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Comparative daily activity patterns of Nilgai, *Boselaphus tragocamelus* and white-tailed deer, *Odocoileus virginianus* in South Texas

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ABSTRACT

Nilgai antelope, *Boselaphus tragocamelus* and white-tailed deer (WTD), *Odocoileus virginianus* are hosts of cattle fever ticks, *Rhipicephalus* (*Boophilus*) *microplus* and *Rhipicephalus* (*B.*) *annulatus*, in the South Texas. Daily activity patterns were studied to develop optimum timing for field treatment methods for cattle fever ticks on these wildlife hosts. Motion detecting game cameras (n=160) were deployed between Aug and Oct 2016 at the East Foundation's Santa Rosa Ranch, Kleberg Co., TX. A total of 218 animal images comprising of 114 nilgai and 104 WTD observations were recorded, by time of the day. White-tailed deer showed two distinct peaks in activity during morning and evening whereas, nilgai activity showed multiple peaks throughout the day. Both species were active during morning followed by evening, whereas minimum activity was seen in the heat of the afternoon. Nilgai were more active at night than WTD, with 30% and 17 % of the images recorded respectively. Treatment of nilgai for control of cattle fever ticks may be most efficient at night when they are most active.

Additional index words: Texas, pathogenic landscape, cattle fever ticks, livestock entomology

In North America, deer of the genus *Odocoileus* are considered the most important ungulates in both numbers and economic value (McCullough 1987, Conover 2011). White-tailed deer (WTD), *Odocoileus virginianus* (Zimmerman) numbers have increased dramatically in density and distribution during the 20th century in the United States (McShea et al. 2003, Heffelfinger 2011). White-tailed deer are the most sought after big game species in North America and hold much economic, aesthetic and biological value throughout their range (McCullough 1987). Nilgai antelope, *Boselaphus tragocamelus* (Pallas) belonging to the family Bovidae are closely related to cattle (*Bos* spp.). They were brought to the United States from India and were apparently released in South Texas about 1930. By the early 1970s, they were distributed in nine Texas counties and in northeastern Mexico (Leslie and Sharma 2009). Nilgai and white-tailed deer co-exist with cattle in South Texas and they are competent hosts of cattle fever ticks (CFT), *Rhipicephalus*

(*Boophilus*) *microplus* (Cannestrini) and *Rhipicephalus* (*B.*) *annulatus* (Say) (Perez et al. 2012).

Bovine babesiosis is an economically important tick-borne disease which is caused by *Babesia* (*B. bovis* and *B. bigemina*) and is transmitted by cattle fever ticks. Bovine babesiosis was once endemic in the southern United States and severe losses to the cattle industry. However, this disease and its vectors were eradicated from the United States by 1943 by the U.S. Department of Agriculture - Animal and Plant Health Inspection Service (USDA-APHIS), Texas Animal Health Commission, and the cooperation of landowners under the Cattle Fever Tick Eradication Program. Presently, the widespread prevalence of CFT in neighboring border states of Mexico poses a significant threat to United States cattle producers. To prevent reintroduction, a quarantine area between Texas and Mexico is maintained (Perez de Leon et al., 2012 and 2014, Giles et al., 2014). Challenges to CFT incursion in the permanent quarantine zone along the Rio Grande River are more frequent (Giles et al., 2014) due to the increased prevalence of CFT host species such as nilgai (Cardenas-Canales et al., 2011), white-tailed deer (Kistner and Hayes, 1970), stray cattle (*Bos* spp.) and from interactions between CFT and exotic weeds along the trans-boundary region with Mexico, which forms a pathogenic landscape that facilitates the invasion and survival of CFT (Racelis et al., 2012; Esteve-Gassent et al., 2014). Nilgai move widely throughout this environment, are implicated in the spread of CFT in South Texas, and therefore have been implicated in the establishment of temporary preventative CFT quarantine areas that regulate the movement of cattle and other host animals (Texas Animals Health Commission, 2016).

