Estimating deer densities and their impact on vegetation in the Cardinia Shire

An assessment of a transect survey approach.

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Summary

Transect survey were carried out in the Cardinia Creek catchment area to assess deer density by the count of faecal pellets. Concurrently, vegetation impact surveys were carried out in the same transect and by measuring the level of browsing of plant species along the transects. The relationship between faecal pellet count and deer impact on vegetation was assessed. Furthermore, we compared the relative density of deer assessed by faecal pellet count with the actual density as observed by drone surveys in Beaconsfield Conservation Nature Reserve. Faecal pellets were present in 30 out of 34 transects and browsed vegetation was observed in all transects. We have found a significant relationship between faecal pellets and vegetation impact: transects that had a higher count of faecal pellets also showed, on average, a higher level of browsed vegetation. The analysis accounted for the presence of other herbivores which, in turn, had a relatively lower impact. We have found that deer density and impact is higher in the south-eastern side of the area investigated: the Cardinia creek parklands and the Beaconsfield Nature Conservation Reserve. The comparison with drone survey show a discrepancy in the relative deer estimate, although the observed differences may be caused by the animals' different use of space in different months given the considerable gap between the two surveys. Overall, this report show that transect surveys can be a valuable and economic assessment tool. However, it should be integrated with more sophisticated methods over longer time spans to provide a more complete picture of deer presence in the area.

Introduction

Introduced deer (family Cervidae) have established populations outside their native range in many areas of the world (Clout et al., 2008; Long, 2003). In the absence of natural predators and other forms of population regulation, deer populations can become overabundant and considerably alter landscapes and habitats, in turn affecting other species (Côté et al., 2004), damage human assets (e.g. agriculture and viticulture), and threaten public safety (e.g. vehicle collisions). Hence, deer management represents a challenge for land managers (Nugent et al., 2011).

In the state of Victoria, Australia, established deer populations negatively impact both native vegetation and agricultural land (Davis et al., 2016; Hampton and Davis, 2020; Lindeman and Forsyth, 2008) and their management is necessary to limit damages (Davis et al., 2016). In order to allocate management resources efficiently, evaluating deer distributions, densities and their impact on vegetation and habtats is pivotal. One such method was recently proved to be effective at assessing deer densities and vegetation impact at the same time by surveying transects (Bennett et al., 2022), a characteristic that can provide relevant information rapidly and efficiently.

In this work, we use the aforementioned method by Bennett et al. (2022) to assess deer density and their impact in the Cardinia Shire, South-East of Melbourne, Victoria, Australia. Two species of deer are known to be present in the area: the sambar deer (*Rusa unicolor*) and the fallow deer (*Dama dama*), although red deer (*Cervus elaphus*) may also occasionally be present (West, 2018). We aim to evaluate the transect survey method as a viable option for the Cardinia Shire, as well as provide insights into the current vegetation impacts and deer densities.

Methods

Study area

The study area was the land surrounding the Cardinia Reservoir and the Cardinia Creek Parklands in the Cardinia Shire, east of Melbourne, Victoria, Australia. A total of 66 different transects were identified based on:

- their importance for local conservation values (in consultation with stakeholders).
- a desire for broad spatial coverage, including overlapping an area (footprint) of an aerial deer survey (see methods section).
- accessibility (some areas on private land or in exceedingly steep terrain were unavailable).

Therefore, transects were distributed across local natural reserves and water courses. Due to limitation of field activities during the COVID-19 pandemic and inaccessibility due to heavy rainfall events associated with a strong La Nina period, survey effort was limited to 32 transects (Table 1), two of which were repeated once for a total of 34 transects surveyed.

Field surveys

To estimate the impact of deer presence on vegetation, we used an established protocol that proved effective in similar locations (Bennett et al., 2022). For a detailed description of the survey protocol, refer to Bennett et al. (2022).

