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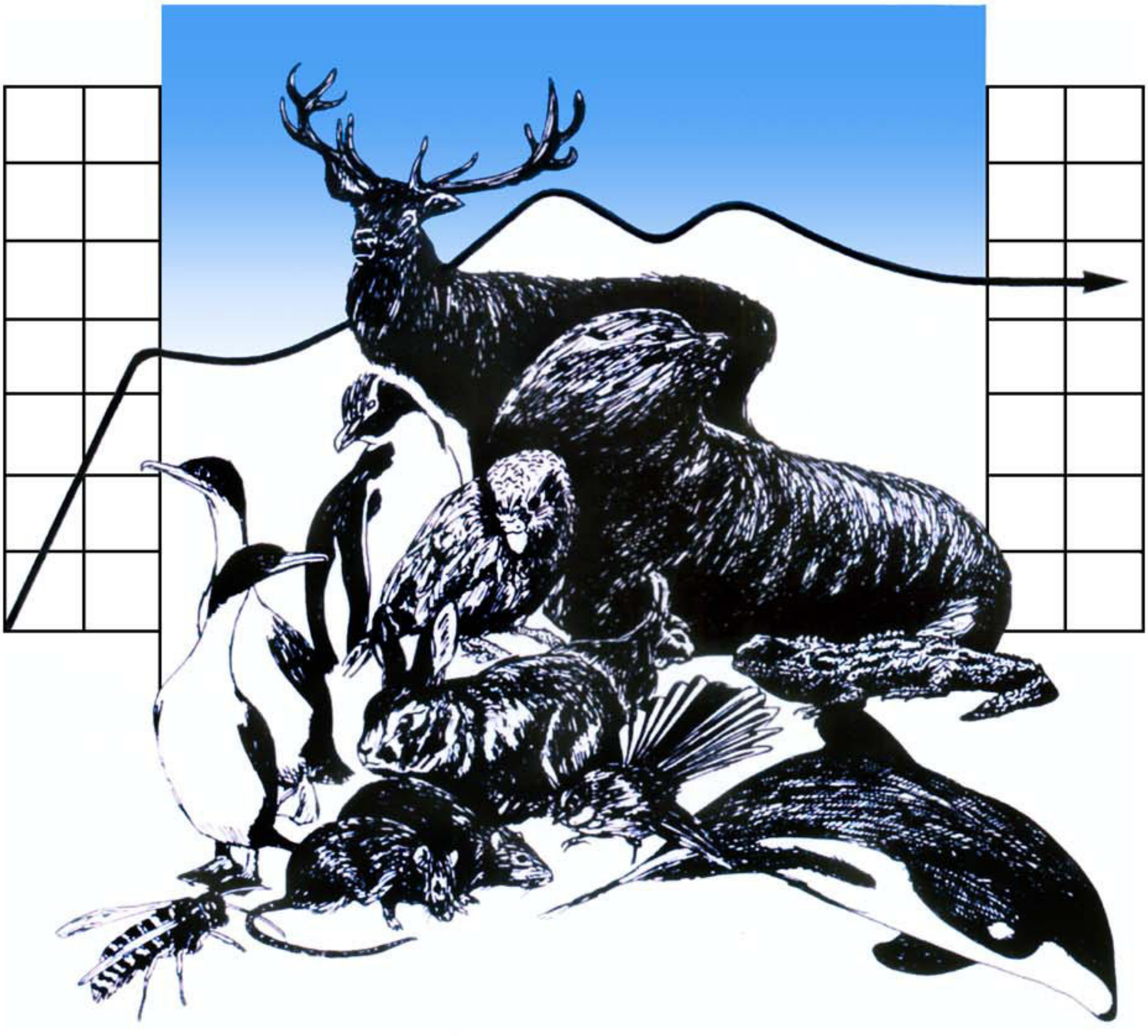

WILDLIFE MANAGEMENT

Activity of GPS-collared sika deer (Cervus nippon) in the Kaweka Forest Park

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1. Executive Summary

The activity patterns of wild sika deer *(Cervus nippon)* in the Kaweka Forest Park of New Zealand were assessed by use of Global Positioning Satellite collars. Data represented positional information recorded every 30 minutes on 14 stags and 16 hinds over a 12-month period in 2011. Culling of sika hinds by helicopter hunting takes place in specific areas where sika deer numbers are high, to reduce damage to the mountain beech forest *(Fuscospora cliffortioides)*. The time of day and year when sika deer are most active was identified for aerial hunting. The most active times should correspond to the highest encounter rates and culling opportunities for efficient allocation of helicopter resources. Sika hinds display a bimodal pattern of activity notably in the colder months, with a peak of activity tending to be around the hours of dawn and another before dusk when days are long and after dusk when days are short. In contrast, sika stags tended to be nycthemeral in nature, demonstrating bouts of activity irrespective of dawn and dusk. In the winter months, activity from dawn to midday was consistently high for hinds, whereas stags demonstrated minimal activity at that time.

