MONITORING IMPACTS OF SAMBAR DEER (*Rusa unicolour*) ON FORESTS IN THE COTTER CATCHMENT, ACT

MONITORING DESIGN AND INITIAL FINDINGS

JOSH MULVANEY, JULIAN SEDDON
AND OLIVER ORGILL

Conservation Research
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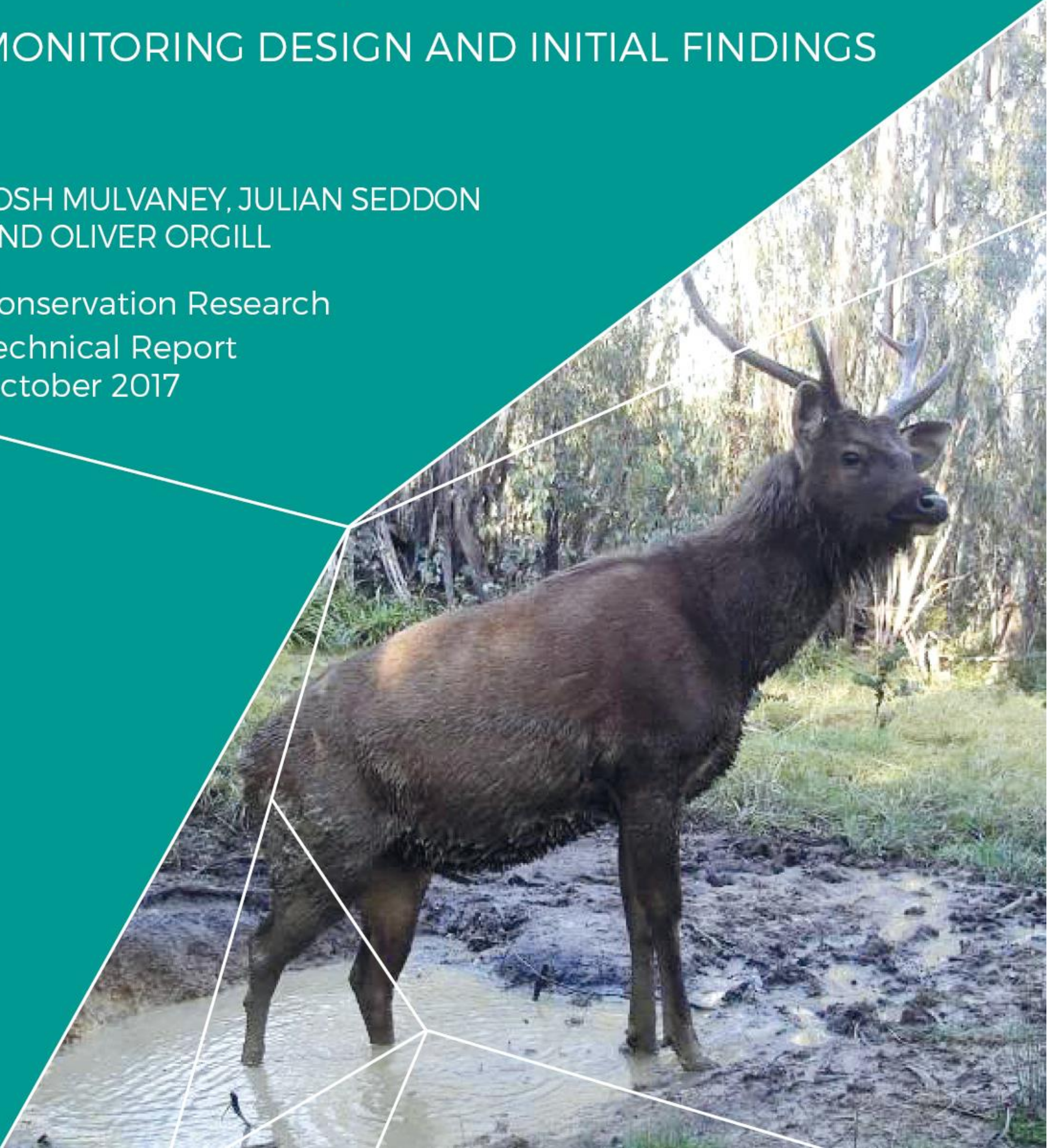

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Front cover

Sambar (*Rusa unicolour*) impact ecosystems through browsing native plants and creating wallows such as this example in montane forest and woodland with the Australian Alps.
(Source: http://photobucket.com/gallery/http://s43.photobucket.com/user/honemccall/media/DSC01687-3.jpg.html)

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Summary

Sambar (*Rusa unicolor*) is a large exotic deer species that has spread throughout much of south-eastern Australian. Sambar are a declared pest animal in the ACT, where they have become established across a range of land tenures. Sambar are known to cause adverse impacts on ecosystems including changing forest composition and structure through selective browsing and impacting alpine ecosystems, including alpine bogs, through wallowing behaviour.

In the ACT the number of sightings of Sambar has increased over the past 10 years. The majority of sightings have occurred in the Cotter Catchment within Namadgi National Park. To assess the ecological risk posed by Sambar and respond accordingly, the ACT Government requires information on when and where deer numbers are reaching unacceptable levels. This study aimed to monitor the impacts of an emerging population of Sambar on vegetation structure and composition in the Cotter Catchment by establishing a set of long-term monitoring sites. The resulting data will inform management decisions within the catchment.

We established nine partial-exclusion plots and paired open plots in tall wet forest in the upper Cotter River catchment in Namadgi National Park, ACT. In spring and summer of 2014/15 and again in spring and summer of 2015/16 each site was surveyed for forest structure and composition using quantitative plot and transect based methods. Evidence of Sambar browsing was recorded and Sambar abundance was estimated using faecal pellet transects. Data from these initial two years of surveys were analysed and are reported here to provide a baseline from which to assess changes in Sambar abundance and associated impacts.

Results suggest there has been little impact from Sambar on vegetation structure or composition at this stage. Vegetation structure was similar in open versus partial-exclosure plots and remained relatively constant from the first to the second year of sampling. There was some variation in the total woody plant species richness of each site between years but no clear trends towards higher or lower richness between open plots and partial-exclusion plots. Similarly, there was no difference between open and partial-exclusion plots within each year for cover of grasses, forbs, low shrubs or bare ground.

Pellet counts indicated sites in the upper reaches of the Cotter River south of Corin Dam have highest Sambar abundance, however there was no change in the number of Sambar pellets surrounding the plots between 2014/15 and 2015/16. This suggests Sambar abundance did not change significantly over the initial year between sampling periods.

While there was no significant difference in browsing between open and partial-exclusion plots within each year, there was an increase in overall signs of vegetation damage from 2014/15 and 2015/16. This was the case for both open and partial-exclusion plots, suggesting damage was caused by the survey methodology itself.

We make the following recommendations:

1. Continue the project as a long-term monitoring program using the same protocol that has been described in this report.

2. Undertake surveys at all sites once every three to five years, leaving sufficient time for vegetation to recover from damage caused by sampling.

3. Undertake routine maintenance checks on the partial-exclusion plots to ensure they retain their integrity.

4. Assess relative deer abundance at the landscape scale in conjunction with the local estimates at each site according to the protocol set out by Forsyth (2005).

5. When monitoring for ecological impacts of Sambar, include surveillance of highly sensitive ecosystems, particularly in and around alpine bogs.

1. Introduction

1.1 Background

Six species of deer have become naturalised in Australia: Fallow Deer (*Dama dama*), Red Deer (*Cervus elephus*), Sambar (*Rusa unicolor*), Chital Deer (*Axis axis*), Rusa Deer (*Rusa timorensis*) and Hog Deer (*Axis porcinus*) (Moriarty, 2004). These species became naturalised as a result of deliberate releases by acclimatisation societies, escapes from deer farms and translocations for hunting purposes (Bentley 1998) and have subsequently dispersed into new parts of the country. Three of the six species are known to occur in the ACT: Fallow Deer, Red Deer and Sambar. The populations in the ACT have established more recently due to farm escapes, translocations and dispersal from other states (Moriarty 2004).

Since 2006 the ACT Parks and Conservation Service has been recording incidental deer sightings in the ACT Deer Sightings Register. While irregular spot-sightings cannot provide accurate assessments of population size, they can indicate changes in populations over time. A 2013 report (Umwelt 2013) showed that while density is still relatively low, deer are widespread across the ACT. The number of sightings of all three species has increased over the past 10 years, Sambar sightings in particular. The majority of these sightings have occurred in the Cotter Catchment within Namadgi National Park.

Sambar were introduced into Australia in the 1860s in Victoria and have since expanded their range throughout much of eastern Victoria, south-east NSW and the ACT. Recent reports from other alpine National Parks in NSW and Victoria indicate that Sambar are in very high densities in some areas and, although largely unquantified across much of their current range, appear to be having significant environmental impact in some areas (Forsyth et al. 2009). Because of their potential to cause harmful impacts to the environment Sambar are a declared pest animal in the ACT under the *Pest Plants and Animals Act 2005.*

Sambar are a large deer species, with mature females weighing 130–150 kilograms (kg) and males up to 200–250 kg. Sambar are browser/grazers and selective browsing may impact on the abundance and distribution of some plant species and thereby alter species composition within forest communities with flow-on impacts to a range of biota. Other behaviour such as tracking, trampling, wallowing and antler rubbing may also impact on vegetation and habitat condition.

Sambar have several traits that make them a particular concern for the conservation of biodiversity and maintenance of water quality in the Cotter Catchment. There is a high likelihood the Sambar population will increase to a high density within the catchment. Sambar have been recorded at very high densities within similar habitats in Victoria (Forsyth et al. 2009) where they have established. Furthermore, based on observation in surrounding areas, Sambar pose a high risk of adverse impact on ecosystems within the Cotter Catchment; have a history of causing adverse impacts in nearby areas; are generalist feeders; have the potential to destroy or modify vegetation and impact on sensitive ecosystems such as alpine bogs; and occur in high value conservation areas (see Bomford 2008).

