EVALUATION OF AN EXCLUSION PLOT DESIGN FOR DETERMINING THE IMPACTS OF NATIVE AND EXOTIC HERBIVORES ON FOREST UNDERSTOREYS

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Cervus unicolor (sambar) were introduced to Australia in the 1860s (Bentley 1998) and have since expanded their range throughout eastern Victoria and more recently into New South Wales and the Australian Capital Territory (Moriarty 2004). They are a large deer; mature hinds weigh 130–150 kg and stand up to 1150 mm at the shoulder and stags weigh 200–250 kg and are up to 1300 mm at the shoulder (Bentley 1998; Mason 2006). *C. unicolor* are opportunistic in their food selection, and depending on availability may be classed as predominantly browsers (Burke 1982; Ngampongsai 1987; Shea *et al.* 1990; Semiadi *et al.* 1995), grazers (Padmalal *et al.* 2003) or intermediate feeders consuming approximately equal quantities of both browse and graze food plants (King 1990; Varman and Sukumar 1993; Stafford 1997). Selective browsing by *C. unicolor* may impact on species abundance and distribution, and thereby alter species composition of forest types, while social behaviours, such as rubbing and wallowing, may lead to impacts on water quality and biodiversity.

Exclusion plots have often been used to evaluate the impacts of browsers and grazers (Opperman and Merenlender 2000; Takada *et al.* 2001). However, impacts of browsing herbivores can be difficult to determine if multiple species occupy the same habitat (Kelton and Skipworth 1987; Stockwell 2003). One solution to this problem is the use of selective exclosures, which allow a chosen species to enter exclosures while preventing access by other species, thereby allowing quantification of browsing impacts of individual species (Baxter *et al.* 2001; Neave and Tanton 1989). The most common large native terrestrial herbivores in the study area are *Wallabia bicolor* (swamp wallaby), which are predominantly browsers (Hollis *et al.* 1986; Jarman and Phillips 1989; Osawa 1990), and *Vombatus ursinus* (common wombat), which are grazers and feed almost exclusively on grasses (Evans *et al.* 2006). Both species are considerably smaller than *C. unicolor*: adult *Wallabia bicolor* weigh up to 25 kg (Di Stefano *et al.* 2005) and are up to 40 cm high at the back when crouched (pers. obs.), whereas adult *Vombatus ursinus* weigh up to 35 kg and reach 25 cm at the shoulder (Triggs 1988).

EXCLUSION PLOT DESIGN

To determine the impacts of *C. unicolor* on forest understoreys and to be able to distinguish these impacts from that of native herbivores, we constructed exclusion plots in 2005 and 2006 in the Yarra Ranges National Park, Victoria, Australia. We arranged 10 x 10 m plots in units consisting of three types: a total exclusion plot, a partial exclusion plot and open (no fence) plot (Figure 1). This layout was chosen to minimise sampling error that may be introduced by spatial variation among the plots in each unit. In practice it was difficult to construct plots exactly as shown in the spatial layout (Figure 1), due to terrain, tree fall and location of understorey shrubs. We often had to move the unit slightly from the random central point, or vary the distances (5–20 m) and angles (40–180°) between plots in order to encompass a variety of understorey species, whilst keeping these species as similar as possible within a given unit.

The cost of materials for each exclusion unit was approximately $530 (Table 1). To keep the cost per unit to a minimum our fences were designed to eliminate the need for stays (supports) on each corner by replacing two extra supporting poles per corner with the two external star pegs (a saving of $144 per unit). This also greatly increased the speed of construction and reduced the quantity of materials to be transported to plot locations, which were accessible only by foot.

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Key words: browsing, *Cervus unicolor,* common wombat, exclusion plots, herbivore impacts, sambar, swamp wallaby, *Vombatus ursinus*, *Wallabia bicolour*.