Briefly, the protocol estimates the deer density from the count of faecal pellets (Faecal Pellet Count, FPC) in a transect. At the same time, vegetation impact assessment is carried along the transects using the point-centred quadrant method (Cottam and Curtis, 1956). Vegetation impact was estimated using a five-point scale (Bennett et al., 2022; Moser and Greet, 2018)(Table 2).

Table 1 List of location surveyed and number of transects in each location.

Location	n transects (+repeated)
Beaconsfield Nature Conservation Reserve	5
Brennans Bushland Reserve	1
Cardinia Aquaduct Trail	2
Cardinia Creek - Guys Hill Reserve	4 (+1)
Cardinia Creek Parklands	6
Cardinia Reservoir Park	2
Dallas Brooks Scout Camp	3
EA Owens Reserve	1
Hamilton Reserve	2
RJ Chambers Flora & Fauna Reserve	3 (+1)
Toomuc Creek Reserve	1
Upper Beaconsfield Nature Conservation Reserve	2
Total	32 (+2)

Table 2: Scoring categories used for vegetation impact assessment. Adapted from Bennett et al. (2022) and Moser and Greet (2018)

Score	Description
0	No impact
1	Low impact: 1–25% foliage browsed
2	Low-moderate impact: 26–50% foliage browsed, stem breakage or rubbing damage
3	Moderate-high impact: 51–75% foliage browsed, multiple stem breakage or severe rubbing damage
4	High impact: 76–100% foliage browsed, main stem broken or extreme rubbing damage

Between the 9th of May 2022 and the 31st of July 2022, trained surveyors walked the 150m-long transects from start to end with the aid of global positioning system (GPS) devices. Every five metres along the transect, the total number of faecal pellets were counted in a circular plot of 1m of radius, for a total of 30 plots for each transect. We also collected FPC data for other common herbivores present in the area: wombats (*Vombatus ursinus*) and macropodid species (mainly swamp wallabies, *Wallabia bicolor*, and eastern grey kangaroos, *Macropus giganteus*).

Vegetation impact assessments were carried out along the transects at 10m intervals (15 plots per transect) in circular plots of radius 5m. The vegetation impact assessments recorded the closest plant to the centre of the plot for each quadrant of the plot. In other words, each plot would record the impact on four plants or less (in case one or more quadrants did not have any plant). For plants over 1m, scores were estimated both below and above the 1m height mark to account for the browsing operated by other herbivores (assumed to be low or null over 1m).

Data analysis

For each transect and for each herbivore group (deer, wombats, macropods), we calculated the Faecal Pellet Index (FPI), which is the density of faecal pellets per square meter (FPC/m^2)(Forsyth, 2005; Forsyth et al., 2007). Furthermore, for each transect, the overall Vegetation Impact Score (VIS) was calculated by averaging the assessed impact across all plots and across all species. The VIS was calculated separately for heights lower and higher than 1m. To quantify the relationship between FPI and VIS we fitted a linear model with VIS for plants <1m of height as response variable and the logarithm of FPI (logFPI) as predictor following the methodology established by Bennett et al. (2022).

Comparison with aerial survey

In September 2021 a deer count in Beaconsfield Conservation Nature Reserve (BCNR; Cardinia Shire, Victoria, Australia) was carried out using a Remotely Piloted Aircraft System (RPAS) by Field Master Systems Pty Ltd (unpublished data). At transect locations within the BCNR (5 transects, Table 1), we evaluated how the relative deer density computed by FPI method compared to the density estimates of deer observed by the aerial survey using Pearson correlation.

Results

Vegetation impact assessment

A total of 42 plant species were identified, of which 14 (33%) were present in a single location (Table A1, Appendix A). The species that appeared to be most browsed (relative to other plants within the same transect) were *Myrsine howittiana* (Mez) Jackes, *Pomaderris aspera* Sieber ex DC., and *Acacia melanoxylon* R.Br. (Figure 1). These and most other plant species were observed in less than 10 transects, so statistical inference is difficult, and results should be interpreted cautiously.