At high densities, deer populations can have several negative impacts on vegetation structure and composition (Cote et al. 2004). Through their role as herbivores, deer can cause direct mortality of plants, particularly at seedling stage (Crawley 1983), but can also affect recruitment by preventing plants from reaching maturity (Zamora et al. 2001; Keith and Pellow 2005). Selective browsing of preferred species can alter competitive hierarchies among communities (Bowers 1993) and can change patterns of relative abundance of a number of species (Kirby 2001). This is particularly problematic when preferred species are rare or threatened (Keith and Pellow 2005). In addition to the effects of herbivory, deer can cause localised erosion and water quality issues through the creation of wallows and faecal pellet contamination. While usually only localised, these impacts can be a cause for concern when they occur in sensitive systems such as bogs and peatlands. Through these modes of action, the introduction of deer into new areas can result in changes to vegetation structure and composition that can have flow-on effects for other fauna species including birds (Gill and Fuller 2007), small mammals (Flowerdew and Ellwood 2001) and invertebrates (Allombert et al. 2005).

While many of the impacts of deer on ecosystems are only apparent at high densities, particularly sensitive habitats such as alpine bogs may be impacted at lower deer abundance. The term 'overabundance' is used to describe populations at such high density that they negatively impact populations of other species (Caughley 1981). The dispersed nature of Sambar populations in forested habitats and their cryptic behaviour suggest that their eradication in the ACT is unlikely using control measures presently available. Consequently, the aim for management is to keep Sambar populations below densities that cause widespread damage and to mitigate against damage to highly sensitive ecosystems. The challenge for land management agencies is in knowing when and where deer numbers are overabundant and in developing effective mitigation actions to protect identified sensitive ecological assets.

The most commonly used method of assessing the impacts of deer on vegetation is through the use of herbivore exclusion plots (Leopold 1933; Hester et al. 2000; Opperman and Merenlender 2000). Bennett and Coulson (2008) described a method for constructing partial-exclusion plots that allow Australian native herbivores into fenced areas while excluding larger Sambar. Their design has been used successfully in Victoria to assess the impacts of Sambar on the structure and composition of forest understoreys (Bennett 2008). Given its success elsewhere in Australia, we selected this method to be applied in the ACT to monitor the impacts of Sambar as their population continues to grow in the Cotter Catchment. Long-term monitoring of these plots will enable detection of changes to native vegetation related to changes in deer abundance; this information can be used to determine the nature of Sambar impacts on montane forests and highlight when these impacts are accelerating.

1.2 Aims and objectives

The aim of this study was to monitor the impacts of an emerging population of Sambar on vegetation structure and composition in the Cotter Catchment. In particular, the aim was to establish a set of permanent herbivore partial-exclusion plots throughout the catchment for a long-term study. Data from this study will provide information on the impacts of Sambar and inform management decisions within the catchment. Specifically, the objectives were the following:

- Identify and establish long term paired 'open' and 'exclusion' plots at locations within vegetation in the Cotter Catchment likely to be impacted by Sambar.
- Design a method for long term vegetation monitoring at these paired plots and to establish a database for storing the monitoring data.
- Conduct preliminary surveys over two years to establish baseline data on the rates of change to vegetation and of deer abundance.
- Provide recommendations about best practice for future monitoring of these sites.

2. Study area and site selection

This study was established in the upper reaches of the Cotter River. This section of the Cotter River lies entirely within Namadgi National Park (NP) and follows the western edge of the ACT. The Cotter Catchment, which extends beyond Namadgi NP in its lower reaches and is the primary water supply catchment for Canberra, contains a series of three dams: Corin, Bendora and Cotter. Dominant plant communities in the Cotter Catchment include: sub-alpine woodlands and montane wet forests, which occupy the steep ranges; rocky heaths and sub-alpine herbfields, which grow on the higher western and southern ranges; and montane grassland communities, which occur in the valleys in the eastern parts of the park (Territory and Municipal Services 2010).

A 2013 report highlighted the increasing number of Sambar sightings in the Cotter Catchment (**Map 1**; Umwelt 2013). A majority of these sightings occurred in Namadgi NP and anecdotal evidence from Parks and Conservation Service staff suggested that Sambar populations were growing within the park, particularly along the Cotter River corridor.

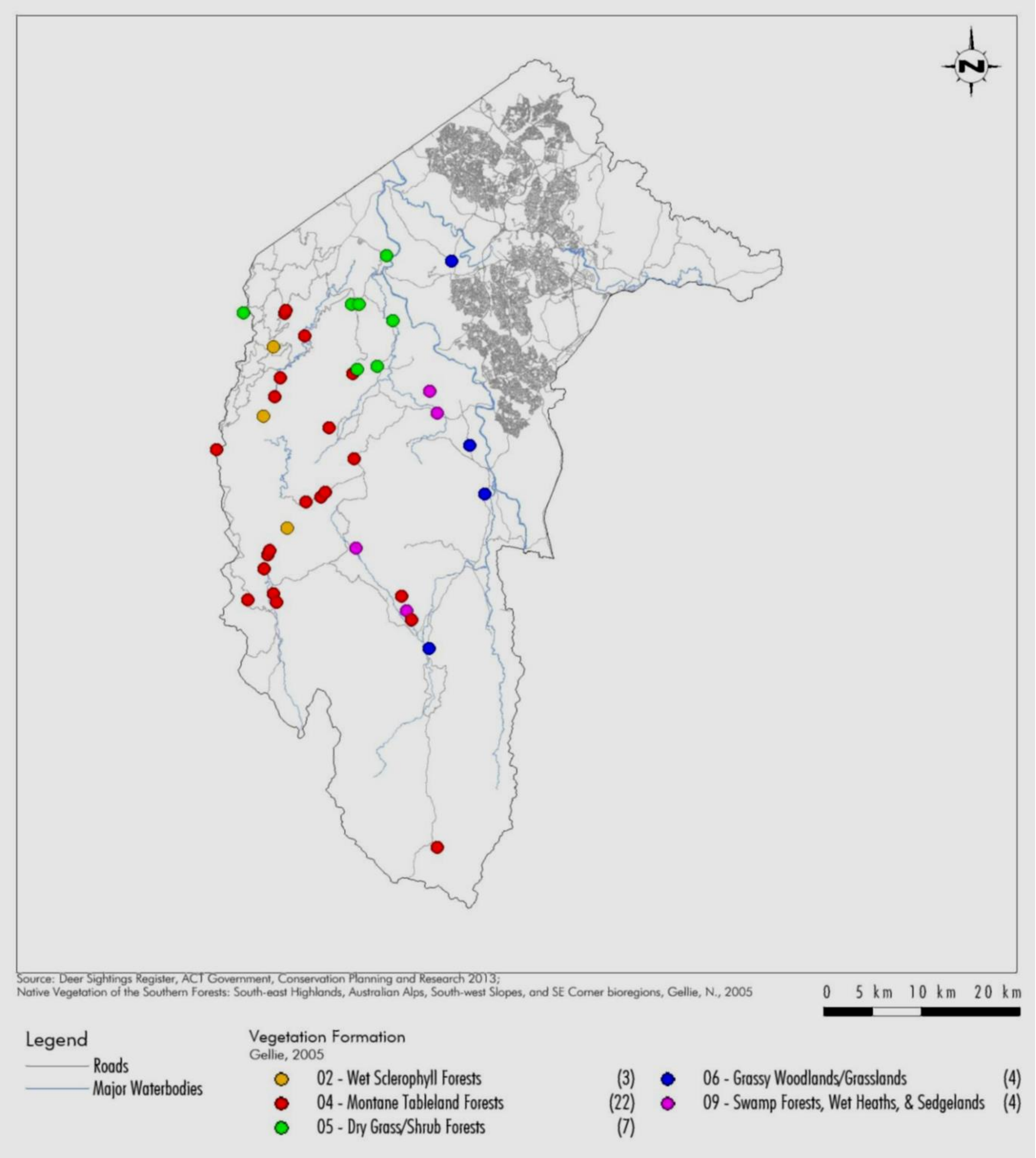
To maximise the chance of detecting impacts related to increasing Sambar populations, long-term monitoring plots were positioned in parts of the landscape likely to support the highest deer densities. A previous study undertaken in Victoria had shown that Sambar preferentially browse particular plant species that are not uniformly common across the landscape (Forsyth and Davis 2011). A number of the plant species preferred as feed in the Victorian study also occur in the ACT (Table 1). Areas of the Cotter Catchment and Namadgi NP supporting these preferred plant species were targeted for placement of monitoring plots. In particular, east-facing moist gullies supporting *Eucalyptus fastigata* or *E. dalrymplyana* and lower altitude western aspects supporting *E. radiata* were selected.

Table 1. Percentage contribution of selected plant species found in Namadgi National Park in the rumen contents of 102 Sambar harvested in Victoria 2007–2009, estimated by macroscopic and microhistological techniques (modified from Forsyth and Davis 2011).

