HOME RANGES OF THE NILGAI ANTELOPE (*BOSELAPHUS TRAGOCAMELUS*) IN TEXAS

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ABSTRACT—Information related to home ranges of the nilgai antelope (*Boselaphus tragocamelus*) was needed to estimate spread of cattle-fever ticks (*Riphicephalus microplus* and *R. annulatus*) and to develop management protocols. We captured, placed telemetry collars on, and monitored 10 male and 12 female nilgai antelopes during February 2006–May 2008. We detected no difference between size of home ranges of males and females and determined maximum axes of home ranges of 16.3 and 13.8 km, respectively. The combination of large home ranges and large axes of home range indicates that if cattle-fever ticks are being maintained on nilgai antelopes, then the area in which these antelopes may spread ticks is great.

RESUMEN—Información de los rangos de hogar de los nilgós (*Boselaphus tragocamelus*) fue necesaria para estimar la propagación de las garrapatas (*Riphicephalus microplus* y *R. annulatus*), vectores de la fiebre de garrapata en bovinos, y para desarrollar programas de manejo sanitario. Se realizó la captura de 12 hembras y 10 machos de nilgós y se les colocaron collares de telemetría y se monitorearon de febrero de 2006 a mayo del 2008. No se encontraron diferencias entre el tamaño de los rangos de hogar de los machos y de las hembras y se determinó que los ejes máximos de rangos de hogar fueron de 16.3 y 13.8 km, respectivamente. La combinación de rangos de hogar grandes y largos ejes máximos del rango de hogar indica que si las garrapatas de la fiebre del ganado se mantienen en los nilgós, entonces el área donde estos antílopes podrían esparcir a las garrapatas es muy amplia.

The United States Department of Agriculture, Animal and Plant Health Inspection Service, Cattle Fever Tick Eradication Program, in partnership with the Texas Animal Health Commission and other state agencies, are charged with preventing introduction and reestablishment of cattle-fever ticks (*Rhipicephalus annulatus* and *R. microplus*) in the United States from Mexico. At the inception of the Cattle Fever Tick Eradication Program in 1906, cattle-fever ticks occurred throughout the southeastern United States and in California. Today, a significant challenge facing landowners and managers in portions of southern Texas is the periodic outbreak of cattle-fever ticks within herds of cattle and associated management activities aimed at eradication of ticks. Infestations of cattle-fever tick are of concern because these ticks carry *Babesia bigemina* and *B. bovis*. These pathogens cause bovine babesiosis, which is the most important arthropod-borne disease of cattle worldwide (Uilenberg, 2006). The reestablishment of bovine babesiosis in cattle in the United States would cause severe financial losses to the industry. For example, annual direct and indirect losses associated with cattle-fever ticks and babesiosis in 1906 was $130,500,000 (James and Harwood, 1969), which equates to ca. $3,000,000,000 in 2009.

Recent discoveries of cattle-fever ticks on the nilgai antelope (*Boselaphus tragocamelus*) in southern Texas (A. Pérez de León, pers. comm.) and presence of *Babesia bigemina* and *B. bovis* in nilgai antelopes in northern Mexico (Cárdenas-Canales, 2009) illustrate the threat these nonnative ungulates pose to eradication of cattle-fever ticks and to production of cattle throughout the United States. Nilgai antelopes likely function as maintenance hosts, similar to white-tailed deer (*Odocoileus virginianus*; Pound et al., 2010). Information related to home ranges of nilgai antelopes is needed to determine estimates of distances they may spread these ticks and to develop management protocols. However, little is known about movements of nilgai antelopes in southern Texas or on their native ranges. For example, Sheffield et al. (1983) radiotracked nine nilgai antelopes for 0.5–2.5 months and documented size of home range as 430 ha.

Nilgai antelopes, which are native to India, Nepal, and Pakistan (Leslie, 2008), were released into southern Texas during 1924–1949. Today, they are one of the most successfully established nonnative species of ungulates in Texas (Sheffield et al., 1983). Statewide, estimates are >36,700 nilgai antelopes (Traweek and Welch, 1992) and, in some instances, their populations exceed those of native ungulates (Mungall and Sheffield, 1994). Presently, free-ranging populations exist from Baffin Bay, Kleberg County, southward to southern Willacy County (Mungall and Sheffield, 1994), including portions of Kenedy, Brooks, Hidalgo, and Starr counties.