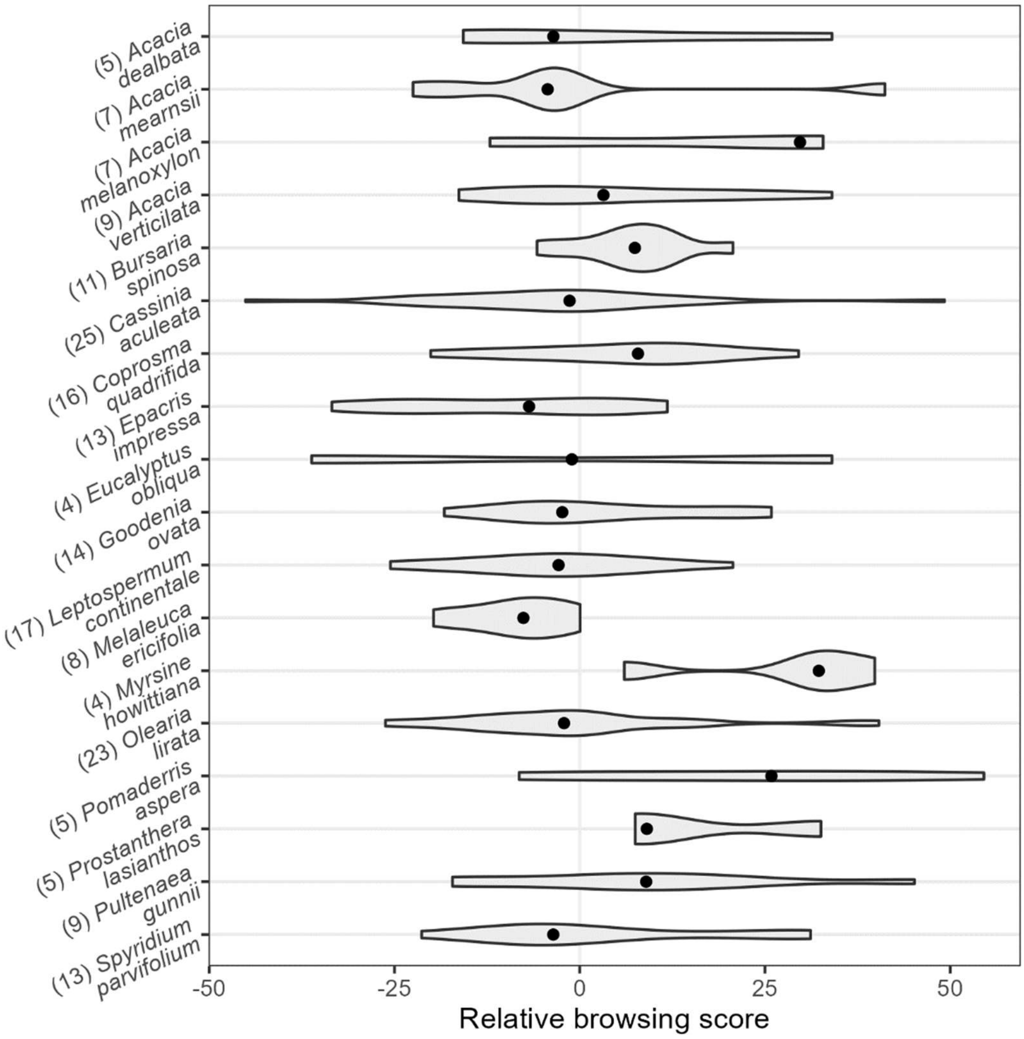

Figure 1: Violin plots of relative browsing score (mean of browsing score of a species in a transect – mean of browsing score of all plants in a transect (VIS)) for species that were present in more than 3 transects (the number in parentheses). Dots represent median values.