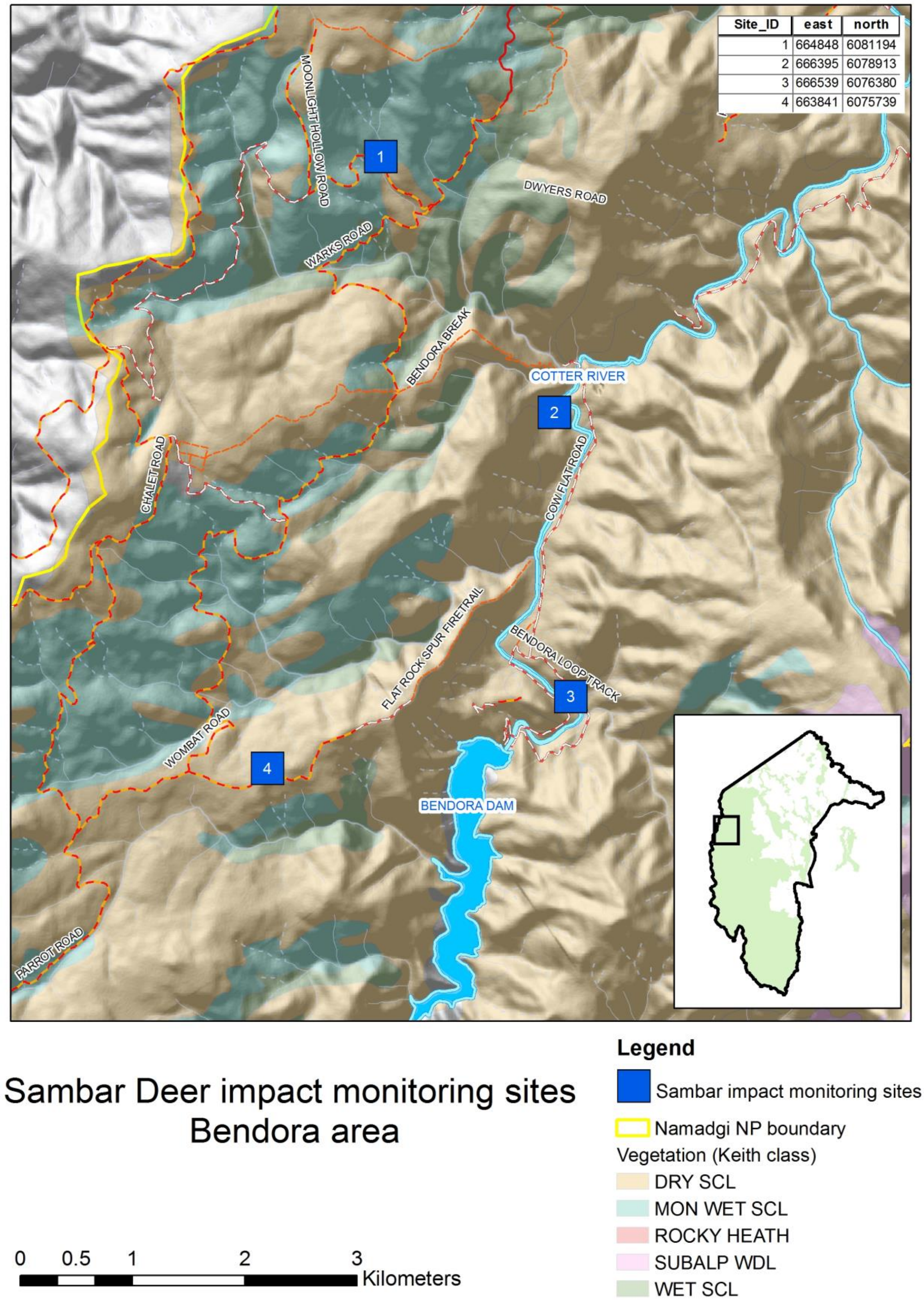
Functional Group	Species	Common name	Frequency of occurrence (% of deer)	
			Macroscopic	Microhistological
Grass	*Poa* spp.	Snowgrasses	88.0	82.4
Fern	*Pteridium esculentum*	Austral Bracken	53.0	52.0
Shrub or tree	*Acacia melanoxylon*	Blackwood	22.0	30.4
	Coprosma quadrifida	Prickly Currant-bush	18.0	2.0
	Coprosma hirtella	Rough Coprosma	6.9	17.6
	Dilwynia philicoides	Small-leaf Parrot-pea	2.9	39.2
	Pomaderris aspera	Hazel Pomaderris	6.9	66.7
	Pultenea juniperina	Prickly Bush-pea	25.0	43.1

The plots covered a broad geographic area, and were clustered around Bendora Dam in the north and Corin Dam in the south (Maps 2**Error! Reference source not found.**). Sixteen paired partial-exclusion and open uadrats were established in winter 2014 (at eight locations). In 2015 a new site was established in the Corin area (Deer 09) after increased sightings of deer and deer traces in an area adjacent to the Cotter River that was burnt at high severity during an escaped prescribed burn conducted in autumn 2015.

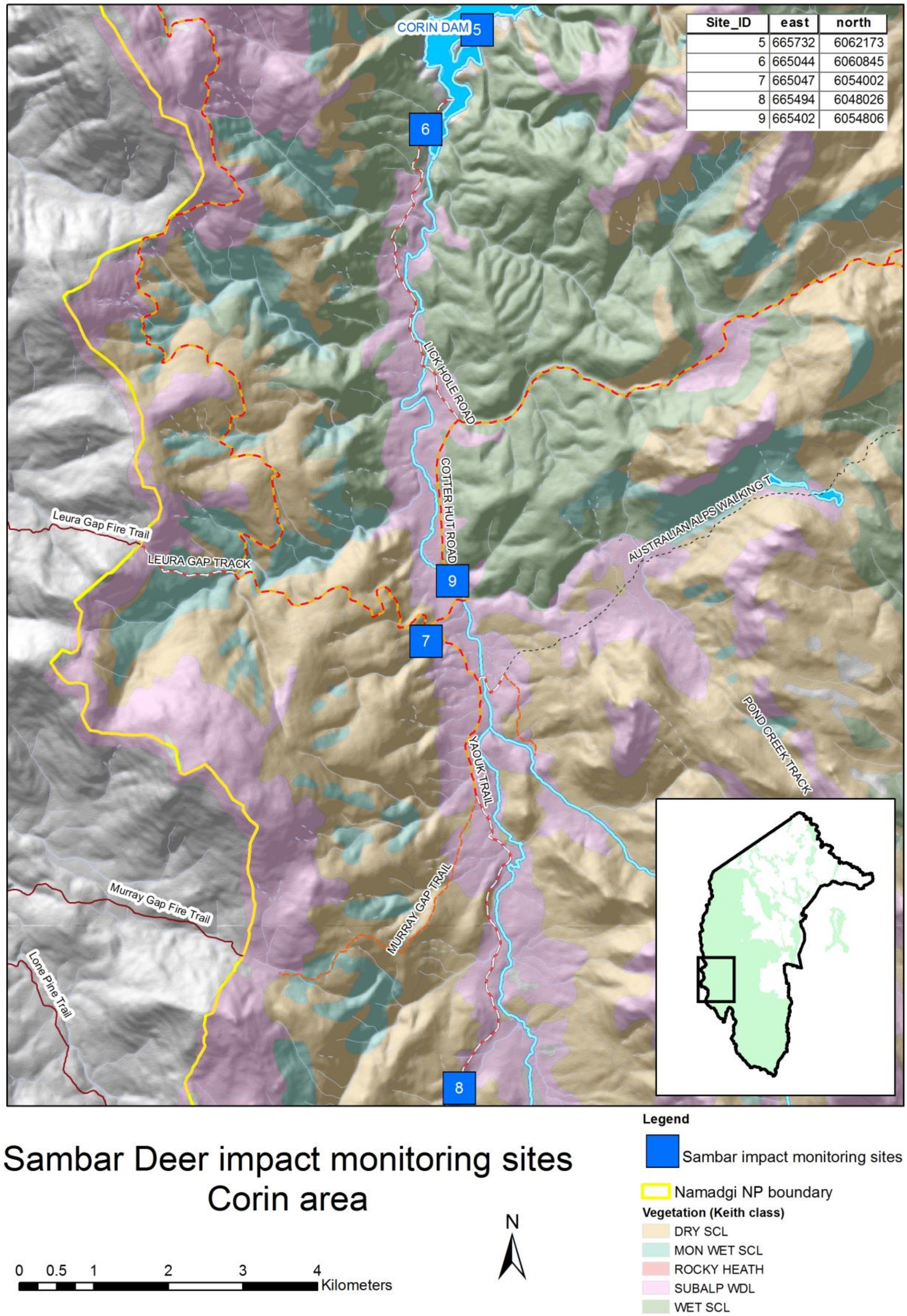
Map 1. Sambar sightings by vegetation formation 2006–2013. Data from the *ACT Deer Sightings Register* (Source: Uwelt 2013).



Map 2. Location of Sambar impact monitoring sites in the Bendora area of Namadgi National Park, ACT. Each site consists of a one open plot and one partial exclusion plot.



Map 3. Location of Sambar impact monitoring sites in the Corin area of Namadgi National Park, ACT. Each site consists of a one open plot and one partial exclusion plot.