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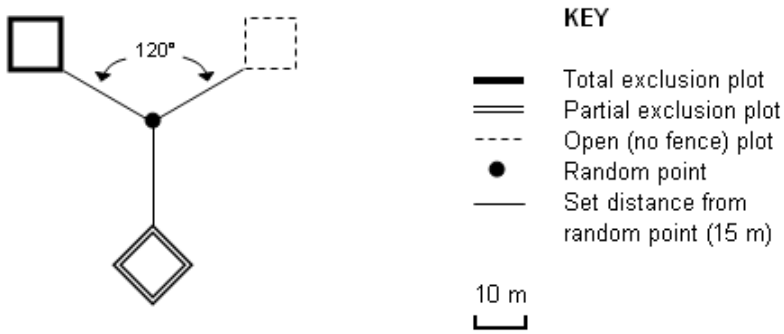

Fig. 1. Plan view of an exclusion unit, showing the ideal arrangement of the total exclusion plot, partial exclusion plot and open (no fence) plot.

Item	Total	Partial	Open	Total No. per unit	Approximate cost	
					Item cost ($)	Total cost ($)
2400-mm star picket	12	12	-	24	9.00 ea	216.00
600-mm star peg	8	8	4	20	1.50 ea	30.00
'Acreage' weld-mesh (1200-mm, 10 strand graduated mesh)	40 m	40 m	-	80 m	2.40 / m	192.00
2.5-mm high tensile plain wire	120 m	40 m	-	160 m	0.15 / m	24.00
2-mm tie wire	~5 m	~5 m	-	10 m	0.15 / m	1.50
10-mm turnbuckles	4	4	-	8	2.80 ea	22.40
Gripple® wire joiners	~15	~15	-	30	1.50 ea	45.00
						$530.90

Table 1. Description and approximate costs of materials used in the construction of one exclusion unit, consisting of a total exclusion plot, a partial exclusion plot and an open (no fence) plot.

We positioned 46 units (138 plots) among five representative Ecological Vegetation Classes (EVCs) throughout the Upper Yarra and O'Shannassy water catchments: Riparian Forest, Wet Forest, Damp Forest and Shrubby Foothill Forest. We installed five of these units at a site in the Upper Yarra catchment known as The Flats, which is an open grass and herb-rich area adjacent to the reservoir, and is periodically covered with water depending on the height of the reservoir. Twenty units were located within 1 km of The Flats, as this area had previously been identified as a major feeding area for *C. unicolor*. Another 15 units were located > 5 km from the reservoir to investigate the relationship between distance from The Flats and degree of understorey impact. A further six units were located in the Wet Forest EVC in the adjacent O'Shannassy catchment. We randomly located units within each EVC by generating random coordinates in Microsoft Excel, then used these as waypoints in a Garmin eTrex Legend GPS unit to guide us to the location.

The total exclusion plot (Fig. 2) was designed to exclude *C. unicolor, W. bicolor* and *V. ursinus*. The partial exclusion plot (Fig. 3) was designed to exclude *C. unicolor* but allow native herbivores access via a 500 mm gap at the base of the fence. Given the much larger body size of *C. unicolor*, we considered that they would be unable to enter through the gap, while native herbivores would continue to use the plot at near-natural levels. The open plot allowed access to all herbivores, so that the relative impacts of *C. unicolor* and native herbivores could be differentiated.

All plots were functioning as intended until winter 2006, when small *C. unicolor* (yearlings) entered the partial plots located on the open area of The Flats via

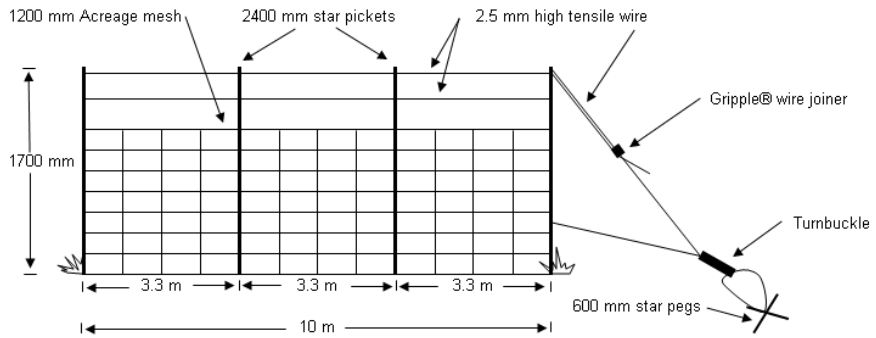

Figure 2. Side elevation of the total exclusion plot, which is designed to exclude all large herbivores.

the 500-mm gap and grazed inside on a number of occasions. *Chenonetta jubata* (wood duck*),* another species that was not previously considered, also appeared to be grazing in the total plots. To prevent this, we added 40 mm grid, 300 mm width chicken mesh to the base of total exclusion plots, as the original mesh was coarse enough to allow access to *C. jubata*. We also reduced the 500 mm gap on the partial plots to 300 mm using a band of the chicken mesh.