Keywords: Activity, *Cervus nippon,* daily rhythm, seasonal variation, hunting, GPS

2. Introduction

Patterns of animal activity are largely driven by nutritional requirements for maintenance, growth, and reproductive needs that vary by time of day, season, and age (Horn & Rubenstein, 1984). There is selective advantage for animals whose behaviour and physiology is synchronised with seasonal events (Regal & Connolly, 1980).

Activity of wild animals is generally hard to quantify, but more so in elusive species. Gaining insight into the time wild animals spend resting, browsing, and travelling is crucial to understanding behavioural factors relevant to management and conservation (Georgii, 1981; Coulombe et al., 2006; Gervasi et al., 2006; Austin et al., 2013), as well as recognising deviations from normal behaviours (Lottker et al., 2009).

Activity has been quantified in certain economically-important farmed ungulate species such as red deer *(Cervus elaphus scoticus)* (Georgii, 1981; Georgii & Schroder, 1983; Berger et al., 2002; Pepin et al., 2006; Lottker et al., 2009), reindeer *(Rangifer tarandus)* (Maier & White, 1998; van Oort et al., 2007), and roe deer *(Capreolus capreolus)* (Gottardi et al., 2010; Krop-Benesch et al., 2013; Pagon et al., 2013). In contrast, little information is available on wild populations like sika deer *(Cervus nippon)*. Elusive in nature, sika deer are highly regarded as a trophy animal (Poole & Johns, 1970; King, 1990).

Sika deer were established in the central North Island of New Zealand, from a single release of six animals at Merrylees Clearing in the Kaimanawa Range in 1905 (King, 1990; Davidson & Fraser, 1991). The herd has since expanded to the Kaweka, Kaimanawa and Ahimanawa Ranges (Banwell, 2009). While sika deer were initially sympatric with red deer throughout this range (Davidson & Fraser, 1991), they displaced red deer in many areas where prime vegetation has been depleted (Banwell, 2009). Sika deer exhibit digestive physiological differences that allow them to thrive despite a diet of poor quality forage (Hofmann, 1985). High deer numbers over an extended period have diminished native vegetation (Davidson & Fraser, 1991). The mountain beech *(Fuscospora cliffortioides)* forests in the Kaweka Forest Park are most notable for studies indicative of the detrimental impact on biodiversity by prolonged browsing of deer (Allen & Allan, 1997). Sika deer are currently considered the greatest threat to mountain beech forest (Herries, 2009). Culling has been put in place to reduce female deer numbers to allow mountain beech forest regeneration, while recreational hunters have been encouraged to maintain adequate harvest levels (Herries, 2009). Aerial hunting would be most effective if targeted at the time of day and season when sika hinds are most active.

Hunters have long recognised that activity patterns of sika deer tend to be crepuscular in nature, being more active at dawn and dusk than other times of the day. This project provides quantitative characterisation of diurnal (during the daylight), and nocturnal (during the night) activity, and its relation to deer sex and season.

3. Methods

3.1 Data collection

One way to assess animal activity levels is through a speed parameter. Speed can be determined from information on location taken at consecutive times (Schlecht et al., 2003; Gottardi et al., 2010). Location information was obtained using collared GPS units programmed to log GPS coordinates every 30 minutes. Collars were activated at the field base prior to deer capture and were programmed to record data every minute for the first hour. Capture was undertaken starting in late December 2010 through to February 2011 as deer were encountered. Collars were scheduled to detach at 12:00 pm on 28th February 2012 for hinds, and 12:00 pm on 30th of April 2012 for stags. Sika stag collars were privately funded and used here as comparative data with hinds. The Kaweka Mountain Beech Monitoring team and enthusiastic volunteers undertook collection of detached collars, manufactured by either Sirtrack (www.sirtrack.com) or Kiwitrack (www.kiwitrackltd.co.nz), with both collars using the same GPS technology.