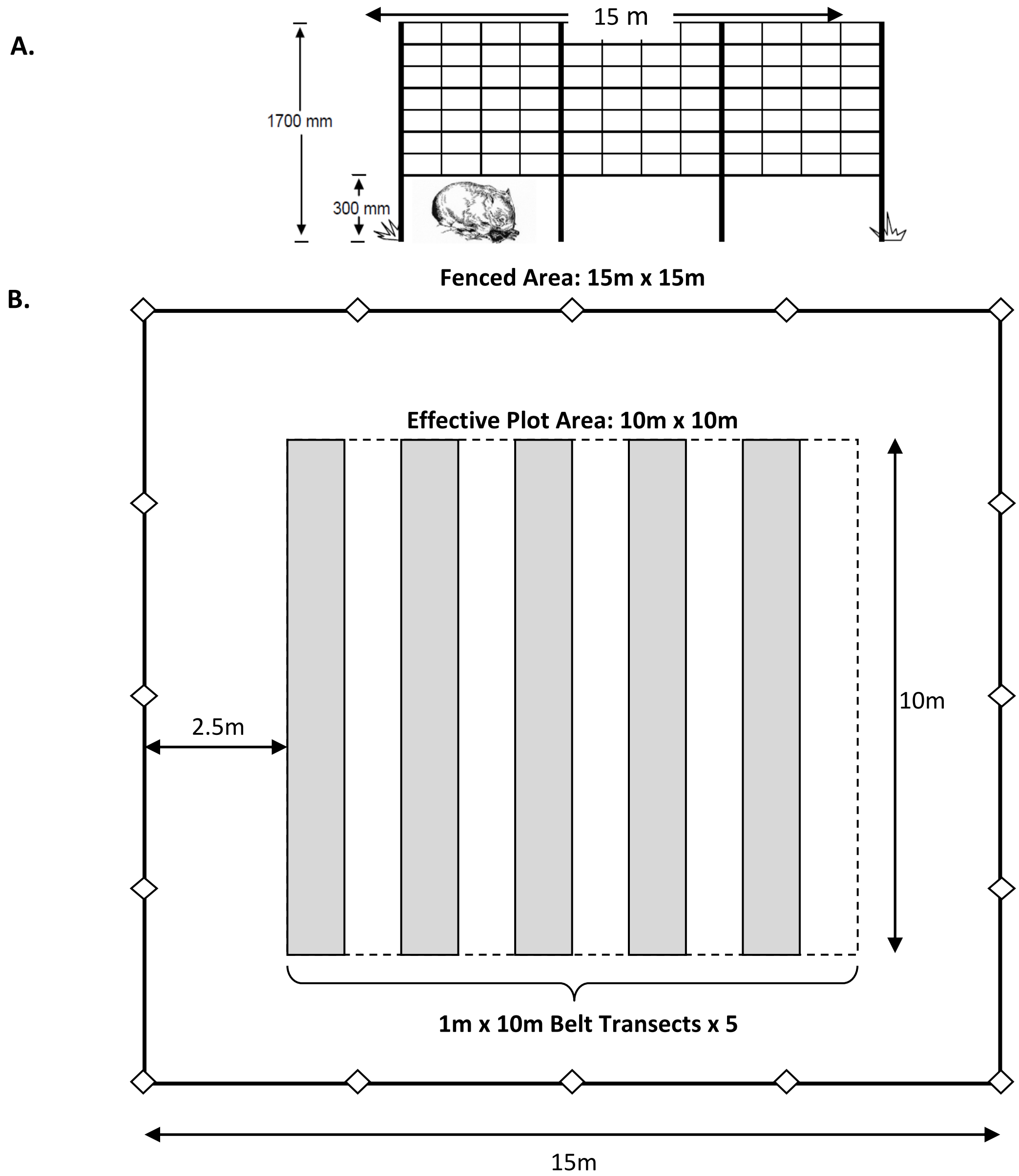


3 Plot design and survey methods

3.1 Plot layout

The partial-exclusion plots were fenced with sheep-yard welded mesh and measured 15 x 15 x 1.8 m with a 0.3 m gap at the base. Partial-exclusion plots are designed to exclude very large Sambar but allow access by native forest dwelling herbivores such as Common Wombats, Red-necked Wallabies and Swamp Wallabies through the 0.3 m gap under the weldmesh (see Bennett 2008 and Bennett and Coulson 2008). A paired open (control) plot was set up 10 to 20 metres away from the partial-exclusion plot, with only the corners of the plot marked with star pickets. Plot layout is shown in **Figure 1**.

Figure 1. Impact monitoring plot layout. A) Side view of partial exclusion plot showing gap for native browsers. B) Aerial view of partial exclusion plot showing fenced area (15 x 15 m), effective plot area (10 x 10 m) and the five belt transects (1 x 10 m shown in grey).



3.2 Impact assessments

In spring and summer 2014/15 (November to January) the vegetation structure and composition at deer sites one to eight were assessed and evidence of Sambar impact and other Sambar signs recorded (see below). The surveys were repeated 12 months later in spring and summer of 2015/16 (November to January) to collect a second year of data. The additional site (Deer09) was surveyed in December 2015.

Our survey method was designed to detect changes in plant community structure and composition; however, given the abundance of grass and forb species is likely to vary with season and rainfall, we focused primarily on woody perennial species, which have been demonstrated to constitute a large proportion of the Sambar diet (**Table 1**; Forsyth and Davis 2011).

At all open and partial-exclusion plots five 1 x 10 m belt transects were undertaken (Figure 1B). For each woody perennial species within a transect the number of stems in each height class and life stage was recorded. The height classes were defined as: <0.25 m, 0.25–1 m, 1–3 m, 3–6 m, 6–12 m, >12 m. The life stages were defined as: vegetative, budding, flowering, fruiting/seeding and indeterminate. Browsing impacts were also recorded for each stem (in accordance with Bennett 2008), and these were classed as: young foliage and shoots consumed; young and old foliage and shoots consumed; bark stripped; inflorescences damaged or consumed; or none.

Groundcover assessments were also made at one metre intervals along each belt transect. These were classified as the presence/absence of: grass, shrub (<0.5 m tall), forb, fern, sedge/rush, exotic, cryptogam, bare ground, rock or litter at each point.

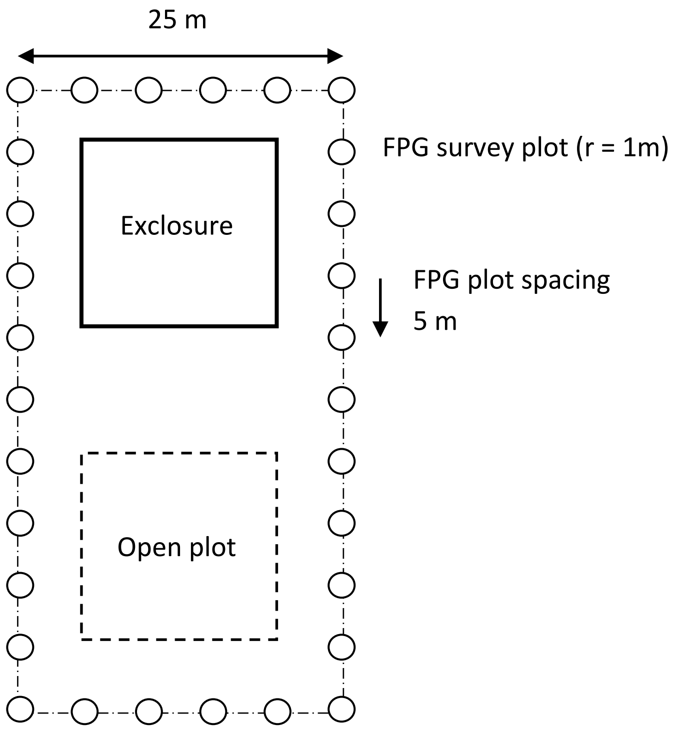
While total vascular plant species richness was assessed across the 10 x 10 m effective plot area in spring–summer 2014/15 this was not repeated in the second year due to time constraints. The total number of vascular plant species in each growth form was counted for: trees, shrubs, ferns, xanthorrhoea, tussock grasses, non-tussock grasses, sedges/rushes, forbs, creepers/vines, woody exotics and non-woody exotics. The three dominant species by cover in each of the overstorey, mid-storey and understorey were also recorded.

3.3 Sambar relative abundance estimates

Faecal pellet group transects have been used widely throughout Australia and New Zealand to assess relative abundance of Sambar Deer (Bennett 2008; Forsyth et al 2009). While it is difficult to derive absolute deer abundances from faecal pellet group transects, the number of faecal pellet groups in the landscape is correlated with deer abundance (Forsyth et al 2009) and, as such, monitoring changes in the number of faecal pellet groups at a site over time provides a relative measure of changes in deer abundance.

To assess the relative abundance of Sambar at each monitoring site, faecal pellet group transect surveys were undertaken around the perimeter of each site in a manner similar to that described by Bennett (2008). One faecal pellet group survey was conducted along a rectangular transect around each pair of partial-exclusion and open plots (**Figure 2**). The total transect distance was 150 m. These surveys used a plot radius of 1 m and were conducted every 5 m along the transect. Scats within the transect were identified for all species, including native fauna. In each plot, the number of Sambar faecal pellet groups, as well as the number of pellets within each group, was recorded.

Figure 2. Plan view of a faecal pellet group transect survey.



Wildlife cameras were trialled at each open plot to capture still images of large fauna using the site. The cameras were not baited and were left in place for approximately one month after the first round of monitoring took place in the summer of 2014/15. Issues of camera placement and density of vegetation led to unreliable results and the cameras were removed after several months. Cameras should be considered for future surveys at the Sambar impact monitoring sites, but we first recommend a review of literature and a pilot investigation to establish optimal methods.

3.4 Data analysis

The aim for the first two years of this study was to gather baseline data in order to assess the pre-impact structure and composition of vegetation in the parts of the upper Cotter Catchment most likely to be affected by Sambar. We undertook exploratory statistics to determine the rate of change in relative deer abundance and any impacts associated with their abundance. Given the baseline nature of data collected to date, no formal statistical tests were undertaken at this stage; however, the data collected here stands as valuable pre-impact baseline for statistical tests in the future.

4 Results

4.1 Vegetation structure

We assessed vegetation structure in terms of the number of woody perennial stems split across six height classes. Site Deer09 was not included in our exploratory analyses of vegetation structure because it was not surveyed in 2014/15. **Figure** shows the mean number of stems per plot for each treatment over the two years. The mean number of woody perennial stems across all sites (excluding site Deer09) was around 250. The mean across exclosure plots was slightly higher in 2015 largely due to a high number of stems at site Deer06 (total stem count in 2015 was 795, but only 436 in 2016). This difference may be the result of secondary thinning after a period of dense regeneration following a bushfire in 2003, or may be caused by differences between observers across the two years.

The distribution of stems across height classes remained relatively stable between 2015 and 2016 (**Figure**). However the high number of stems 1–3 m tall in the exclosure at site Deer06 again resulted in a much higher mean and variation in that class compared to the other treatment/year classes. Across all treatments the mean number of woody perennial stems was around 50 for short plants, around 100 stems per plot for medium plants, and less than 10 stems per plot for large and very large plants (Figure 4) reflecting the shrubby nature of the wet forest communities in which sites Deer01 to Deer08 were located 12 years after the 2003 Canberra wildfires.

Figure 3. Mean total number of woody perennial stems per plot by year. Site 09 is not included because it was not surveyed in 2015. Error bars represent one standard error.