Relationship between FPI and VIS

Across the transects, the VIS for plants at heights <1m and the FPI showed similar geographic patterns, with higher values in the south-eastern side of the area investigated and lower values on the western sides (Figure 2). The VIS significantly increased with increases in logFPI (Table 3, Figure 3).

Comparison with aerial survey in BCNR

The RPAS aerial survey showed that, in September 2021, deer density was higher in the southern and eastern parts of BCNR, while the western parts of the park showed a lower density (Figure 4). The density estimates computed from the drone survey data at transect sites did not correlate significantly with the FPI (Figure 4).

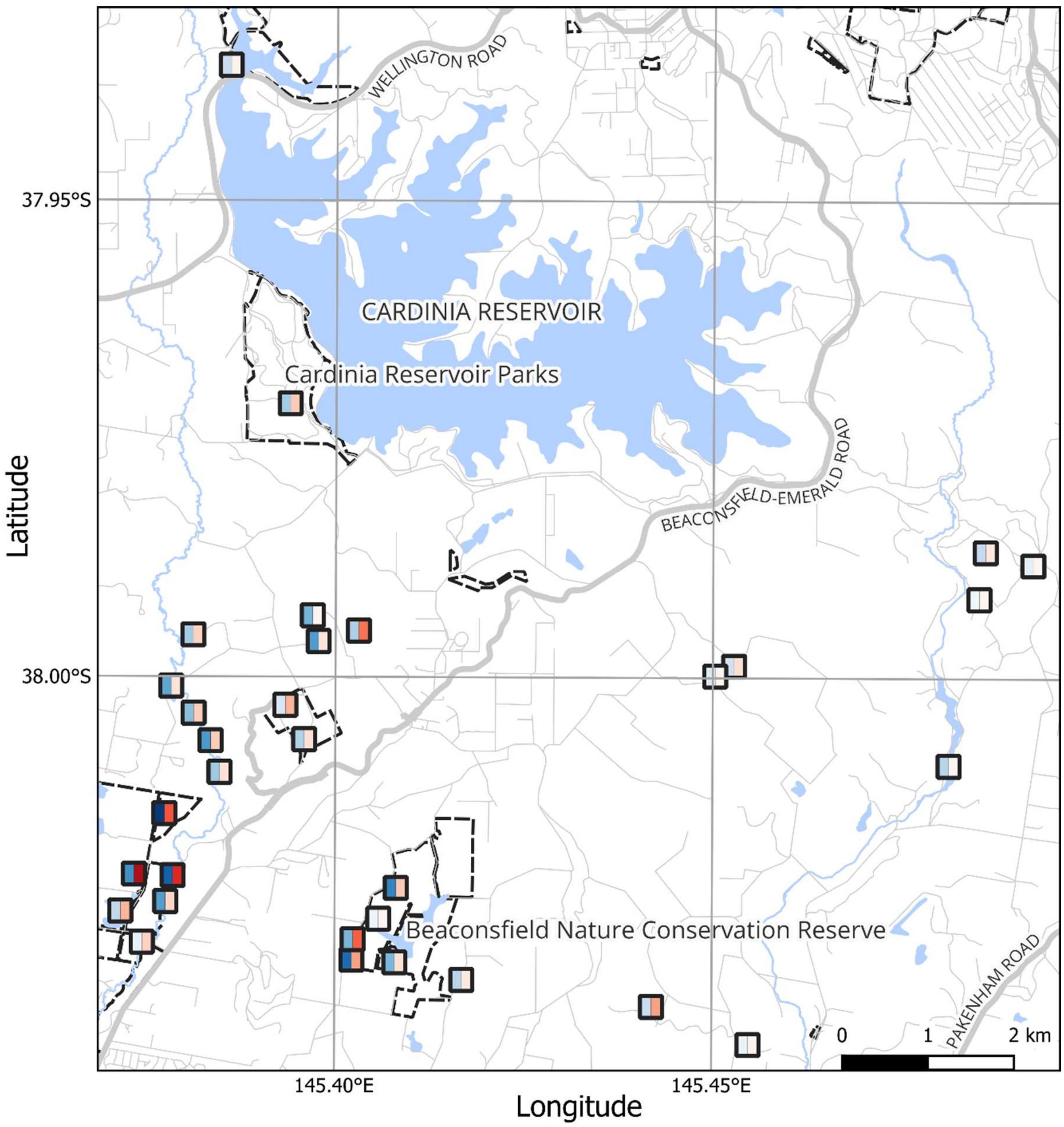

