feral donkeys in the Karpaz Peninsula continue to be monitored with line transect surveys. If it is not possible to monitor these populations on an annual basis, surveys conducted every 2–3 years may still provide useful data on population dynamics over time. Obtaining quantitative data on these populations is essential for making and justifying resource management decisions.

The high donkey densities we found suggest a need for concern relative to their impact on native vegetation and wildlife. This population is not uniformly distributed, and the population density within the fenced area far exceeds densities in areas where donkeys were anecdotally known to be damaging vegetation. Investigations about the effects of feral donkeys on habitat and other species of wildlife need to be undertaken. We recommend exclosure (fencing out small areas of habitat to exclude donkeys) experiments to assess vegetation where donkeys may graze and where they are excluded. In the Karpaz Peninsula study area, exclosures should be randomly stratified among habitat and topography classes within sample units.

If feral donkeys in the Karpaz Peninsula are having adverse ecological impacts, then there may be adequate justification for controlling these populations. If some form of feral donkey population control is practiced, it is important to continue monitoring populations and habitat to ensure that management efforts are producing the desired results. A good monitoring program allows managers to evaluate management goals (e.g., maintain donkey populations with minimal adverse habitat effects) and manipulate management objectives (e.g., reduce and maintain donkey populations to a proportion of baseline levels) if necessary.

Acknowledgements A large number of people assisted with the field surveys, including students at Lefke European University, Near East University, Eastern Mediterranean University, and Girne American University. Other volunteer participants in the surveys included members of the Biologists Society, Women Organisation KAYAD, and Anglo Turkish Society. We thank Mr Hasan Karaokcu and Mr Haluk Dogandor for their support. We thank SID - Lefkosa Chapter for creating an awareness of this issue. Maps and GPS used in the survey supplied by the Karpaz Peninsula Mapping office, the Karpaz Peninsula Environmental Protection Office director and personel made great contribution to the survey. Major funding for the research was provided by Turkish Embassy (mainland Turkish Republic), the the Karpaz Peninsula Hunting Association, and Warnell School of Forest Resources of the University of Georgia.

References

Buckland ST, Anderson DR, Burnham KP, Laake JL (1993) Distance sampling: estimating abundance of biological populations. Chapman and Hall, London. (http://www.colostate.edu/depts/coopUnit/distancebook/download.html)

Choquenot D (1990) Rate of increase for populations of feral donkeys in northern Australia. J Mamm 71:151–155

Choquenot D (1991) Density-dependent growth, body condition, and demography in feral donkeys: testing the food hypothesis. Ecology 72:805–813

Hanley TA, Brady WW (1977) Feral burro impact on a Sonoran Desert range. J Range Manag 30:374–377

Johnson RA, Carothers SW, McGill TJ (1987) Demography of feral burros in the Mohave Desert. J Wildl Manag 51:916–920

McCool CJ, Pollitt CC, Fallon GR, Turner AF (1981) Studies of feral donkeys in the Victoria River-Kimberleys area: observations on behavior, reproduction, and habitat and some possible control strategies. Austral Vet J 57:444–449

Reid SWJ, Godley BJ, Henderson SM, Lawrie GJ, Loyd D, Small K, Swannie N, Thomas RL (1997) Ecology and behaviour of the feral donkey, *Equus asinus*, population of the Karpas Peninsula, northern Cyprus. Zool Middle East 14:27–36

Rudman R (1998) The social organisation of feral donkeys (*Equus asinus*) on a small Caribbean island (St. John, US Virgin Islands). Appl Anim Behav Sci 60:211–228

Seegmiller RF, Ohmart RD (1981) Ecological relationships of feral burros and desert bighorn sheep. Wildl Monogr 78, 58 pp

Thomas L, Laake JL, Strindberg S, Marques FFC, Buckland ST, Borchers DL, Anderson DR, Burnham KP, Hedley SL, Pollard JH (2002) Distance 4.0. Release 2. Research Unit for Wildlife Population Assessment, University of St. Andrews, UK. http://www.ruwpa.st-and.ac.uk/distance/

Wagner FH (1983) Status of wild horse and burro management of public rangelands. Trans North Am Wildl Nat Res Conf 48:116–133

Woodward SL, Ohmart RD (1976) Habitat use and fecal analysis of feral burros (*Equus asinus*), Chemehuevi Mountains, California, 1974. J Range Manag 29:482–485