Understanding animal activity patterns can be important in developing management strategies for alternate wildlife hosts of a livestock pest. Studies of white-tailed deer (WTD) activity studies have focused on movements at varying spatial scales, from large-scale dispersal and migration to small-scale movements within home ranges and habitats (Webb et al. 2009). Seasonal movements of WTD have been well documented across most regions and habitats within its range (Grund et al. 2002), and few studies have focused on 24-hour movement patterns and fine-scale temporal movements (Pepin et al. 2004). However, no such comprehensive data are available for nilgai activity patterns that can readily be compared with movements of coexisting WTD. Nilgai have large home ranges with mean year-round ranges (Foley et al. in review) for females of 8,234 range = 851-31,533 ha) and for males of 6,626 (range = 733-20,864 ha). In comparison, WTD have much smaller home ranges of approximately 600 ha, thus nilgai have potential to move long-distances within their home range.

Animal movements are influenced by a variety of factors ranging from physiological requirements to short term weather events (Ran et al. 2008). Lunar phase has been suggested to influence activity patterns of all species, and this is particularly apparent among WTD hunters (Webb et al., 2010). One lunar factor commonly believed to impact deer activity is lunar phase, although field studies have failed to document any association between lunar phase and WTD activity (Michael 1970, Zagata and Haugen 1974, Beier and McCullough 1990, Webb et al. 2010). The effect of lunar phase on WTD has received much attention and most studies of lunar phase and deer activity have used visual observations (Michael 1970, Zagata and Haugen 1974, Buss and Harbert 1950). An efficient way to determine activity pattern is to use remote trail cameras which are triggered by heat or movement within a certain distance and thereby document animal activity (Moruzzi et al. 2002). Trail cameras offer many advantages for wildlife research including definitive species identification, multiple species detection, and a permanent photographic record (Schlexer 2008, Texas A&M 2009). The current study uses trail cameras to investigate the comparative activity patterns of WTD and nilgai in South Texas. Understanding daily activity patterns is of critical importance because of the association of these two wildlife species with CFT. Treatment methods for CFT on WTD have been developed and are deployed by the USDA-APHIS and Texas Animal Health Commission, Cattle Fever Tick Eradication Program, however, no such methods has been developed for nilgai. Remote acaricide delivery systems using trip sensors are being developed for CFT-infested nilgai in South Texas. The information from this study will be used to develop optimum treatment times. Our objectives were to (1) document and compare circadian activity patterns of WTD and nilgai, and (2) determine the effects of lunar phase on WTD and nilgai activity in South Texas.

MATERIALS AND METHODS

Study Site. The study was conducted from August to October 2016 on the East Foundation's Santa Rosa Ranch, a 9,000 ha ranch located in Kenedy County, Texas (26°55'N, -97°42'E;Fig. 1). The commercial cow-calf operation is managed to support wildlife conservation and other and private land stewardship. Nilgai are common and surveys conducted in 2016 reported a population density of 4.5/km^2. The ranch is situated in a sub-tropical region which receives an average rainfall of 60 cm annually with average daily temperatures ranging from 19-27 °C. The study site is characterized by a dense chaparral honey mesquite (*Prosopis* *glandulosa* Torr.) and huisache (*Acacia farnesiana* (L.) Willd.) savannah, and oak woodlands (*Quercus virginiana* Mill.).

Fig. 1. The location of study site (East Foundation's Santa Rosa Ranch, Kenedy Co., near Riviera, TX)

Set-up of sites. The data for this study were gathered as part of a larger study focused on nilgai odor lures (Goolsby et al., 2017). The 80 cameras were set up at four sites, each one km apart on 10 transects, that were randomly assigned on the ranch property. At each selected transect site, four Trail Cameras, Gen2, Moultrie A-5 Model: MCG-12688 with motion sensors (Moultrie, Alabama), were mounted on wooden stakes at approximately 1m height. Each trail camera was equipped with a 12-LED near-infrared flash with a 15m range to capture clear images both during day and night.. The cameras were placed strategically to cover almost all areas in a radius of 15m from the center of each site. All vegetation in front of the cameras were removed to ensure that false triggers of the motion detectors were minimized. The cameras were set to take 3 digital images per triggering event to determine the travel direction of the animal. Digital images were stored on 16 GB digital (SD) memory cards which were replaced every two weeks to collect data. Memory cards of all cameras were also switched after two weeks to collect and store data. The study was carried out in two phases starting August 8-September 6 and September 9-October 14, 2016 with five transects deployed during each period. For comparison of daily activity patterns, four time periods with differing abiotic qualities were used: morning (5:01 am to 12:00 pm), afternoon (12:01 pm to 5:00 pm), evening (5.01 pm to 9.00 pm), and night (9:01 pm to 5:00 am).