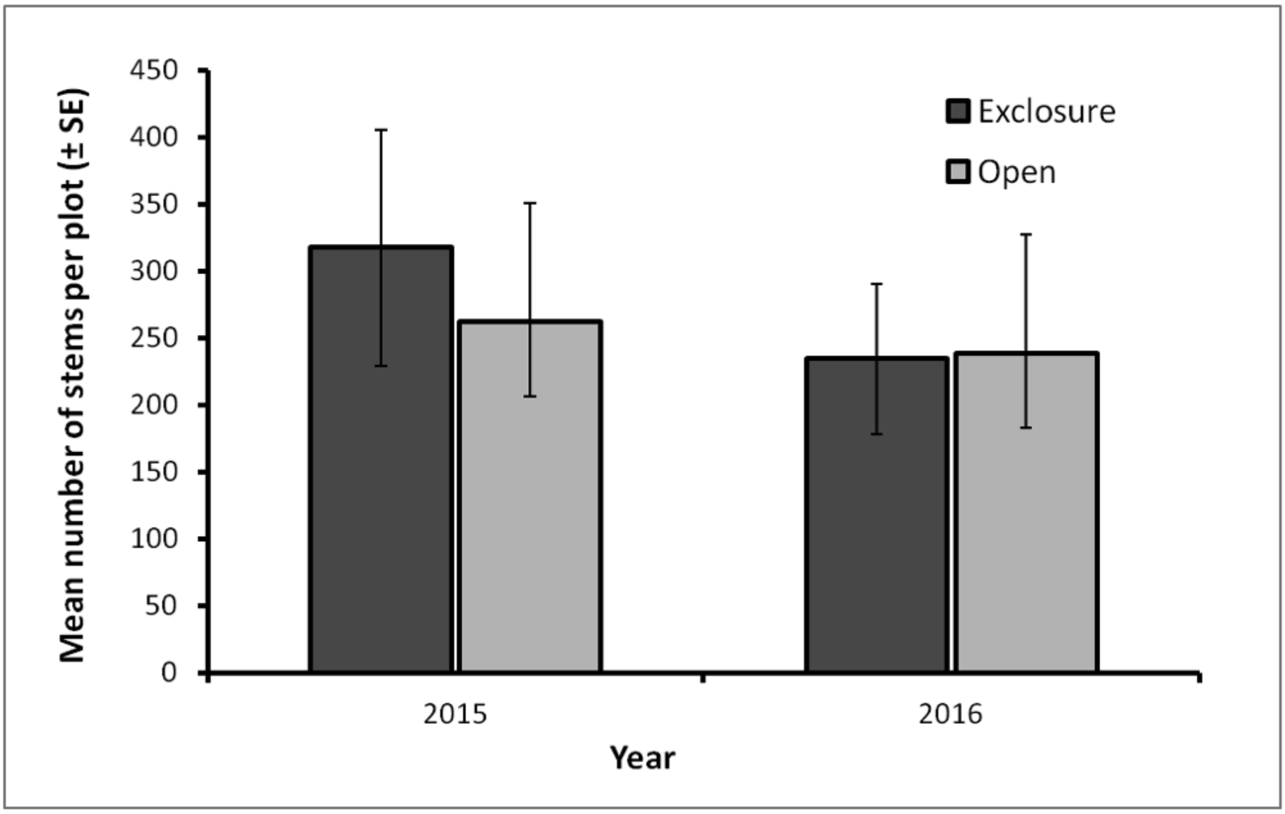
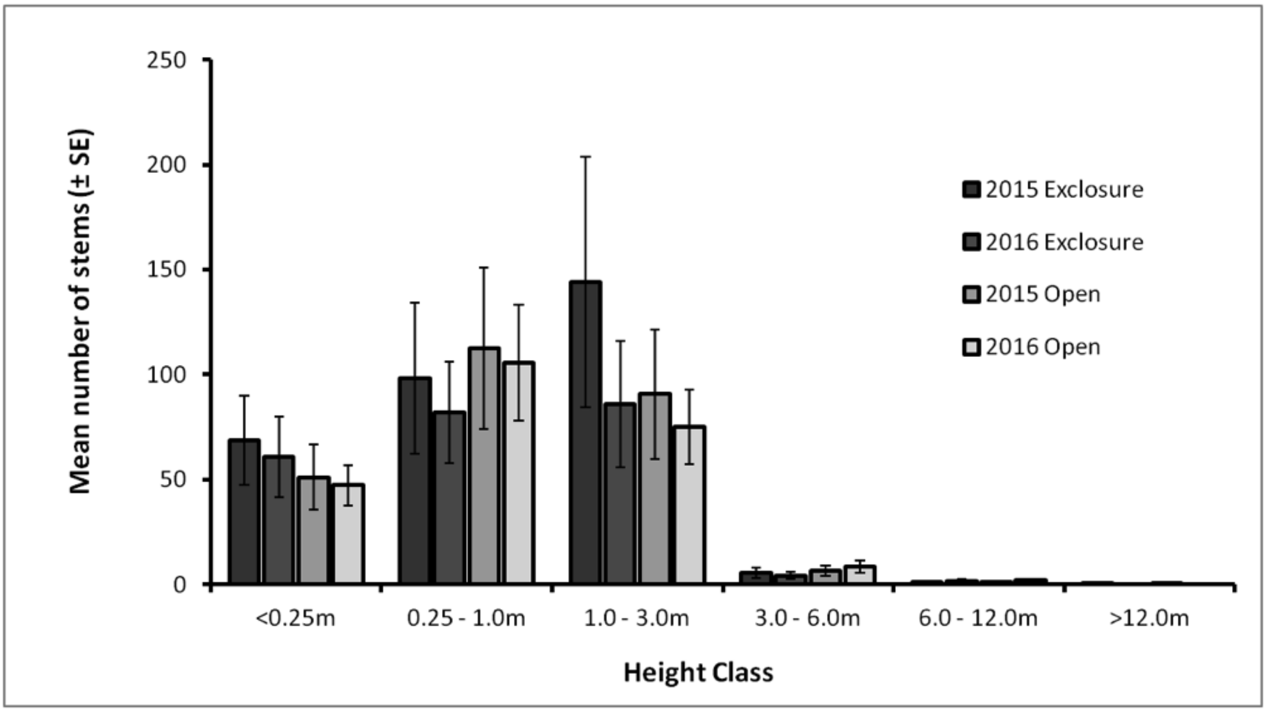


Figure 4. Mean number of woody perennial stems in six height classes averaged by treatment and year. Site 09 is not included because it was not surveyed in 2015. Error bars represent one standard error.



4.2 Vegetation composition

Vegetation composition was assessed at each plot in terms of the total number of woody perennial species present and the percentage of the plot covered by each life form. The absolute number of woody perennial species within each plot varied to some extent between sites, treatments and years (**Figure 5**). Variation in richness between years at a given plot may be the result of true changes in composition associated with climate and season or due to differences between the observers undertaking the surveys. Woody perennial species richness was much lower at the new site Deer09 because it is in grassy sub-alpine woodland on the valley floor that was burnt in 2015. As well as being naturally dominated by grasses, this area of sub-alpine woodland was still recovering from the recent and high severity fire so some species that were present before the burn may not have regrown at the time the surveys were conducted. At this stage it appears that while there was some variation in the total woody plant species richness of each site between years, there were no clear trends towards higher or lower richness amongst either the partial-exclusion plots or the open plots.

Grass and shrub cover remained relatively stable between 2015 and 2016, but forb cover appeared to have decreased and bare ground increased slightly over the 12 months between surveys (**Figure 6**). Again, this may be due to seasonal and climatic changes between years, rather than herbivory, particularly given that there are no differences between the open and partial-exclusion plots within each year.

Figure 5. Total number of woody-perennial plant species found at each plot in 2015 and 2016

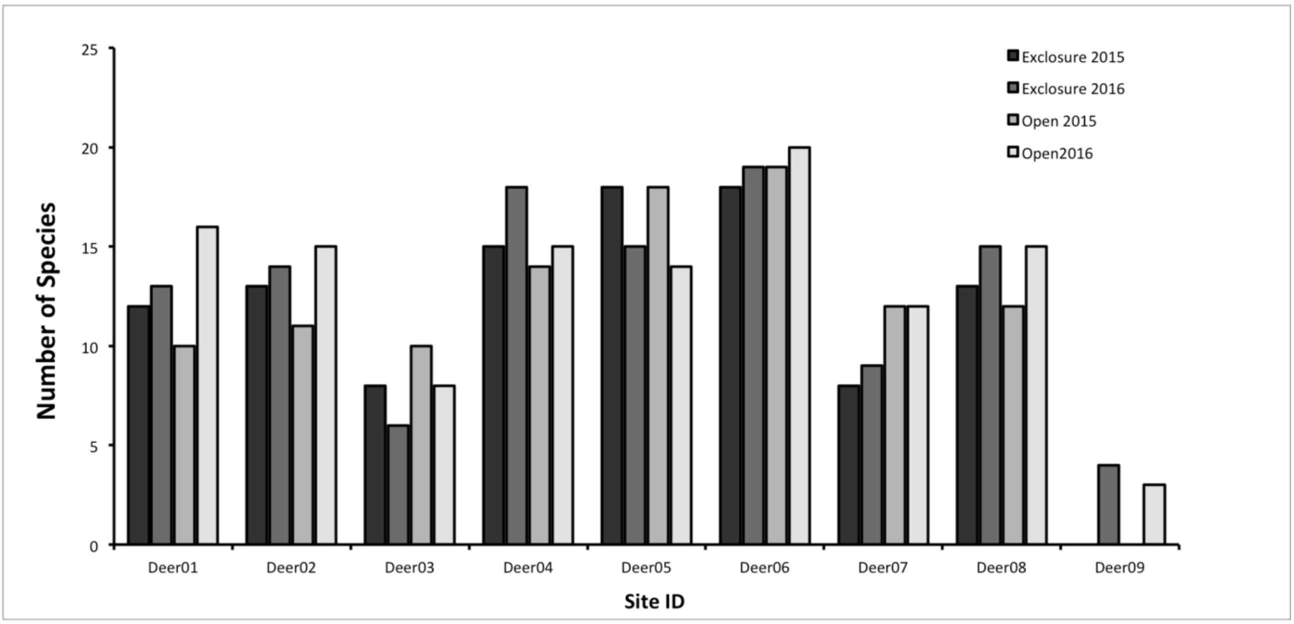
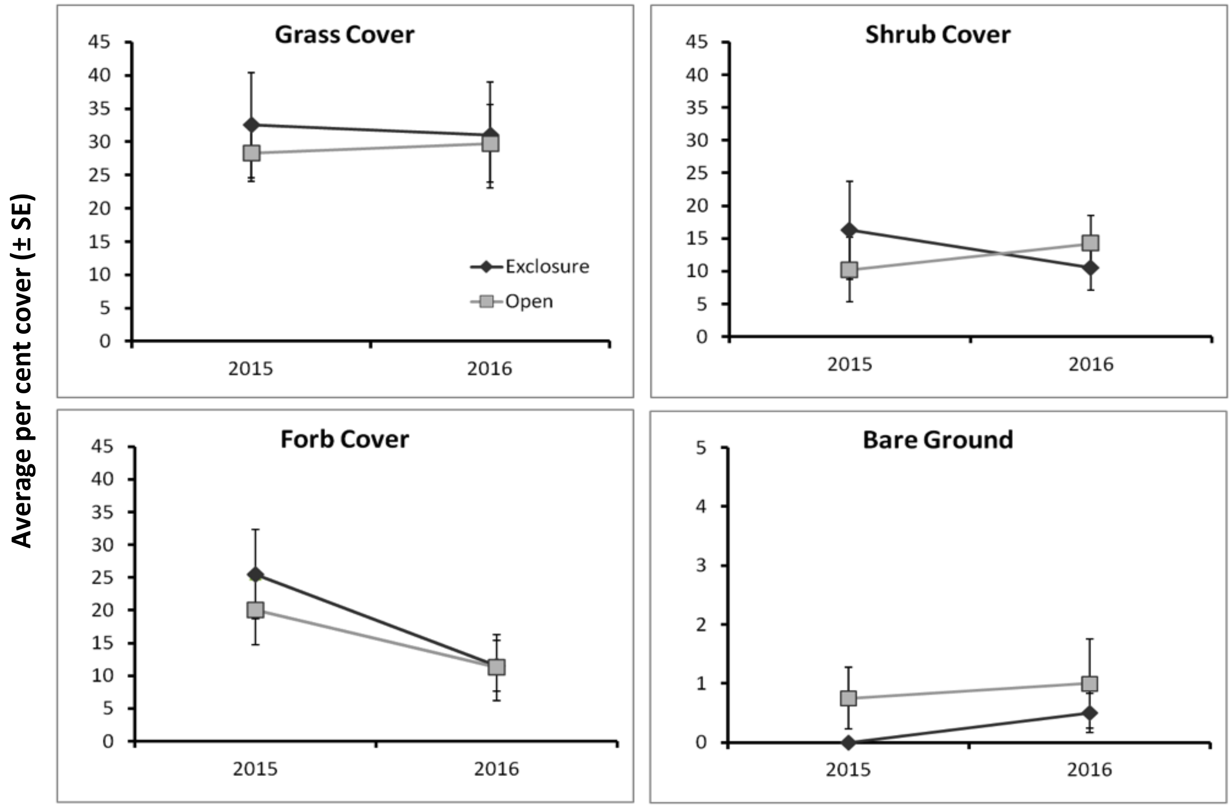