Figure 2: Map of the study area. Dashed lines delimitate parks. Water bodies are in light blue and roads are in grey. Each square symbol represents a transect. A higher intensity of the blue colour on the left half of each square represents a higher value of Vegetation Impact Score. A higher intensity of the red colour on the right half of each square represents a higher value of Faecal Pellet Index.

Table 3: Results of a linear regression of VIS on logFPI.

			CI			
	Estimate	SE	LL	UL	t value	p value
Intercept	11.3	3.4	4.5	18.2	3.37	0.002
logFPI	18.7	4.4	9.7	27.8	4.213	<0.001

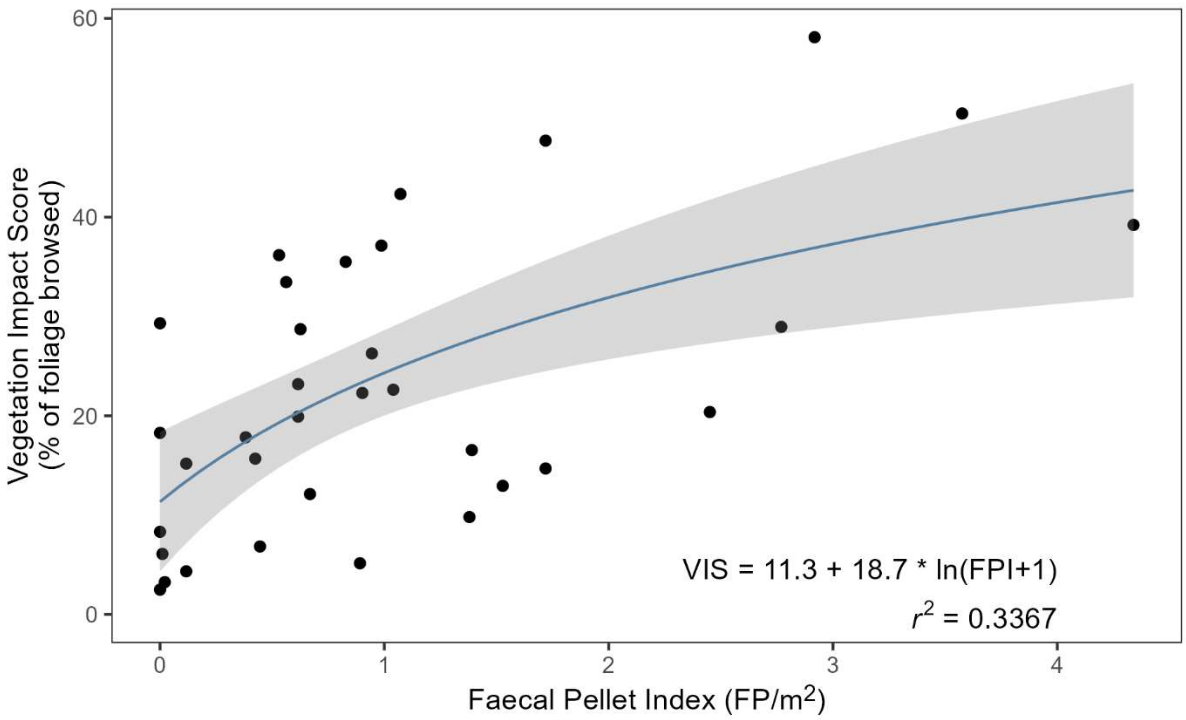

Figure 3: Scatterplot of Vegetation Impact Score (VIS) on Faecal Pellet Index (FPI). The line represents the fitted model (line equation in the bottom right corner). The shaded area represents the 95% confidence interval of the fitted line. FP = Faecal Pellets.