Our objectives were to determine and compare size of home ranges of nilgai antelopes, estimate daily rates of movement, and assess the effect of changes in cattle-stocking rates on use of pastures by nilgai antelopes. We expected that home ranges of males would be larger than home ranges of females because of greater metabolic demands on females (Beier and McCullough, 1990); nilgai antelopes would display high daily rates of movement compared to other ungulates in the region because they have been reported to traverse their entire home range daily (Leslie, 2008); and cattle would influence use of pastures by nilgai antelopes, similar to white-tailed deer (*Odocoileus virginianus*) in the region (Cohen et al., 1989; Cooper et al., 2008).

Materials and Methods—We conducted research on private property in Kenedy and Willacy counties (26°40′N, 97°35′W) consisting of ca. 100,000 ha in Texas Gulf Prairies and Marshes vegetation (Gould, 1975). The area was a mixed-shrub rangeland dominated by live oaks (*Quercus virginiana*) and honey mesquites (*Prosopis glandulosa*), and it had a mean annual precipitation of 85 cm and a mean temperature of 22°C during 2006–2008. Ungulates in the area included white-tailed deer, collared peccaries (*Pecari tajacu*), nilgai antelopes, wild boars (*Sus scrofa*), and cattle. Nilgai antelopes and wild boars were hunted year-round on the area because of their nonnative status, whereas white-tailed deer and northern bobwhites (*Colinus virginianus*) were hunted during regulated seasons. Throughout the area, cattle were managed intensively using rotational grazing. A 43,140-ha area was used to study the effect of changes in density of cattle on use of pastures by nilgai antelopes. This area had 14 pastures 202–5,438 ha in size. Each pasture was enclosed with 1.25-m-tall, woven-wire fence. Although nilgai antelopes have difficulty passing over fences, they regularly travel under or through fences at numerous breaching sites (Sheffield et al., 1983).

We used the helicopter and net-gun technique (Webb et al., 2008) to capture nilgai antelopes during January and April 2006. We physically restrained, weighed, and individually marked nilgai antelopes with ear-tags upon capture. Additionally, we placed either a VHF radiocollar (Telemetry Solutions, Concord, California) or global-positioning-system (GPS) collar (Televilt Tullus GPS, Lindesberg, Sweden) on all animals. All capturing and handling protocols were approved by the Institutional Animal Care and Use Committee at the National Wildlife Research Center (protocol QA-1363).

We collected observational and radiotelemetric data during daylight in all months during April 2006–January 2008. We collected observational data opportunistically using ear-tags to identify individuals and a hand-held GPS unit to record Universal Transverse Mercator (UTM) coordinates of locations where animals were first observed. We collected radiotelemetric data from the ground using georeferenced telemetry stations, radioreceivers, 4-element Yagi antennas, and compasses. To generate an estimate of location, we obtained 3–6 azimuths using the loudest-signal method (Mech, 1983) within 20 min and generated UTM coordinates using Location of a Signal (Ecological Software Solutions, Sacramento, California). We located animals from the ground weekly. We collected radiotelemetric data from the air following methods of Hoskinson (1976) using one pilot with >40 years of experience. We located animals from the air twice a month. We overlaid data for locations onto a Digital Orthophoto Quadrangles coverage map of the study areas using ARCVIEW (Environmental Systems Research Institute, Redlands, California).

We collected data on location from GPS collars at 4-h intervals during February 2006–May 2008. We recovered GPS collars from harvested animals by August 2008. We overlaid data for locations onto a Digital Orthophoto Quadrangles coverage map of the study areas using ARCVIEW. We determined rates of movements from sequential locations (at 4-h intervals) using the Animal Movement Extension of ARCVIEW (Hooge and Eichenlaub, 1997). We report mean minimum daily movement (km/day) on a monthly basis.

We used the animal-movement extension to generate size of home ranges using minimum-convex polygons from all sources of data on locations (Mohr, 1947). We did not partition data on locations into home ranges by years or seasons. However, we only included nilgai antelopes in the analysis if they were monitored ≥9 months. Also, we report maximum axis (km) of home range, as determined using the animal-movement extension, to understand the potential area for spread of cattle-fever ticks.