DISCUSSION

The use of exclusion plots can provide powerful information on the impacts of herbivores on individual flora species and community composition, particularly over a mid- to long-term time frame of five to twenty years or more (Barret and Stiling 2006; Bellingham and Allan 2003; Husheer et al. 2003; Wilson et al. 2006). However plots do require ongoing maintenance, particularly for those located in a forested environment where falling trees and branches are the main sources of damage. One advantage of the design of our exclosures is that they are relatively easy to repair when a branch falls across a fence. Once the branch is cut, the flexible mesh can be stretched back into shape, the poles in most cases can be adequately straightened, and the whole fence can be easily tightened by adjusting the wire through the Gripple® wire joiner and using the turnbuckles on the external end assembly.

This fence design is effective only for the selective exclusion of medium to large-sized, ground-dwelling species, and therefore does not exclude smaller terrestrial mammals or arboreal species such as possums. The fence design may be modified, obviously at extra cost, to exclude all terrestrial species by the addition of appropriately-sized mesh at the base. However, an effective covering to exclude arboreal species would not be feasible in a forest environment due to the presence of trees in the plots and damage caused by falling timber. Furthermore, it may not be possible to adapt this design to suit deer that are significantly smaller than *C. unicolor,* such as *Axis porcinus* (hog deer).

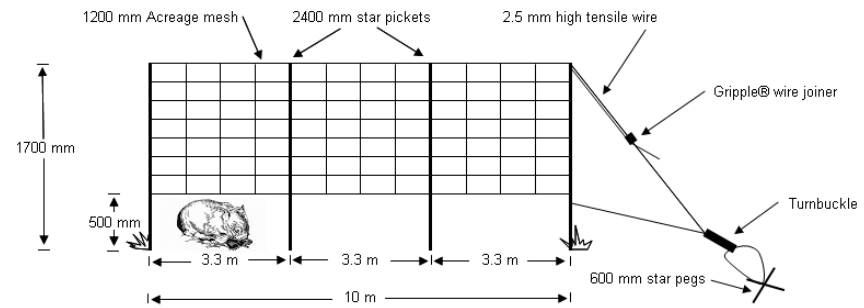

Figure 3. Side elevation of the partial exclusion plot, which is designed to exclude *C. unicolor* while allowing access to native herbivores via the gap at the base of the fence.

We recommend that plots located in the forest are revisited within a few weeks of construction to ensure that *C. unicolor* have not damaged the fence while they are becoming accustomed to these new obstacles. *C. unicolor* did cause considerable damage to some fences, but nothing that was irreparable. When *C. unicolor* are confronted with an obstacle (or fence), they either go around it or attempt to crawl under the obstacle rather than jump over it. The presence of plastic flagging tape did not prevent *C. unicolor* colliding with fences, but shiny, reflective items hanging on or near the fences may be more effective. Following these initial damage checks early on and the first plant survey in winter 2006, 3–6 months after construction, all forest plots appeared to be functioning as intended. We found *W. bicolor* and *V. ursinus* scats in the partial plots, and have seen *C. unicolor* in close proximity to the units, indicating that they have become habituated to the plots, whilst being excluded from partial plots. However, after the second survey in summer 2006–07 approximately a year after construction, it was evident that *C. unicolor* had entered several of the partial exclusion plots in the forest via the 500 mm gap, perhaps due to scarcity of food in a prolonged period of below-average rainfall. We therefore decided to reduce the height of the gap on all partial plots to 300 mm, as shown to be effective for the plots on The Flats. This was considered unlikely to deter use by native herbivores, which were accustomed to entering the partial plots and small enough to fit beneath. To minimise the cost of this modification, we lowered the existing mesh and added a single strand of plain wire to the top, rather than the addition of chicken mesh that was required for the plots on The Flats. Following the third survey in winter 2007, these modifications have apparently been successful in selectively excluding the target species.

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