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Home ranges of rusa deer (*Cervus timorensis*) in a subtropical peri-urban environment in South East Queensland

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ABSTRACT

Wild rusa deer (*Cervus timorensis*) are increasing in numbers and distribution in peri-urban eastern Australia. To effectively manage rusa deer, land managers need to know the extent of their movements to determine the appropriate scale of control through trapping and shooting. We found that in a subtropical peri-urban environment in South East Queensland, four rusa deer (three male, one female) with GPS collars annually ranged over areas of <400 ha with core areas of ~100 ha over a period of 10–17 months. Our limited data indicated their relatively small home ranges varied little in size and location from season-to-season, suggesting that these deer can be effectively managed at the local level.

Keywords: Brisbane, deer management, exurban, kernel density estimation, minimum convex polygon, ranging behaviour, satellite telemetry, site fidelity, space use.

Introduction

Deer are not endemic to Australia and, of the many deer species introduced by acclimatisation societies in the late 19th century, only six species have established free ranging populations in Australia (Bentley 1998; Moriarty 2004*a*). Rusa deer (*Cervus timorensis*) are one of those six species and have established numerous populations along the eastern seaboard of Australia (Bentley 1998; Moriarty 2004*a*). These populations appear to be increasing in both density and extent (Davis *et al.* 2016). The current distribution of rusa deer in Queensland includes the original liberation on islands adjacent to Cape York Peninsula, coastal locations stretching from Cooktown to the Gold Coast, and several inland locations such as south-east of Normanton, north-east of Longreach and south of Emerald (Biosecurity Queensland 2019). Deer in suburbia are problematic (Burgin *et al.* 2015) and rusa deer are present in populated areas of Brisbane, Moreton Bay, the Sunshine Coast and the Gold Coast. Impacts include causing vehicle accidents, modification of native vegetation, competition with livestock and damage to crops.

Wild rusa deer are listed as a restricted invasive animal in Queensland under the *Biosecurity Act 2014* providing a legal framework and requirement for their control. Land managers in peri-urban South East Queensland report rusa deer impacts and presence varying over the year, with complaints peaking in winter-spring. This suggests seasonal movements, yet data on ranging behaviour of rusa deer are lacking for this region and in peri-urban areas in general. This study investigated movements of wild rusa deer in peri-urban areas to support land managers in planning control programs.

Materials and methods

Study area

The study was undertaken north of Brisbane, in subtropical Queensland. GPS collaring of rusa took place at two sites: Kurwongbah (−27.21°, 152.95°, 40 km north of Brisbane) near Caboolture in the Moreton Bay Regional Council area, and Cambroon (−26.64°, 152.69°, 100 km north of Brisbane) near Kenilworth in the Mary Valley, in the Sunshine Coast Council area. Both sites are dominated by eucalypt woodlands or open forests but have been modified for residential or agricultural production purposes. Kurwongbah comprises mainly hobby farms of ~2.5 ha that have been highly modified (cleared). Camboon comprises mainly rural farms of ~ 150 ha that have been partly cleared and used for grazing beef and dairy cattle.

Animal capture and collar deployment

Animal capture and handling was approved by the Queensland Department of Agriculture and Fisheries Animal Ethics Committee (approval number CA 2015-09-902). Free ranging rusa deer were darted from the ground with a mixture of xylazine (3.0 mg kg^{-1}) and tiletamine-zolazepam (4.0 mg kg^{-1}) as reported in Hampton *et al.* (2019). Deer handling, collar fitting and antagonism of xylazine with 0.3 mg kg^{-1} yohimbine hydrochloride followed methodology reported in Amos *et al.* (2014).

Five rusa deer, comprising two adult males (≥2.5 year), two sub-adult males (~1.5 years) and one adult female (≥2.5 years), were captured and fitted with Lotek® Lifecycle ungulate GPS-Globalstar collars between 12 July and 4 August 2016. The GPS collars were programmed to record a GPS location every 13 h and upload locations once a day via the Globalstar Satellite Network to the Lotek® website. The collars were also programmed to emit a VHF signal in daylight hours for manual radio-tracking and were fitted with a mortality feature that would transmit an alert via sms if a collar remained stationary for 24 h.

Location accuracy

The average position error was calculated for one of the collars at four locations where it was left for approximately a week in each location to simulate varying study conditions. Estimated position error was calculated as per Lewis *et al.* (2007). The collar returned 74 positions over 33 days with an overall average position error of ±7.8 m for all locations without any data screening. GPS fix success rate was calculated as the proportion of successful GPS fixes to potential fixes given the collar recording rate of a fix every 13 h.