3.2 Study area

The Kaweka Forest Park is located in the Central North Island of New Zealand, comprises 62,230 ha and extends to 1,724m in elevation. It is an important ecological and recreational resource, with soil and water conservation values (Herries, 2009). Sika deer, red deer, rabbits *(Oryctolagus cuniculus)*, hares *(Lepus europaeus)*, brushtail possums *(Trichosurus vulpecula)*, pigs *(Sus scrofa)*, sheep *(Ovis aries)* and goats *(Capra hircus)* have also inhabited the park over the years, greatly impacting its vegetation (Elder, 1959).

3.3 Study animals

A total of 30 wild sika deer (14 stags, 16 hinds) were captured within the Kaweka Forest Park and each was fitted with a GPS collar and mortality transmitter. Capture was undertaken from a Hughes 500D helicopter with competent net gun operators; defined by having recent deer capture experience and a history of capturing at least 3,000 deer. Selection of capture targets was based on several visual factors to maintain consistency across study animals, and for animal welfare reasons. Deer needed to be healthy looking, mature animals (>3 years), with hinds in late gestation avoided. Deer were held captive using blindfolds and leg restraints for a maximum of 6 minutes to minimise stress and risk of injury. A brass ear tag was used for identification of captured animals once the collar had fallen off. Animals were photographed and hair sampled for possible DNA analysis. Attempts at capture were made on the first deer sighted that met the above requirements, to overcome selection bias, until target sample size was reached.

Subjects were caught in 3 areas: Area 1 (5 stags, 5 hinds) had no history of aerial deer hunting but considerable ground hunting pressure. It is mostly tussock country with high quality vegetation easily accessible to deer. Area 2 (5 stags, 5 hinds) had aerial hunting operations in place, but less pressure from ground hunters. Deer required more travel to access forage than for those in Area 1. Area 3 (4 stags, 6 hinds) previously had aerial deer hunting. It is expansive country, requiring an increased amount of travel by deer to meet metabolic demands, and has the most ground hunting pressure.

3.4 Statistical analysis

After recovering the collars following their detachment, data collected was downloaded into ArcGIS 10.1. Attribute tables were viewed on Microsoft Excel 2007 where time and distance was calculated between successfully logged GPS positions. This data was uploaded into R *(v 0.98.501)* for visualization.

Some GPS locations were not valid. These included recordings that resulted in a calculated distance greater than 3,500 m between 30-minute locations. Locations that were recorded more than 900 minutes or less than 27 minutes apart were deleted.

4. Results

4.1 Summary of study animals

Data could only be used from 22 of the 30 collared deer due to equipment failure and other issues. The remaining animals include 3 stags and 5 hinds from Area 1, 3 stags and 4 hinds from Area 2, and 3 stags and 4 hinds from Area 3.