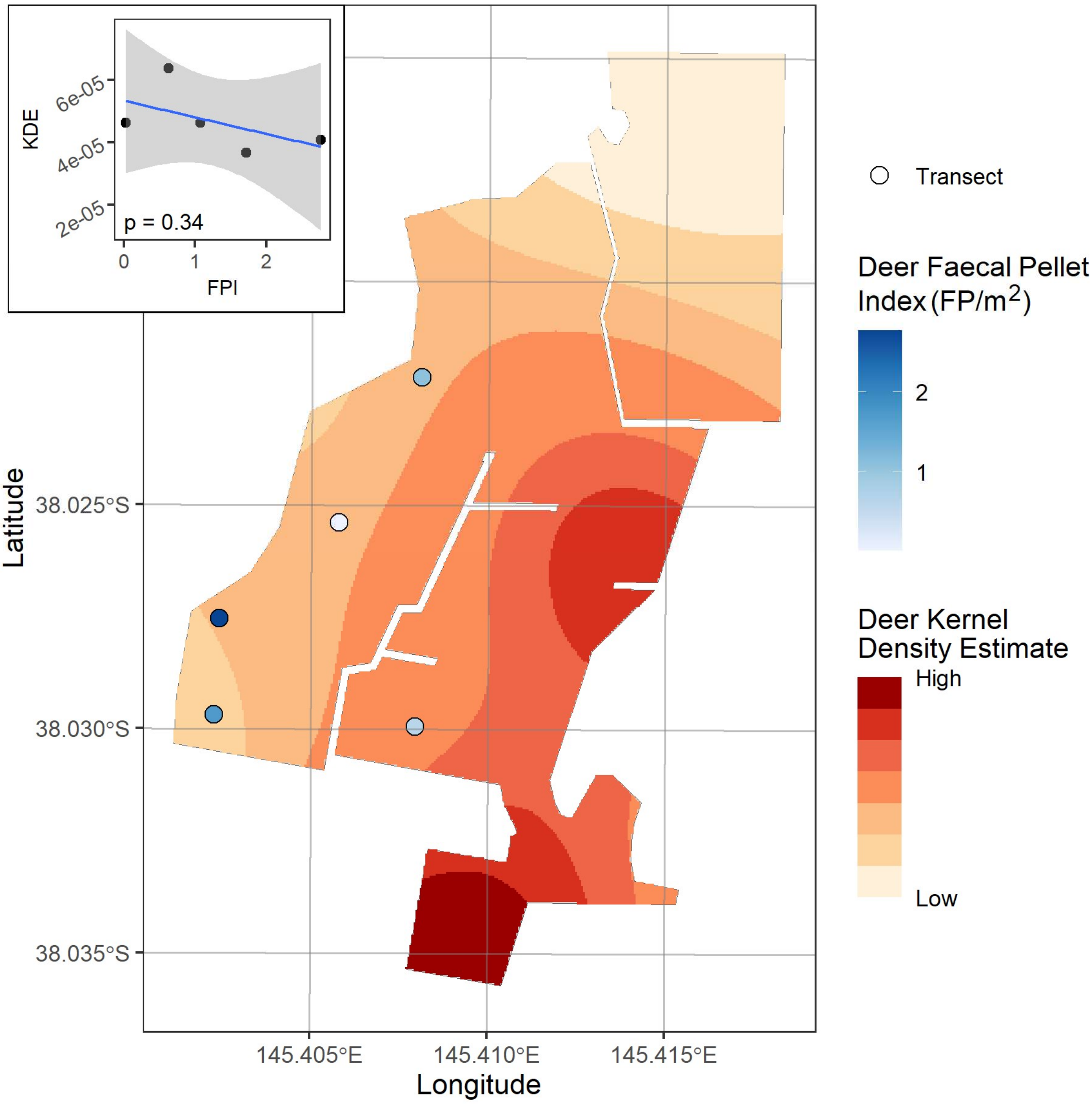

Figure 4: Map of Beaconsfield Conservation Nature Reserve showing the position of transects surveyed. Kernel Density Estimate was computed from the position of individual deer observed during aerial surveys carried out in September 2021 (Field Master Systems Pty Ltd, unpublished data). FP = Faecal Pellets. Top left inset: scatterplot of Kernel Density Estimate (KDE) on Faecal Pellet Index (FPI) with fitted least square line and p value. The shaded area represents the 95% confidence interval.

Discussion

In this work we have found a clear relationship between deer faecal pellet counts and the level of vegetation browsed in the Cardinia Shire. Our results confirm previous findings that carrying out transects can be a viable and economic method to assess deer density and vegetation impact at the same time (Bennett et al., 2022; Forsyth et al., 2007). Furthermore, our results suggest that the impact of deer on the vegetation surveyed greatly exceeds that of macropodid species and common wombats along the transects investigated.

Specifically, we found that deer density and vegetation impact were highest in the south-eastern side of the area investigated: the Cardinia creek parklands and the Beaconsfield Nature Conservation Reserve. These parks would likely benefit the most from deer population management and impact mitigation in the immediate future. Milder impact was recorded along the Cardinia creek and further north in the Cardinia reservoir park. Conversely, both deer density and vegetation impact were lower in the Eastern side of the area investigated, along the Toomuc creek.

Our results partially confirm the results of an earlier (3^{rd} – 4^{th} of July 2021) deer count survey that was carried out by helicopter transects using thermal imaging equipment in the same area (Cox, 2021). In fact, Cox (2021) found a higher density of deer in BCNR than the area surrounding the Cardinia Reservoir, a situation that was observed by our surveys by faecal pellet count. On the other hand, the results of Cox (2021) pool the western and eastern side of the Cardinia Creek Catchment (excluding BCNR and