Home range

We calculated home range areas using the 'adehabitat' package (Calenge 2006) in R (R Core Team 2020). Annual (12 months – 1 September to 31 August) and seasonal (Spring – 1 September to 30 November, Summer – 1 December to 28 February, Autumn – 1 March to 31 May, and Winter – 1 June to 31 August) home ranges were calculated using minimum convex polygons (MCP) (Mohr 1947) set at the 95% level and kernel density estimation (KDE) with the h_{ref} smoothing parameter (Worton 1995) set at the 50 and 95% levels. This selection of home range estimators allowed comparison of home ranges with other studies. We used 50% KDE contours as a proxy for core utilisation areas to compare with studies that had done likewise, although there are more biologically meaningful ways of determining core areas (Goldingay 2015). Site fidelity was calculated as the Euclidean distance between core area centroids (geometric mean of 50% KDE contours) for consecutive seasons.

Results

GPS data from four deer (two adult male, one subadult male (Kurwongbah) and one adult female (Cambroon)) were obtained over 10–17 m (Table 1). The fifth deer collar,

Table 1. Home-range statistics from wild rusa deer collared at Kurwongbah (M1, M2, SM1) and Cambroon (F1), South East Qld between July 2016 and December 2017.

	Deer ID			
Deer details	**M1**	**M2**	**SM1**	**F1**
Sex	Male	Male	Male	Female
Age class	Adult	Adult	Sub-adult	Adult
Total GPS fixes	184	156	210	366
Average monthly GPS fix success rate	23%	25%	21%	38%
Range of monthly GPS fixes	7–20	6–23	2–25	4–43
Months collared	13	10	17	16
Annual 95% MCP (ha)	296	372[A]	345	360
Annual 95% KDE (ha)	456	788[A]	551	527
Annual 50% KDE (ha)	61	84[A]	137	94
Seasonal average 95% MCP (ha ± s.e.)	197 (± 63)	183[A] (± 61)	193 (± 58)	202 (± 33)
Average seasonal site fidelity (m ± s.e.)	269 (± 118)	380[A] (± 170)	404 (± 90)	490 (± 91)
Number of seasons	5	4[A]	6	6

[A]Collar data mid-July to mid-May only.

fitted to a subadult male (Cambroon), went into mortality mode within a fortnight of collaring and was found detached from the deer. The number of GPS fixes obtained overall from individual deer varied from 156 to 366, and the average (±s.e.) monthly GPS fix success rate (FSR) was 27.1% (±2.0%) for all deer (Table 1). There appeared to be a trend for the seasonal home range to be greater in winter-spring and smaller in summer-autumn (Fig. 1). Annual core utilisation areas were small (<140 ha), and all deer showed strong site fidelity, with short distances (<500 m) between seasonal core area centroids over time (Table 1). An example of this ranging behaviour is shown for deer M1 in Fig. 2. GPS points in Fig. 2 that appear to be in Lake Kurwongbah are on the dam foreshore due to extremely low water levels from drought at the time of the study.

At Kurwongbah, collared deer used the lower lying riparian areas adjacent to and upstream of Lake Kurwongbah throughout the year. At Cambroon, the one collared deer similarly used the lower lying areas and small hills in the Mary Valley adjacent to the Mary River throughout the year.

Discussion

This research provides the first insight into the home range use of rusa deer in an Australian sub-tropical, peri-urban

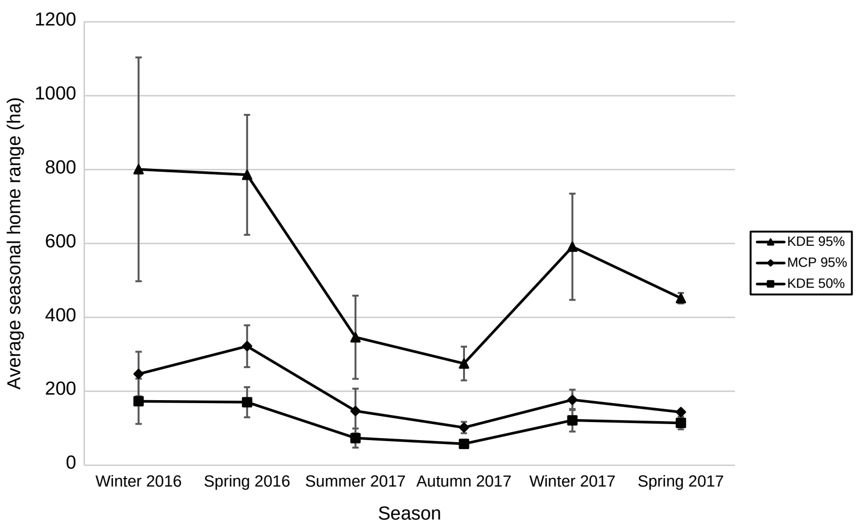

Fig. 1. Average (± s.e.) seasonal home ranges for collared free ranging rusa deer at Kurwongbah and Cambroon, South East Queensland between July 2016 and December 2017. Four deer per season shown except for winter 2017 ($n = 3$) and spring 2017 ($n = 2$).