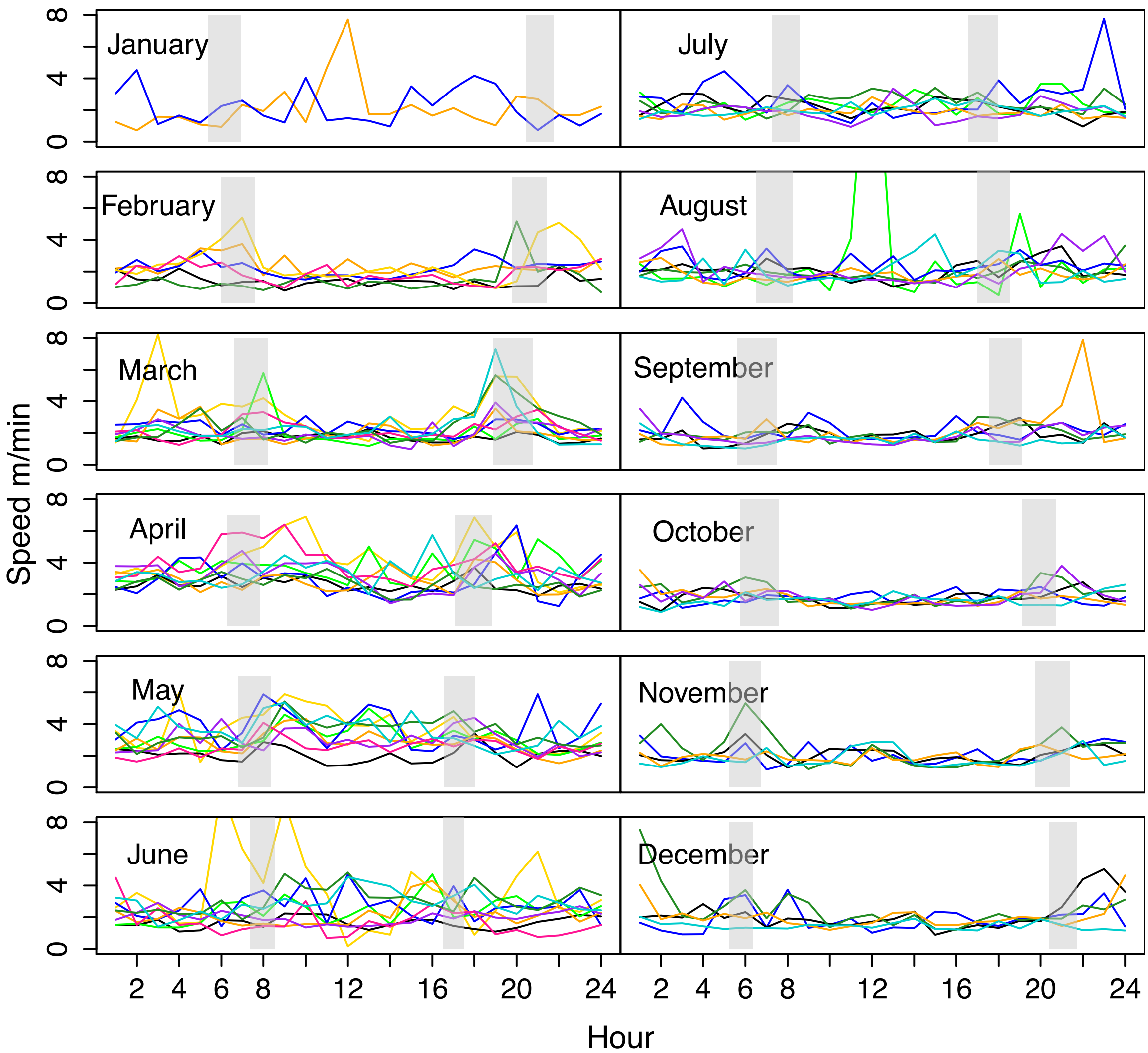

Figure 1: Hourly average speed (metres per minute) of 9 sika stags (each stag representing a different colour) in the Kaweka Forest Park in 2011. Sunrise and sunset times vary over the month and are depicted in shaded bands that extend 30 minutes either side.

4.2 Daily activity patterns

4.2.1 Stags

Sika stags demonstrate individual variation in daily bouts of activity (Figure 1). Stags are slightly bimodal with increased activity near dawn and dusk in February, March and April, although individual activity bouts varied across several hours. April and May coincide with the rutting period and stags display high rates of nycthemeral activity, where both number of bouts and distance travelled is irrespective of dawn and dusk. June, July and August have a high variation in the timing of bouts, with September through December showing more nocturnal than diurnal activity. In August, one stag captured in the open country consistently travelled around noon every few days. October, November and December show a trimodal distribution with peaks around dawn, dusk and midnight.