the Melbourne Water Catchment surrounding the Cardinia Reservoir). This general area showed an overall relatively lower density of deer compared to the other two locations (Cox, 2021). As mentioned above, our results suggest that the general area may also bear considerable differences between the western and eastern sides. Future work may further explore these differences using the methodology employed by Cox (2021) and by dividing the overall area into smaller sections to provide further information about deer density on the territory.

Comparing the FPI methodology with the drone survey data to estimate deer distribution and an index of abundance indicates that the two methodologies cannot be viewed similarly, but rather may offer complementary insights. Deer are known to alter their use of space throughout the day-night and during the year (e.g. Comte et al., 2022). As the two survey methods were conducted between 7 and 10 months apart from each other, it is likely that the poor correlation observed is in part a result of shifts in space use. In the future, conducting a drone survey around the same period as the transect survey may provide better insight as to how each survey technique may inform results of the other and an overall picture of deer distribution, abundance, and impacts on vegetation/habitats. Another possibility is that a correlation could not be detected as all five transects within the BCNR were located close to the western border of the park, where the RPAS survey detected a low and similar deer density. Extending the amount of transects to include the eastern and southern sides of the park, where deer were observed in higher density, might reveal different patterns and inference.

Our analysis suggests that deer may show a mild preference for some plants: *Myrsine howittiana* (Mez) Jackes (muttonwood), *Pomaderris aspera* Sieber ex DC. (hazel Pomaderris), and *Acacia melanoxylon* R.Br. (Australian blackwood). Such preference may translate to a more rapid growth of the deer population where these species are abundant. However, this result would need further investigation with larger sample sizes to be confirmed.