We used data on locations from radiocollared nilgai antelopes to assess the effect of changes in cattle-stocking rates on use of pastures by nilgai antelopes. Each time a nilgai antelope was located, we noted the pasture, which enabled us to track changes in use of pastures. We used daily stocking-rates of cattle by pasture to document changes in density in each pasture. We then constructed a database where each line of data was an interval between locations of an individual. Each line of data contained number of days in the interval, whether the nilgai antelope changed pastures during the interval, change in density of cattle in the pasture during the interval, and, for intervals in which nilgai antelopes changed pastures, the difference in density of cattle between the pasture the nilgai antelopes left and the pasture it entered during the interval.

All statistical analyses were performed with SAS statistical software (SAS Institute, Inc., Cary, North Carolina). We used a pooled *t*-test to compare differences in size of home ranges between males and females. We used a repeated-measures logistic regression (PROC GLIMMIX with logit-link function) to assess the effect of changes in density of cattle on the probability that nilgai antelopes would change pastures. Each radiocollared nilgai antelope was a subject in our repeated-measure analysis. Our model contained number of days in the interval between locations to account for greater probability of a nilgai antelope changing pastures during longer intervals. To determine if they

TABLE 1—Number of locations, size of home range, and maximum axis of home range for male and female nilgai antelopes (*Boselaphus tragocamelus*) in southern Texas, February 2006–May 2008.

	Sex					
	Males (n = 10)			Females (n = 12)		
Parameter	Mean	*SE*	Range	Mean	*SE*	Range
Number of locations[a]	42	7	18–87	58	6	28–76
Size of home range (ha)	9,356	3,255	1,137–29,864	8,355	2,600	1,028–22,690
Maximum axis of home range (km)	16.3	3.1	5.5–30.7	13.8	2.6	4.5–31.6

[a] Number of locations includes radiotelemetry only and excludes locations from global-positioning-system collars.

moved to pastures with higher or lower densities of cattle, we used the mean and 95% CI of the difference in density of cattle between pastures to determine if that value differed from zero. To avoid pseudoreplication, we used average difference in density of cattle between pastures for each nilgai antelope in this analysis (i.e., each nilgai antelope contributed one value to the analysis).

RESULTS—We captured and placed radiocollars on 10 male and 8 female nilgai antelopes. Additionally, we captured and placed GPS collars on four females. We collected 885 locations from observations and radiotelemetry (Table 1) and we uploaded 13,837 locations from GPS collars of females. Males were monitored for 17.5 months (±1.4 *SE*), and females were monitored for 22.7 months (±1.1 *SE*). There was no difference (t_{20} = −0.24, P = 0.810) between size of home ranges of males and females; maximum axis of home ranges were 16.3 (±3.1 *SE*) and 13.8 km (±2.6 *SE*), respectively (Table 1). Mean minimum daily movements of GPS-collared females ranged from 1.5 km in January to 2.8 km in May (Fig. 1).

Controlling for number of days in the interval between subsequent locations of radiocollared nilgai antelopes, the probability of changing pastures during the interval was not related ($F_{1,644}$ = 2.04, P = 0.154) to change in density of cattle in the pasture during that interval. When nilgai antelopes did change pastures, there was no indication they consistently moved to pastures with different densities of cattle (average difference in density of cattle between pastures = 0.0004 cows/ha, 95% CI = −0.0088–0.0097).

DISCUSSION—Our data on home ranges of nilgai antelopes validate the threat that they pose to success of the Cattle Fever Tick Eradication Program. Specifically, nilgai antelopes display large home ranges compared to native ungulates that occur within the region. For example, Hellickson et al. (2008) reported annual size of home ranges of male white-tailed deer in southern Texas was 427–922 ha, depending upon age. Our mean size of home ranges of nilgai antelopes exceeded size of home ranges of white-tailed deer in southern Texas by ≥9 times, depending upon which age was compared to our estimates for male and female nilgai antelopes. Additionally, maximum axis of home ranges was large and exceeded 30 km for one male and one female. Contrary to our prediction, however, we detected small daily rates of movement for females compared to other nonnative ungulates in the region. For example, Campbell and Long (2010) documented that wild boars in southern Texas moved an average of 4.0–5.4 km/day, depending