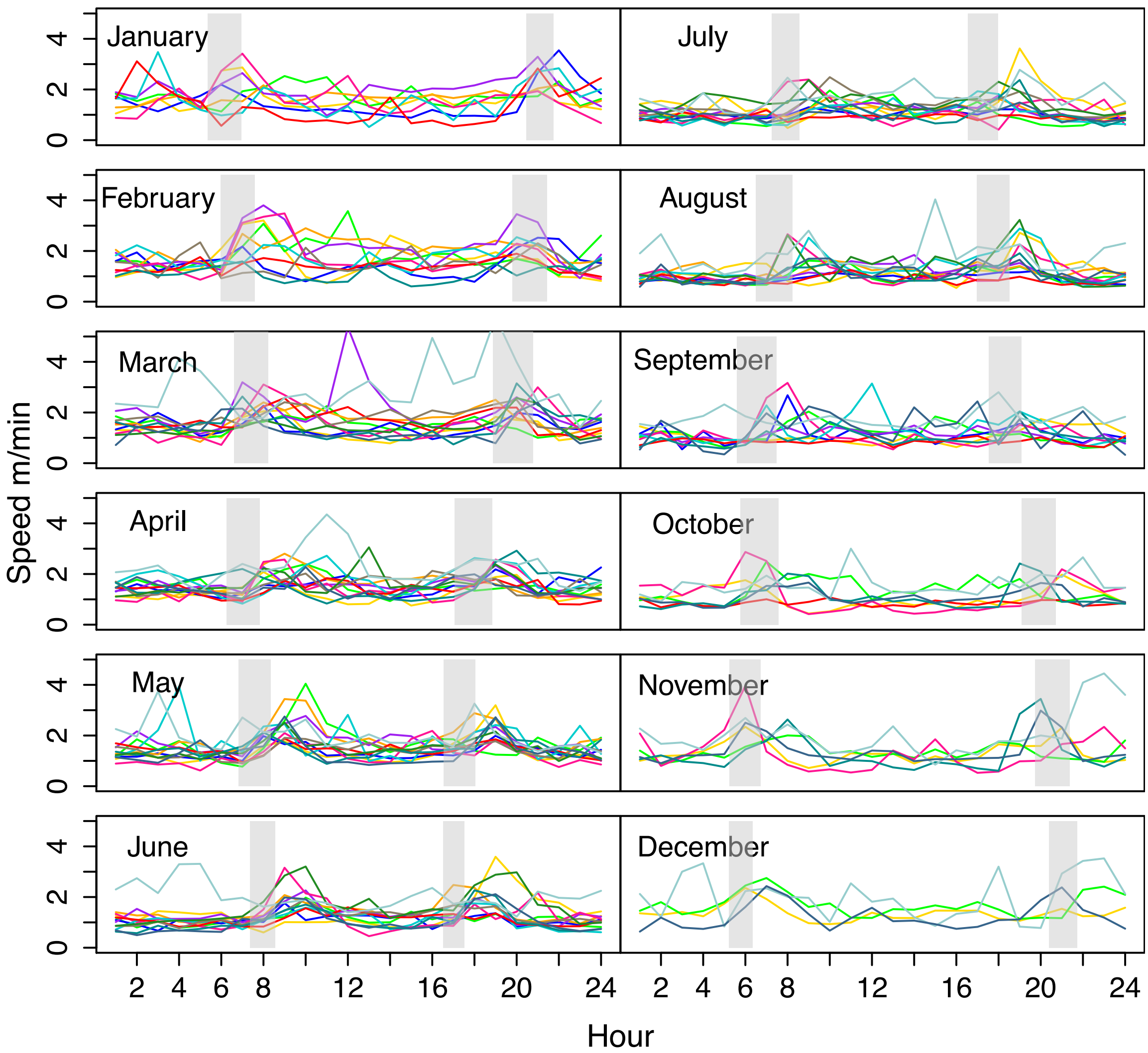

Figure 2: Hourly average speed (metres per minute) of 13 sika hinds (each hind representing a different colour) in the Kaweka Forest Park in 2011. Sunrise and sunset times vary over the month and are depicted in shaded bands that extend 30 minutes either side.

4.2.2 Hinds

Across the year, all months show slight bimodal distributions of sika hinds active over a 24-hour period, but considerable individual variation exists in the timing of activity peaks, particularly in the late winter and spring months of August through December (Figure 2). February and March show bimodal distribution with increased bouts of activity at dawn and dusk. January is similar but with an additional burst of activity noticed in the early hours of the morning, shortly after midnight. Sika hinds show a reasonable amount of activity in April, particularly promptly after dawn until the early afternoon period, with a second peak of activity noted shortly after dusk. May shows a comparable distribution, but including an additional rise of activity in the early hours of the morning with a lull at the coolest time of day, immediately before dawn. June, July and August show a similar variation in activity, with a morning peak from dawn through to late morning, and then another peak shortly after dusk. September has noticeably more diurnal than nocturnal activity; while October, November and December have similar levels of activity with individual variation spread throughout the day.