Lunar phase was used as a quantitative measure of the moon's appearance and was classified as new, first quarter, full and third quarter moon. The amount of cloud cover during the night was not accounted for as this study focused only on lunar phase rather than moon visibility. Astronomical data were downloaded from the site www.calendar-12.com/moon_phases/2016. Although these parts of the day are approximately equal in terms of hours, they correspond to periods of time with similar abiotic qualities. We used lunar phase as a quantitative measure of the lunar's appearance. We also did not account for cloud cover because we were only interested in documenting activity relative to lunar phase and not lunar visibility. The lunar phases were classified as new, first quarter, full and third quarter lunar. Astronomical data were downloaded from the site www.calendar-12.com/lunar_phases/2016.

Data analysis. Activity of nilgai and WTD were determined by examination of digital images. We recorded the number of observations by species and transect. We defined an observation as a clearly identifiable digital image of a nilgai or WTD. It is likely that the same animal was counted as an observation multiple times in the study. However, if there were multiple digital images of the same animal during a few minute periods and in these cases we counted this only as one observation. Hourly observations were tabulated by species. All activity data recorded between 9:00 pm to 6:00 am was utilized for lunar phase effect. Data was analyzed using ANOVA with group multiple comparisons by Tukey test using GraphPad Prism 4.

RESULTS

A total of 218 animal activity events, comprising of 114 nilgai and 104 WTD observations, were recorded during the study. Nilgai activity peaked from 7.00-8.00 pm (11.4%) followed by 8.00-9.00 pm (10.5%) whereas, no activity was recorded during 8.00 -9.00 am, 12.00-1.00 pm and 2.00-3.00 pm. Similarly, peak activity of WTD was recorded during 7.00-8.00 pm (16.3%) followed by 8.00-9.00 am (12.5%) whereas, no activity was recorded during 4.00-7.00 am and 11.00-12.00 am. The activity pattern of WTD over a 24 hour-period exhibited two distinct peaks, morning and evening, whereas nilgai activity patterns showed various peaks throughout the day (Fig 2).
The activity pattern of WTD on 24 hour scale shows

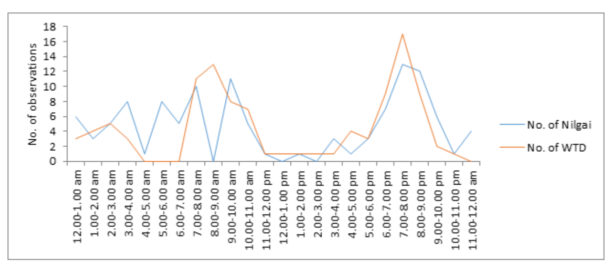

Fig. 2. Comparative activity patterns of nilgai and white-tailed deer showing average observation per site in 24 hour scale in Sept. 2017 at the Santa Rosa Ranch, near Riviera, TX (August-October 2016).

two distinct peaks at morning and evening hours whereas, nilgai activity patterns shows various peaks throughout the day (Fig 2). The activity pattern of both species with respect to various parts of the day showed

Table 1. Activity pattern of nilgai and white-tailed deer in various parts of day at the Santa Rosa Ranch, near Riviera, TX (August-October 2016).

Parts of day	Hours	Nilgai		White-tailed deer	
		No. (%)	Hourly Mean ± SE*	No. (%)	Hourly Mean ± SE
Morning	5 am to 12 pm	40 (35.1)	5.71 ± 1.59^a	40 (38.5)	5.71 ± 2.04^a
Afternoon	12 pm to 5 pm	5 (4.4)	1.00 ± 0.55^a	8 (7.7)	1.60 ± 0.60^a
Evening	5 pm to 9 pm	35 (30.7)	8.75 ± 2.32^a	38 (36.5)	9.50 ± 2.87^a
Night	9 pm to 5 am	34 (29.8)	4.25 ± 0.88^a	18 (17.3)	2.25 ± 0.65^b
Total		114	4.75 ± 0.81^a	104	4.33 ± 0.95^a

*Means within rows with different letters represent significant differences in Tukey-adjusted mean comparisons.

significant variation (P=0.003) (Fig. 3). Nilgai were more active than WTD at night with 29.8% of activity in comparison to 17.3% for WTD (Table 1).