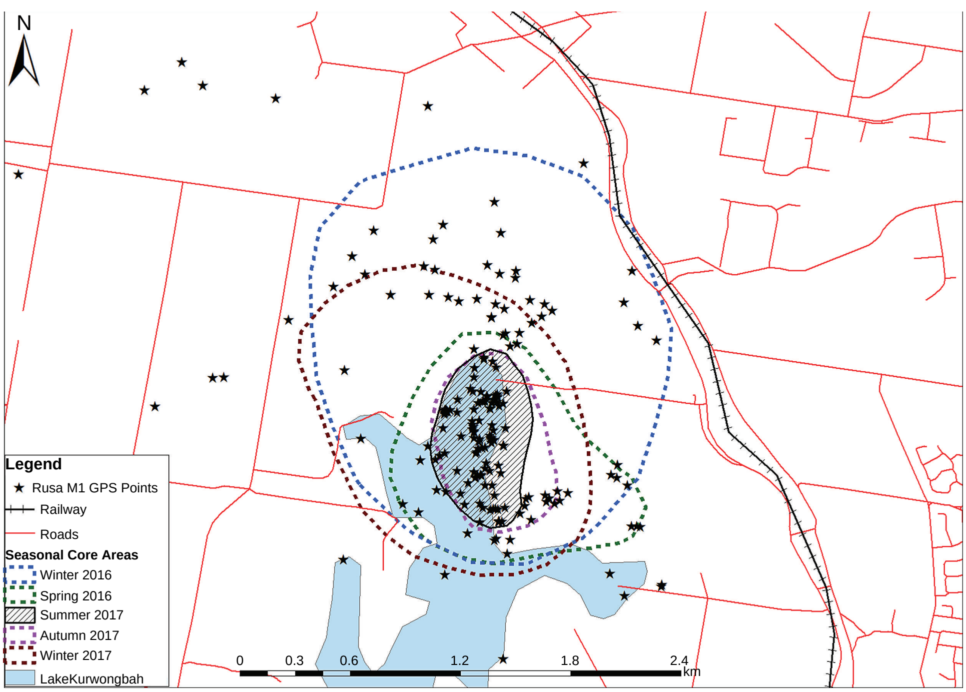

Fig. 2. Seasonal core areas (50% KDE) for rusa stag M1.

environment. Despite the small sample size (four collared deer) and the low GPS fix success rate (on average a GPS fix was recorded every second day), our results indicate rusa deer have strong site fidelity across the seasons in these environments and activity focussed in relatively small areas of ~100 ha.

The patterns in home range use and site fidelity described in this study are consistent with those of rusa deer in other sites and environments. For example, the average (±s.e. (range)) seasonal MCP home range from our study (195 ± 25 ha (183–202)) was comparable to Moriarty's (2004*b*) study (245 ± 14 ha (25–821), $n = 29$) at Royal National Park near Sydney. The annual home range estimates from our study (581 ± 72 ha 95% KDE) were similar to those reported in New Caledonia (501 ± 33 ha 95% KDE, $n = 6$) (Spaggiari and de Garine-Wichatitsky 2006) where rusa deer are also an introduced pest species. The site fidelity of rusa deer in peri-urban Queensland is high and consistent with that of rusa deer at Royal National Park (Moriarty 2004*b*), which showed strong site fidelity (on average little range shift between seasons) except for three juvenile males that dispersed from their original pre-rut home range. Average site fidelity (±s.e.) displayed by the four collared rusa deer at our study site (393 ± 53 m) was smaller than that reported (904 ± 109 m between centres of activity) from a rural area of New Caledonia (Spaggiari and de Garine-Wichatitsky 2006). Even though these older studies were conducted with VHF tracking rather than GPS collars, we believe the results are comparable to our study due to the poor GPS fix rate of our collars. In fact, Moriarty (2004*b*) averaged more seasonal locations than our study (53 vs 44).

These results are consistent with studies from other deer species in peri-urban areas. For example, white-tailed deer *(Odocoileus virginianus)* in the United States also display small home ranges and high site fidelity in peri-urban areas (Storm *et al.* 2007; Rhoads *et al.* 2010). Porter *et al.* (2004) linked small home ranges of white-tailed deer in urban areas to availability of key resources. Morrison *et al.* (2021) suggest that site fidelity in ungulates is linked to predictable resources. It is likely that small home ranges and high site fidelity at our study site were linked to available and predictable food resources important to rusa deer.

Given that peri-urban landscapes increase the complexity of deer management and increase the potential for deer-human conflict (Storm *et al.* 2007; Burgin *et al.* 2015), the relatively small home ranges and high site fidelity of rusa deer at our study site are important for local land managers. Strong site fidelity and small home ranges have both been listed as key attributes for successful control in these environments (Porter *et al.* 2004; Rhoads *et al.* 2010). In peri-urban Queensland, deer control is undertaken by landholders in response to property-level impact. Local governments also undertake control in response to complaints and pre-emptively at a similar scale and plan and coordinate control among land managers. The data presented here give pest managers in the region an appreciation of the spatial scale at which control methods need to be deployed to reduce impacts at the local level. Future work should build on this pilot study, increasing sample size and covering a range of peri-urban environments including other land uses. Assessment of specific habitat use will help determine timing and areas of conflict with people and identify optimal locations and times for control.

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Data availability. The data that support this study will be shared upon reasonable request to the corresponding author.

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