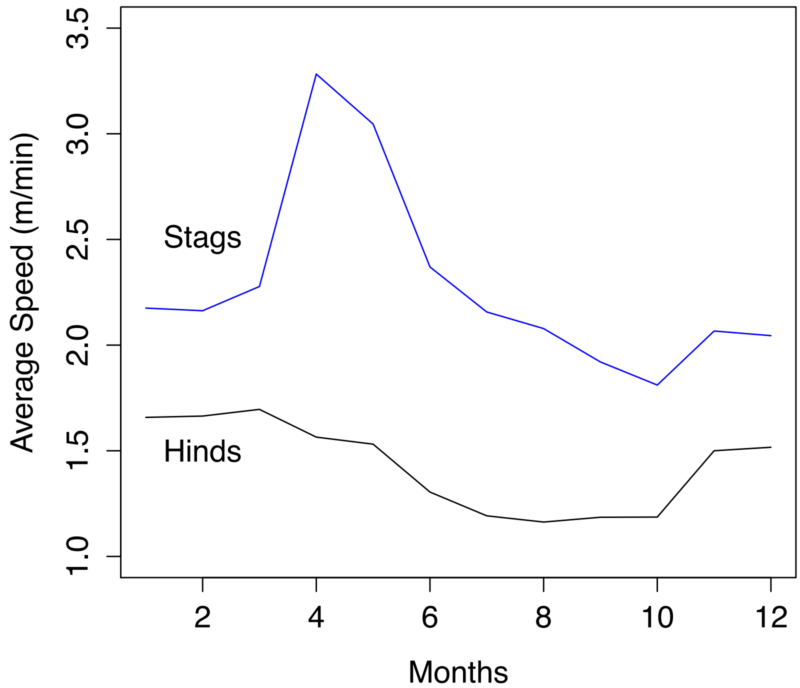

Figure 3: Average activity of adult sika deer by sex (metres/minute) during 2011 in the Kaweka Forest Park.

4.3 Monthly activity patterns

Both sexes exhibit a marked decrease in activity over winter months (Figure 3). Sika stags increased activity over November, with most activity demonstrated during April and May. Sika hinds also increased activity starting in November, and activity stayed consistent across summer and autumn dropping off after May.

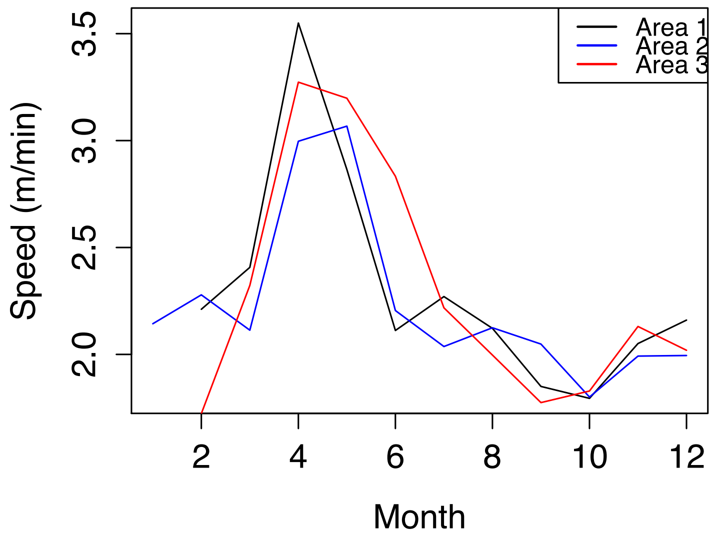

Figure 4: Sika stag average speed in the Kaweka Forest Park in 2011 between three study areas; Area 1: no aerial hunting, Area 2: current aerial hunting and Area 3: previous aerial hunting.

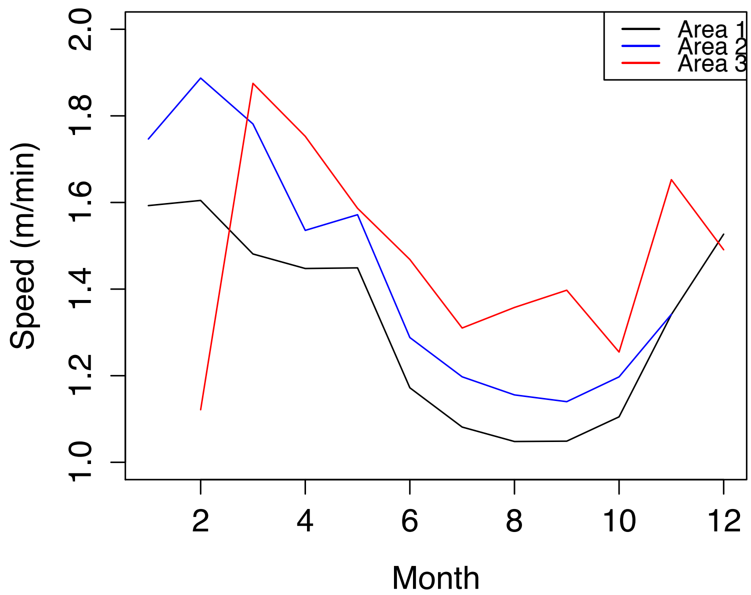

Figure 5: Sika hind average activity in the Kaweka Forest Park in 2011 between three study areas; Area 1: no aerial hunting, Area 2: current aerial hunting and Area 3: previous aerial hunting.