A total of 42 (36.8%) nilgai and 18 (17.3%)

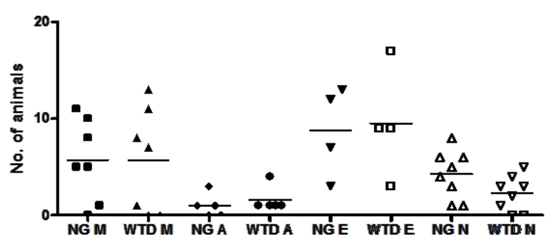

Fig. 3. Distribution by transect of hourly activity pattern of nilgai (NG) and white-tailed deer (WTD) in various parts of day (M-morning, A-afternoon, E-evening, N-night) at the Santa Rosa Ranch, near Riviera, TX (Aug-Oct 2016) Symbols represent lure sites with activity.

WTD activity were recorded during the 9.00 pm to 6.00 am and used to investigate the effect of lunar phase on activity patterns (Table 2).

Number of activity events recorded were greatest during a full moon, for both the species, however overall,

Table 2. Activity pattern of nilgai (NG) and white-tailed deer (WTD) in various lunar phases from Aug-Oct 2016 at the Santa Rosa Ranch, near Riviera, TX.

Lunar Phase	No. NG	% NG	WTD	% WTD
New moon - First Qtr.	6	14.3^a	1	5.6^a
First Qtr. - Full moon	19	45.3^a	9	50.0^a
Full moon - Last Qtr.	8	19.1^a	3	16.7^a
Last Qtr. - New moon	9	21.4^a	5	27.8^a
Total	42		18	

lunar phase did not influence (P > 0.05) activity events within and between the two species.

DISCUSSION

A number of factors influence WTD activity including breeding and parturition, general changes in season and day length, and environmental influences such as weather (Webb et al., 2010).. Similarly, nilgai activity is influenced by environmental factors, such as availability of food, and human disturbance. Nilgai allocate their time satisfying y their basic nutritional requirements, movements, social interaction, and rest (Gautam and Bissa, 2015). There are several reports on activity patterns of WTD, but even though they are sympatric with nilgai in southern Texas, there is no information regarding their comparative activity patterns. We found white-tailed deer exhibited two primary peaks in activity and were greatest in morning and evening hours, which closely corresponded with sunrise and sunset and is similar to trends previously reported (Michael 1970; Beier and McCullough, 1990). Few studies have documented changes in diurnal and nocturnal movements of WTD. Kammermeyer and Marchinton (1977) reported deer moved twice as much during diurnal hours as compared to nocturnal hours in a Georgia study. However, in the current study activity events of WTD during the day time (83%) was almost five times higher than during night (17%).

Nilgai had a similar to activity pattern to WTD, with peak the activity during morning and late evening hours. However, nilgai had more nocturnal activity (30%) compared to WTD (17%). This activity appears to fluctuate during the night hours (Fig 2). Nilgai activity patterns reported from their native range in India is similar to our findings. Results from two separate study locations in India, South-Western Haryana region (Singh, 1995) and Tadoba–Andhari Tiger Reserve located in Chandrapur district of Maharashtra (Bayani and Watve, 2016), have shown that nilgai are most active at night. Night time activity in India is believed to be influenced by the presence and activities of farmers working and defending their crops during the day. Because of the depletion grasslands and forest areas in the plain regions of India, nilgai have become more dependent on agricultural crops and are causing significant economic losses to farmers (Bayani et al., 2016). Whereas in South Texas, even with almost no human interference, other than hunting, and no large co-evolved predators, these animals are still most active during nocturnal hours and into the early morning.

Lunar phase did not influence either WTD or nilgai activity events in the present study. It is possible that additional, comprehensive research studies of Lunar phase influences on WTD, and especially nilgai, activity events may show differences. Deer activity during the 24-hour period did not appear to be affected by proximity in time to the new or full moon, which is a commonly accepted dogma (Beier and McCullough 1990, Webb et al. 2010).

This study was undertaken primarily to obtain information on comparative daily activity patterns and influence of moon light on activity of nilgai and WTD in South Texas. Our study shows differences in activity patterns of these two species particularly in nocturnal activity. Nilgai were more active at night as compared to WTD. Treatments to control CFT on nilgai, including the use of remotely deployed spray units should be designed for night operation. Treatment of nilgai at night could also minimize effects on other non-target species such as WTD, cattle and other diurnally active species. Future research on control of CFT on nilgai will need to consider activity patterns to optimize treatment methods.

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