Figure 6. Mean percentage cover of grass, shrubs (<0.5 m), forbs and bare ground in exclosures and open plots for 2015 and 2016. Each class was assessed independently. Note the difference in the scale of the y-axis for the bare ground plot.



4.3 Sambar abundance

Assessments of the relative abundance of Sambar were from the faecal pellet group transects undertaken at each site (one transect for each pair of plots). Over the years 2015 and 2016 we found Sambar faecal pellets at four sites: Deer05, Deer06, Deer07 and Deer09 (**Figure 7**). These four sites all lie at the southern end of the Cotter Catchment upstream from Corin Dam (Map 3). While it appears that deer abundance is relatively low at sites Deer05, Deer06 and Deer07, the site Deer09 had just over 120 pellets across 18 faecal pellet groups. Again, Deer09 was constructed in winter 2015 after being burnt in autumn 2015 and in response to high numbers of Sambar having been seen in the area post fire.

Figure shows the mean number of faecal pellets per site across the two years, but Deer09 is not included because it was not surveyed in 2015. Evidently there have not been changes in the number of Sambar pellets surrounding the plots, and the inference is that Sambar abundance did not change drastically between 2015 and 2016.

Figure 7. Total number of Sambar deer faecal pellets at each site across 2015 and 2016.

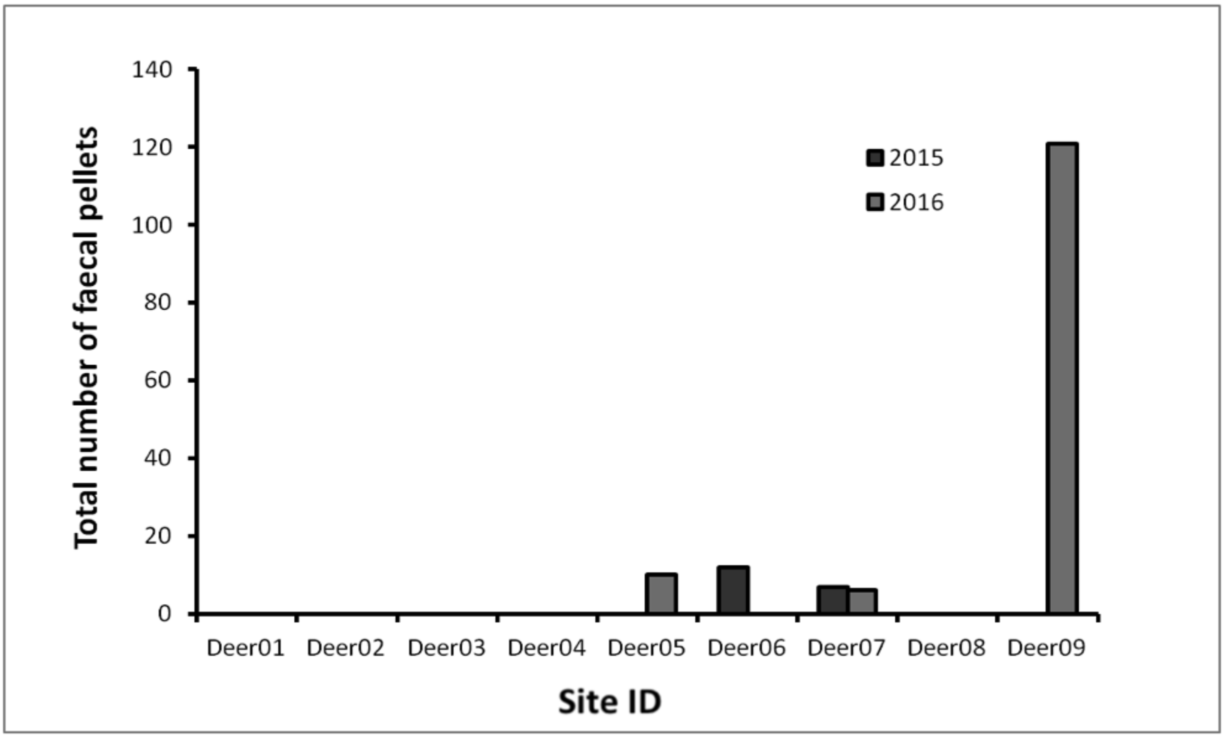
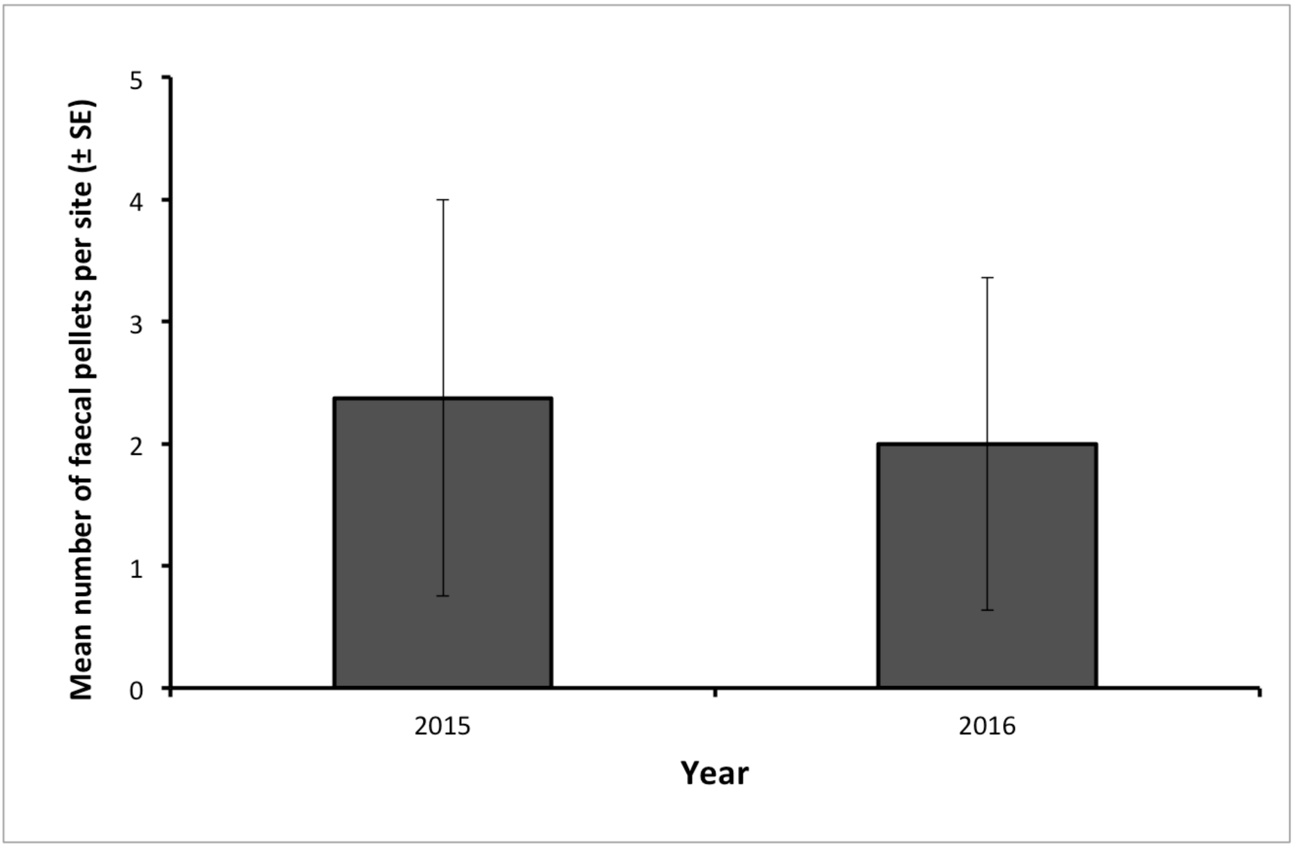


Figure 8. Mean number of Sambar faecal pellets at each site. Site Deer09 is not included as it was not surveyed in 2015.