4.4 Variation in activity between areas

Sika stag activity is fairly consistent between the three study areas (Figure 4), but demonstrates a very slight variation for sika hinds (Figure 5). There does not appear to be differences in activity associated with past or current aerial hunting.

5. Discussion

Animal speed is zero when at rest, high when travelling, and intermediate for an actively browsing animal (Schlecht et al., 2003). GPS errors make the distinction between zero and slow moving speeds difficult (Gottardi et al., 2010). Consequently, average activity levels were calculated for every hour across the span of a month, losing fine-scale quantitative data but gaining rhythms inherent to the average activity patterns over time (Georgii & Schroder, 1983).

Both sexes demonstrate varying activity levels throughout the year, relating to reproductive needs, differing seasonal vegetation availability and individual energy requirements (Georgii & Schroder, 1983; Berger et al., 2002). The four seasons in New Zealand comprise of spring (September – November), summer (December – February), autumn (March – May) and winter (June – August). However, the higher altitude in the Kaweka backcountry results in spring occurring later than in the front country, with vegetation growth tending to start in late October (Philpott, 1998).

5.1 Stag activity

Sika stags will cast their antlers in November or December, growing new velvet immediately, with the most rapid antler growth occurring in January (King, 1990; Lentle & Saxton, 1993; Philpott, 1998). Dietary protein demands increase during the velvet growth period (Xiuhua et al., 2003) and sika stags will seek a positive energy balance in preparation for the rut (Philpott, 1998; Krop-Benesch et al., 2013).

Average sika stag activity increased dramatically in April, coinciding with the rut period, when stags actively seek out females in oestrous (King, 1990). The sika roar starts in late March, peaking in April with the last cycling hinds winding down in May (Daniel & Baker, 1986; King, 1990; Philpott, 1998). On Kinkazan Island, Northern Japan, sika stags exhibit a "reproductive territory" mating system where a piece of land is defended in order to copulate with females passing through the territory (Minami, 2009). In New Zealand, sika stags may round up hinds during the rut, or typically follow a single hind (King, 1990), spending energy in advertising for females and competing with conspecifics (Lentle & Saxton, 1993). Minami (2009) suggests sika stags change rutting behaviour strategies based on female density and visibility within habitat.

During the rutting season, sika stags demonstrate an increase in the number of active movements throughout the day and night, with higher activity peaks at dawn and dusk correlating with times when hinds are more active, presumably to increase oestrus hind encounter rates. Lower activity is noted by the completion of the rut, likely due to a combination of reduced feeding behaviour and loss of appetite (Lentle & Saxton, 1993), lower stag body condition, a lull in ground hunting pressure and a decline in vegetative quality. Rocky Mountain Elk *(Cervus elaphus canadensis)* increase resting and ruminating time while decreasing foraging bouts with the decline in vegetation quality over winter (Green & Bear, 1990).

Ground hunting pressure is present across the Kaweka Forest Park throughout the year, with an increase during the rut period and lower hunter interest over the shorter days in the colder winter months (C. Whittle pers. comm., 2014). The extent of anthropogenic disturbance has been associated with nocturnal levels of activity (Georgii & Scroder, 1983), with an increase in hunting pressure resulting in an increase in twilight peaks or nocturnal activity (Pepin et al., 2006; Krop-Benesch et al., 2013). While this study had a relatively small sample size, these animals did not particularly display an increased level of nocturnal activity than their diurnal levels other than a trimodal distribution of stag activity during October, November and December. This may be related to an increase in hunting pressure, or active avoidance of the early summer heat while still carrying winter coats.

5.2 Hind activity

The fawning period of sika hinds is November - January, with most parturition occurring by Christmas Day to align with spring vegetative growth (King, 1990; Lentle & Saxton, 1993; Philpott, 1998). An increase of activity in November would thus correlate to an increase in energy requirements during the last trimester of pregnancy (Georgii, 1981), or early fawning. Energy demands and consequently, forage intake, dramatically increase over the lactation period (Jiang, 2009), with maternal dietary intake having a significant effect on a nursing fawns body weight gain (Xiuhua et al., 2003). Consequently, hind activity consistently stays elevated over the summer – autumn season until declining at the end of the rut. The increase in energy requirements in sika hinds could explain the wider variation in the bimodal peaks of activity over the late winter and spring period as forage intake is largely influenced by vegetative quality and limited by gut volume (Pepin et al., 2006).