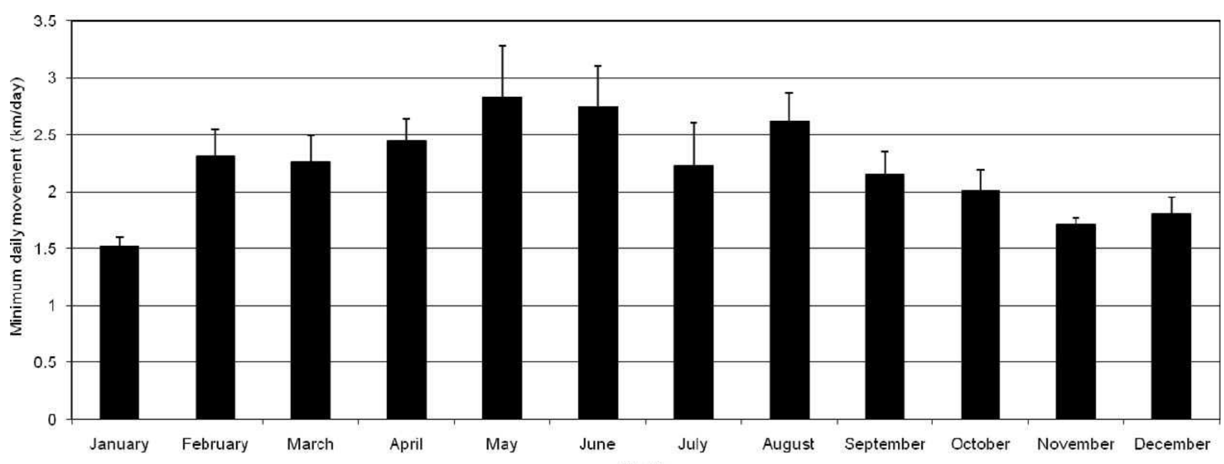

FIG. 1—Mean (±*SE*) minimum daily movement (km/day) of female nilgai antelopes (*Boselaphus tragocamelus*; n = 4) by month in southern Texas, February 2006–May 2008. Data are from global-positioning-system collars collecting locations at 4-h intervals.

upon sex and study area. Our estimated daily rate of movement for females was ca. two times less than those of wild boars, despite the larger size of nilgai antelopes. Furthermore, we discovered that nilgai antelopes were not more likely to move when stocking-rates of cattle in the pasture changed, and when they did change pastures, on average, there was no difference in stocking rates between their former and new pasture. Consequently, our data suggest that nilgai antelopes move among pastures without regard to presence or stocking-rate of cattle and further implicate nilgai antelopes as a threat to success of the Cattle Fever Tick Eradication Program.

The combination of large home ranges and large axes of home ranges indicate that if cattle-fever ticks are being maintained on nilgai antelopes, then the area in which they may spread ticks is great. McCoy et al. (2005) used estimates of dispersal and size of home ranges of yearling male white-tailed deer in southern Texas to determine that size of viable management units would need to be >25,000 ha. Given that we detected home ranges >29,000 ha and that mean size of rural properties are 250–6,000 ha in southern Texas (McCoy et al., 2005), viable management units for nilgai antelopes would be large, difficult to establish, and likely involve multiple properties. Further complicating management is inability of standard, woven-wire fencing to restrict movements of nilgai antelopes. Similar to Sheffield et al. (1983), nilgai antelopes did not cross a nearby four-lane highway with 40-m median and 1.25-m-tall woven-wire fence paralleling both sides of the highway. In the event that management for cattle-fever ticks is performed within populations, we believe that highways with the previous criteria can be used as boundaries of management units. Also, our observed daily rate of movements was comparatively low and suggests that quick management actions may be more effective at controlling spread of cattle-fever ticks on nilgai antelopes, as opposed to actions requiring a long time to take effect, thereby increasing the probability that nilgai antelopes would make long-distance movements.

Successful implementation of the Cattle Fever Tick Eradication Program is critical to ensuring healthy herds of cattle throughout the United States. Technologies were developed to topically and systemically treat ticks on white-tailed deer, thereby reducing the threat of tick-borne diseases to livestock and humans (Pound et al., 1996, 2009). Acaricide delivery systems for nilgai antelopes and other nonnative ungulates may be needed in support of the Cattle Fever Tick Eradication Program. Until new technologies are developed, we recommend increased monitoring of populations of nilgai antelopes throughout southern Texas for ticks to better understand the role they play as hosts for cattle-fever ticks.

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