4.4 Herbivore browsing

We recorded any signs of herbivore browsing on each stem within the set of five belt transects at each site (paired open and partial-exclusion plots). While there was no significant difference between the open and partial-exclusion plots within each year, it did appear that overall damage to vegetation increased between 2015 and 2016 (Figure 9). This is an interesting result given there were no increases in the mean number of native herbivore or Sambar faecal pellets detected on faecal pellet group transects (Figure 8). This finding may have been caused by a confounding factor associated with the sampling itself; that is, observers moving around the plots (particularly those with dense shrub layers) likely damaged some plants in the process, and this may look similar to browsing impacts in subsequent surveys.

This may have contributed to the fact that there was not a clear relationship between the number of browsing signs and the number of Sambar faecal pellets at a site (Figure 10). Furthermore, the site with the highest number of faecal pellets (Deer09) had no signs of herbivore browsing. This is likely to be because there were few woody perennial plants at that site and instead the deer were grazing on regenerating shoots of grass tussocks in the recently burnt area, and/or moving through the area.

Figure 9. Mean number of browse signs per plot. Deer09 is not included.

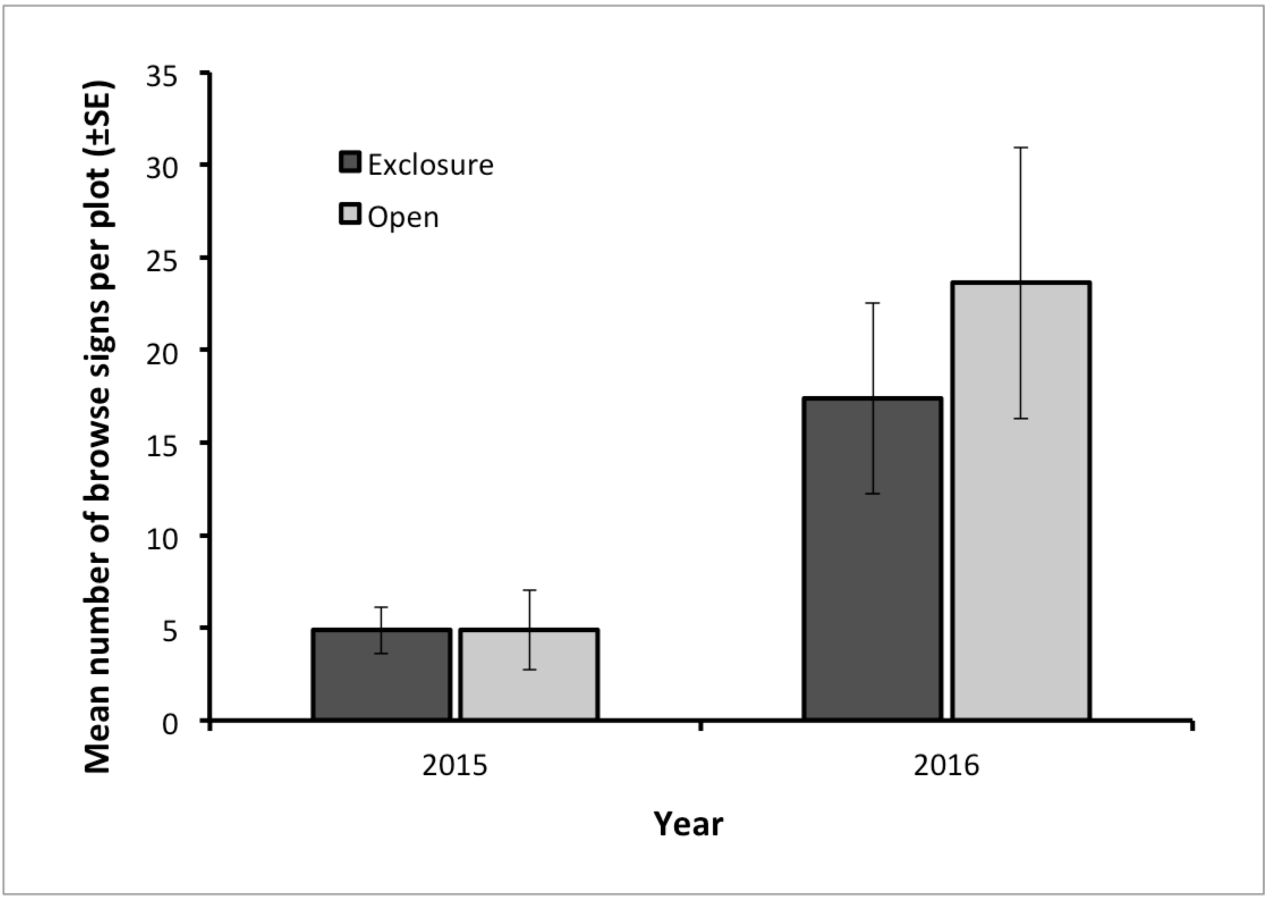


Figure 10. Relationship between the number of browsing impacts per plot and the number of Sambar scats per site.

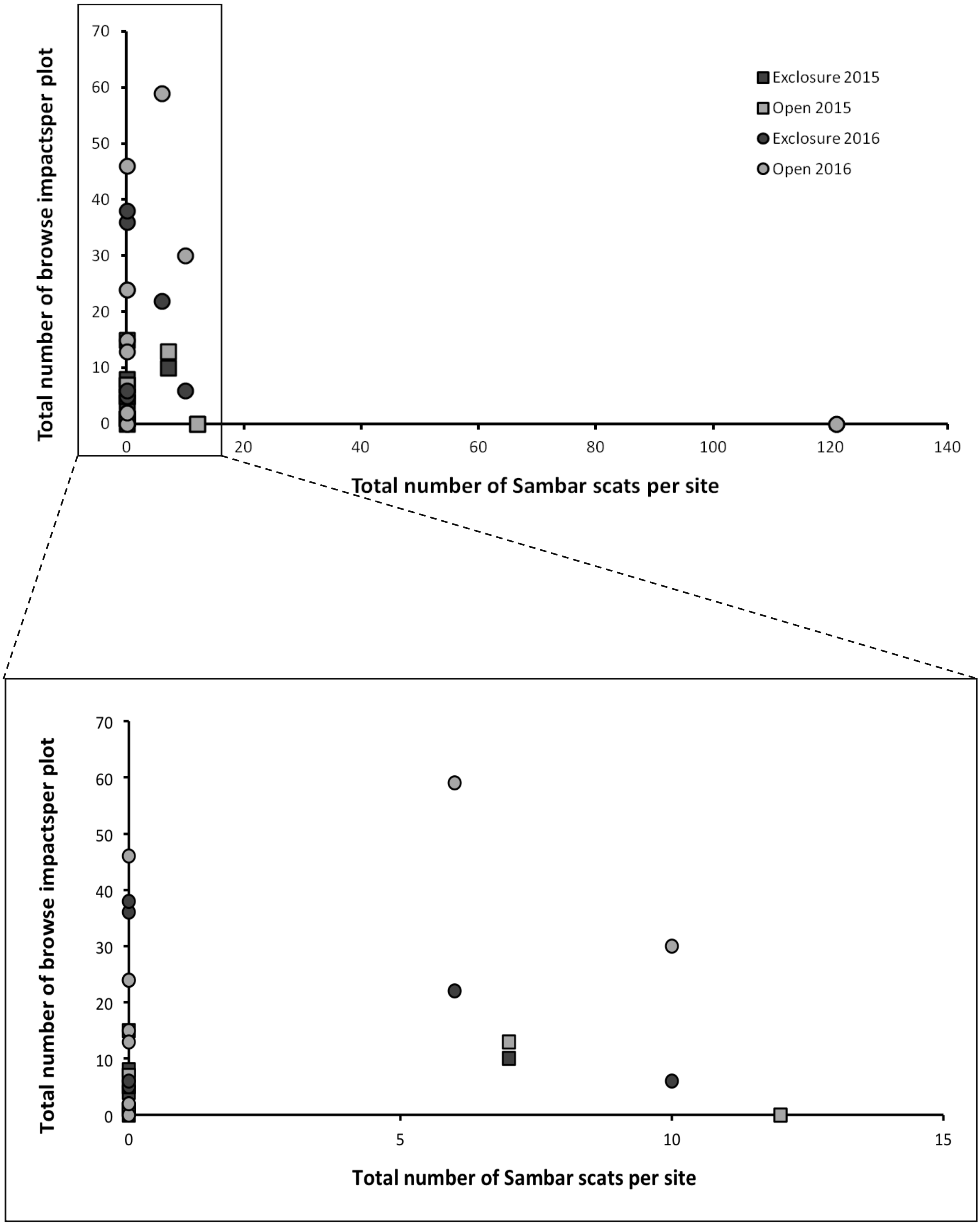
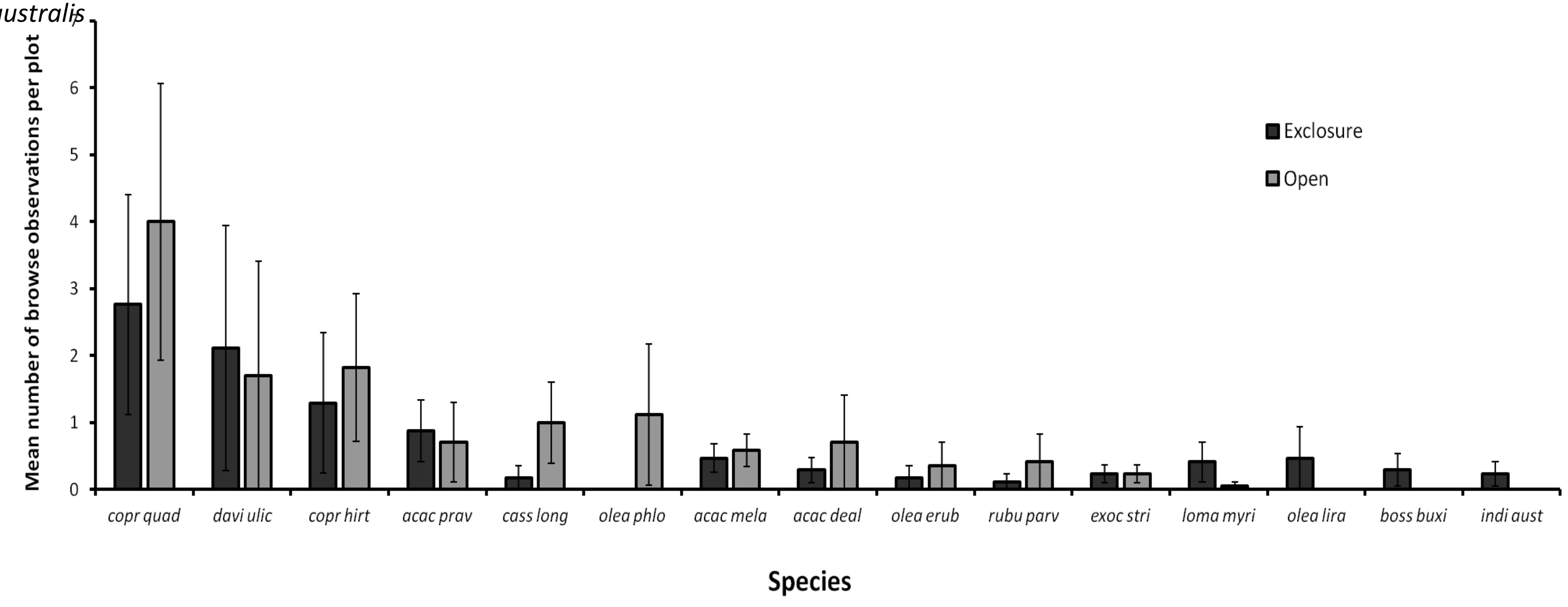