Conclusion

Our analysis confirms that ground-based transects are a valuable methodology for investigating deer presence and their impact on native vegetation across the Cardinia Shire. As this study was limited in its scope by the COVID-19 pandemic and persistent poor weather (heavy rain) impacting track accessibility, future work should aim at increasing the territory covered by surveying more transects to provide information of deer impact at a finer scale. Increasing the number of transects will also allow comparison with areas subject to deer control and impact mitigation management practices and unmanaged areas to better evaluate the effect of such practices. Lastly, future effort should focus on at least repeating the same transects to observe changes through time. As this work was carried out during the La Niña phase (cool phase) of the El Niño Southern Oscillation phenomenon, repetition during the upcoming El Niño phase (warm phase) would provide valuable information about deer use of space and impacts across the different climatic conditions that can occur in the area.

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Appendix A

Table A1: List of observed and identified plant species.

Species	Number of plants observed	Number of sites
Acacia dealbata Link	21	5
Acacia genistifolia Link	2	2
Acacia mearnsii De Wild.	37	7
Acacia melanoxylon R.Br.	25	7
Acacia myrtifolia (Sm.) Willd.	6	1
Acacia paradoxa DC.	12	3
Acacia stricta (Andrews) Willd.	4	2
Acacia verticilata (L'Hér.) Willd.	17	9
Bursaria spinosa Cav.	84	11
Cassinia aculeata (Labill.) R.Br.	164	25
Cassinia longifolia R.Br.	5	2
Coprosma quadrifida (Labill.) B.L.Rob.	100	16
Dicksonia antarctica Labill.	2	1
Epacris impressa Labill.	72	13
Eucalyptus leucoxylon F.Muell.	2	1
Eucalyptus macrorhyncha F.Muell. ex Benth.	1	1
Eucalyptus obliqua L'Hér.	5	4
Eucalyptus polyanthemos Schauer	4	1
Eucalyptus radiata Sieber ex DC.	20	3
Eucalyptus viminalis Labill.	1	1
Goodenia ovata Sm.	46	14
Hakea decurrens R.Br.	8	1
Hakea nodosa R.Br.	1	1
Indigofera australis Willd.	2	1
Kunzea leptospermoides F.Muell. ex Miq.	6	3
Leptospermum continentale Joy Thomps.	102	17
Lomatia fraseri R.Br.	1	1
Melaleuca ericifolia Sm.	144	8
Melaleuca squarrosa Donn ex Sm.	18	2
Myrsine howittiana (Mez) Jackes	19	4
Olearia argophylla (Labill.) F.Muell. ex Benth.	2	2
Olearia lirata (Sims) Hutch.	213	23
Pimelea flava R.Br.	12	1
Pimelea humilis R.Br.	1	1
Pittosporum bicolor Hook.	29	3
Polyscias sambucifolia (Sieber ex DC.) Harms	5	2
Pomaderris aspera Sieber ex DC.	16	5
Prostanthera lasianthos Labill.	22	5
Pultenaea gunnii Benth.	105	9
Pultenaea scabra R.Br.	1	1
Spyridium parvifolium (Hook.) F.Muell.	58	13
Tetratheca ciliata Lindl.	1	1

Appendix B

To evaluate the impact of other herbivores, two more models were fitted and compared: a model including the logFPI of wombats and macropods as covariates, and a model using the VIS for height >1m as response variable in place of the VIS for height <1m.

Table B1: Results of linear regressions of VIS on logFPI for heights over 1m and for heights lower than 1m including macropods and wombats logFPI as covariates..

			CI			
	Estimate	SE	LL	UL	t value	p value
VIS over 1m						
Intercept	8.1	3.7	0.6	15.5	2.214	0.034
logFPI	18.5	4.9	8.5	28.4	3.781	0.001
VIS with covariate						
Intercept	11	3.5	3.8	18.2	3.126	0.004
logFPI (deer)	17.5	5.3	6.6	28.4	3.282	0.003
logFPI (macropods)	-0.6	7.3	-15.6	14.3	-0.085	0.933
logFPI (wombats)	13.1	15.4	-18.3	44.5	0.85	0.402