Over the rutting period, continual diurnal activity is most likely a result of harassment by sika stags throughout the day. In the winter months, there is a lull in activity across all sika hinds at the coldest time of day, just prior to the sun rising. Prominent bouts of activity promptly follow sunrise with individual variation in duration into late morning. This is probably due to sika hinds taking advantage of the morning winter sun when foraging, as has been demonstrated in red deer hinds (Pepin et al., 2006) and roe deer (Pagon et al., 2013). The short winter days consistently show extended active periods during the morning and are associated with a second peak of activity being after dusk, probably in relation to the timing of the need to forage. These cold mornings would suggest an ideal time for a recreational hunter to encounter a hind. Hunter belief of the crepuscular nature of cervids probably stems from the increased activity of deer at dawn, and from hunters seeking out areas of particular importance to deer for the evening period. In contrast to winter, the longer days in November result in the second bout of activity being just before dusk. A similar yearly pattern of activity has been demonstrated in red deer (Berger et al., 2002; Pepin et al., 2006) and roe deer (Krop-Benesch et al., 2013).

Sika hinds seem to demonstrate synchronised levels of activity in comparison to the collared sika stags in this study, who illustrated bouts of activity relating to a more nycethemeral trend throughout the night and day with large individual variation in timing. This nycthemeral strategy is exhibited in wild and captive reindeer, allowing maximization of foraging efficiency, with regular bouts of feeding (Maier & White, 1998; van Oort et al., 2007). Additionally, this could be due to the increased independence of sika stags while hinds will typically have family members in their vicinity (Lentle & Saxton, 1993).

Weather events can alter activity and habitat use with differences in sensitivity between individuals (Conradt et al., 2000). Other individual factors such as age and dominance stature may influence activity levels. One would assume a dominant stag in his mating territory would expend less effort in travelling, and defending females, than a lesser subordinate who may have to travel further in search of females. Dominance would likely be a combination of physiological condition, antler quality and behaviour; stemming from genetics and hormone levels, particularly testosterone (Chunwang et al., 2004). Home range activity in red deer stags is quite erratic between different age classes (Georgii & Schroder, 1983). 4 of the 9 collared stags have a confirmed age from tooth analysis and those ages were 4, 5, 7 and 9 years of age. A further study taking such individual factors into account would be of considerable value.

5.3 Variation in activity between areas

Mountainous habitat may support a more uniform distribution of activity bouts throughout the day as sika deer may not need to travel far between resting and feeding areas (Georgii, 1981). Activity levels were similar between the three areas for sika stags (Figure 4). Since 2009, sika stags became non-target animals for aerial hunting in order to maintain recreational hunter support (Herries, 2009). This is further emphasized by visual observation during aerial culling operations. When sika stags are encountered from the helicopter, they display a lack of interest. On the other hand, hinds typically react by heading for cover at the approach of a helicopter (D. Herries, pers. comm. 2014).

Only slight differences are noted for sika hinds in average activity over the year between blocks (Figure 5). Pagon et al. (2013) found that roe deer demonstrated lower activity levels when the perceived hunting risk was high, possibly due to increased vigilance, and choosing feeding places in close proximity to safe cover. Hunting is not restricted to a certain season or time period in New Zealand, resulting in quite varying hunting pressure across the landscape (Banwell, 2009). The minor variation in hind activity could be due to fine scale differences in habitat, weather and landscape between the areas effecting behaviour (Georgii, 1981; Conradt et al., 2000; Pepin et al., 2008; Hurley et al., 2012), including sika deer synchronising activity with the varying pressure by ground hunters (Regal & Connolly, 1980; Pagon et al., 2013).

6. Conclusion

A focus on hunting from daylight through to late morning in the cooler temperature months of May through September would be recommended to increase encounter rate and efficiency of aerial hunting of sika hinds. The evening hours prior to dark appear to be times of lower activity over these months, contrary to popular hunter belief. These results demonstrate that over the winter months, the morning would be the best time for recreational hunters to encounter sika hinds. Conversely, for sika stags, there is little activity over this time. The best time of year to encounter a stag would be March, April and May when they are covering lots of ground presumably seeking out hinds in oestrous with activity extending throughout the day and night hours. Sika stags do show slight trends of bimodal activity but with large individual variation around dawn and dusk. Ongoing work to enhance sika deer encounter rate should encompass the interaction of fine scale habitat, vegetation, landscape and individual life history effects on behaviour.

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