Figure 11. Mean number of browse signs for the top 15 most browsed species in the open and partial-exclusion plots. Error bars represent ± 1 SE. Species are labelled according to their eight letter codes.
Scientific names (from left to right):
Coprosma quadrifida, Davesia ulicifolia, Coprosma hirtella, Acacia pravissima, Cassinia longifolia, Olearia phlogoppapa, Acacia melanoxylon, Acacia dealbata, Olearia erubescens, Rubus parvifolius, Exocarpos strictus, Lomatia myricoides, Olearia lirata, Bossiaea buxifolia, Indigofera australis



5 Discussion

5.1 Survey results from 2015 and 2016

The data collected in 2014/15 and 2015/16 will provide valuable baseline information about the state of vegetation in the upper Cotter Catchment and will allow the ACT Parks and Conservation Service to detect any changes to vegetation structure and composition caused by future increases in the abundance of Sambar.

These baseline surveys have shown that, while some variation exists, the overall vegetation structure did not change greatly over the 12 month period. The distribution of woody perennial stems within the six height classes has remained the same, with the exception being the class 1–3 m. This was largely due to very high stem density at one site in 2015 (Deer06), which may still be recovering from fires in 2003. Similarly patterns of woody perennial species richness and ground cover appear to exhibit some variation between years, but there are no clear trends towards increases or decreases in either of these measures.

Where Sambar were negatively impacting the structure and composition of the vegetation in the upper Cotter Catchment, we would expect to see one or more of the following: decreases in the number of stems in open plots compared with partial-exclusion plots; changes to the distribution of stems across height-classes in open plots; statistically significant decreases in species richness in the open plots; and/or increases in the percentage cover of bare ground and/or grass layer in open plots. We would expect these changes would occur as Sambar abundance increases, such that we would observe: increases in signs of browsing in the open plots (and not the partial-exclusion plots); and/or increases in the number of faecal pellets at each site. This set of data is intended to be the baseline from which we can observe whether these changes take place in future years.

At this stage it appears Sambar are at relatively low densities at all sites except Deer09. Furthermore, their relative abundance has not changed dramatically in the initial two years. The low deer density may be contributing to the fact that there is not a clear relationship between browsing signs and number of faecal pellets at each site. However the number of browsing signs appears to have increased in 2016 in both open and partial-exclusion plots; this may have been caused by the nature of the sampling itself, which unavoidably caused some damage to woody plants that can resemble damage from browsing.

The high number of faecal pellets at site Deer09 combined with the lack of evidence of browsing is interesting. It is probable Sambar are grazing on fresh regrowth of grasses, which is difficult to detect using our method, and/or they are moving through the site on the way to other feeding areas. It is possible Sambar started using this area after it was burned in 2015, which may indicate they are able to adapt their diets depending on what is available. This also raises the possibility that Sambar, as is the case for a number of other native and introduced species, may be attracted to recently burnt areas to take advantage of fresh plant growth. Should this prove to be the case, there may be implications for post-fire recovery of forest and sub-alpine woodland ecosystems and highlights a need for further research into interactions between fire and fauna including exotic species.

Faecal pellets were also observed at the site Deer06, but again no browsing signs were observed. This area contains particularly thick mid-storey cover (we observed 15 stems per square metre in 2015) and is adjacent to more open grasslands on the shores of Corin Dam. It is likely that deer use this area for shelter rather than browsing and this reaffirms the notion that deer use different parts of the landscape for different activities.

5.2 Plot design and survey methods

Our initial findings indicate that the partial-exclusion plots have been effective in allowing access to native herbivores. Recent browsing occurred both inside and outside the exclusion plots in the second year, indicating that herbivores other than Sambar were still accessing and feeding within the partial-exclusion plots as intended. The lack of a clear distinction between the browsing impacts in the open plots and the partial-exclusion plots indicates that the browsing pressure that can be attributed solely to Sambar is still relatively low.

Our vegetation monitoring method was useful for exploring the structure and composition at each of the plots. It focuses on woody perennial species because their abundance is less likely to vary with season and rainfall and have been demonstrated to constitute a large proportion of the diet of Sambar Deer (Forsyth and Davis 2011). However, because of the focus on woody perennial species, we may be missing impacts on other species, particularly at site Deer09 where relative deer abundance is high but few browsing signs were detected in this grassy/herbaceous habitat with our method. Further, it appears that the method may cause some vegetation damage. Browse signs were higher in 2016 in both open and partial-exclusion plots, which may have been in part the result of trampling caused by human presence at the site in the previous monitoring season. Undertaking surveys at a lower frequency may give the vegetation a chance to recover from human disturbances between surveys and help distinguish recent browse from damage caused by past surveys.

Finally, the faecal pellet group transect method that was adapted for this program may not be suited for detecting deer at low densities in this landscape. A key limitation of the method is that scats are not distributed randomly at the site but are more likely to appear on animal trails, in grassy clearings or in bedding areas. This makes it more difficult to detect scats using transect methods focused around the vegetation plots and which may miss these features. Furthermore, small amounts of scat were present at a number of sites other than the four where it was formally recorded on transects, but it was not detected by our survey method. This means that Sambar populations will have to reach a threshold density before they are detected using the method we employed in this study. While the method we employed is still a valid measure of local relative Sambar abundance at our long-term monitoring sites, it may be useful to undertake additional surveys in the manner described by Forsyth (2005) to better measure Sambar abundance at a landscape scale.

Although we have demonstrated that, at this stage, impacts from Sambar in the Cotter catchment are minor, the extent of damage to forested and alpine ecosystems observed in other jurisdiction indicates what will eventually happen in the ACT if Sambar remain unmanaged. This raises the question as to whether or not to wait for Sambar density to reach similar levels in the ACT before management interventions are employed. If early action is deemed prudent as a precautionary measure, key issues to be resolved include what options are available and where should efforts be focused to have greatest impact? Priority research to inform such an approach should focus on the efficacy of available control methods in areas identified as high conservation value and vulnerable to Sambar impact, particularly in alpine bogs ecosystems.

6 Recommendations

1. **Continue the project as a long-term monitoring program using the same protocol that has been described in this report.**

   This preliminary study has shown that the relative abundance of Sambar did not change detectibly in the 12 months between the initial two surveys. We expect the impacts of Sambar will increase as their abundance increases, and these changes are likely to occur at the scale of decades rather than months or years. However, the survey techniques described here provide the necessary information to determine what impacts deer are having on native montane vegetation and this information is invaluable for informing management decisions.

2. **Undertake surveys at all sites once every four years.**

   Given that the relative abundance of Sambar does not appear to be changing rapidly it is not necessary to undertake surveys every year. The apparent increase in browsing in 2016 may have been the result of trampling by observers in the 2015 monitoring season. Allowing a longer interval between surveys may give the vegetation a chance to recover and allow more accurate assessments of browsing signs. However, there were signs of selective browsing on some species (particularly *Coprosma* species) and, as such, these species may be under threat even at relatively low deer density. An interval of four years between surveys may be the best compromise, at least while densities are relatively low, and would tie in with monitoring and reporting cycles under the Conservation Effectiveness Monitoring Program (CEMP).

3. **Undertake routine maintenance checks on the partial-exclusion plots to ensure they retain their integrity.**

   The integrity of the partial-exclusion plots is highly important to the validity of this study. Given that a majority of the plots are in forested areas it is important to ensure they are not compromised by falling timber or debris. It will be important to undertake routine maintenance checks every four months on the partial-exclusion plots and particularly after heavy storm events. The location of partial-exclusion plots should be considered when planning prescribed burning and in wildfire suppression operations and consideration given to their protection or repair if damaged.

4. **Assess relative deer abundance at the landscape scale in conjunction with the local estimates at each site according to the protocol set out by Forsyth (2005).**

   The faecal pellet transect method used to assess relative abundance at the monitoring sites is a valid assessment of local abundance, however there was a large degree of variation between sites. This may indicate that the assessments at each site are not representative of the abundance of deer across the landscape. Forsyth (2005) details a protocol that enables assessment of relative deer abundance at the landscape level. Undertaking these surveys in conjunction with this study would provide a more accurate picture of deer abundance in the upper Cotter Catchment, particularly while deer are still at low abundances.

5. **Assess and monitor ecological impacts of Sambar in highly sensitive ecosystems.**

   The monitoring reported in this study is focused on detecting impacts of Sambar on the structure and composition of montane forests. Sambar are known to have serious impacts on some fragile ecosystems, notably alpine bogs and fens, which should be monitored with appropriate methods to provide early warning of the need for management intervention. Such a program has been initiated by the ACT Government with initial surveys of high priority alpine bogs conducted in autumn 2017 (to be reported elsewhere). It is vital for the long-term conservation of these ecosystems that monitoring is maintained at appropriate intervals to allow intervention should Sambar impacts on bogs become widespread.

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