Supplementary Materials

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Barking up the wrong tree? Are livestock or rabbits the greater threat to rangeland biodiversity in southern Australia?

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Supplementary material

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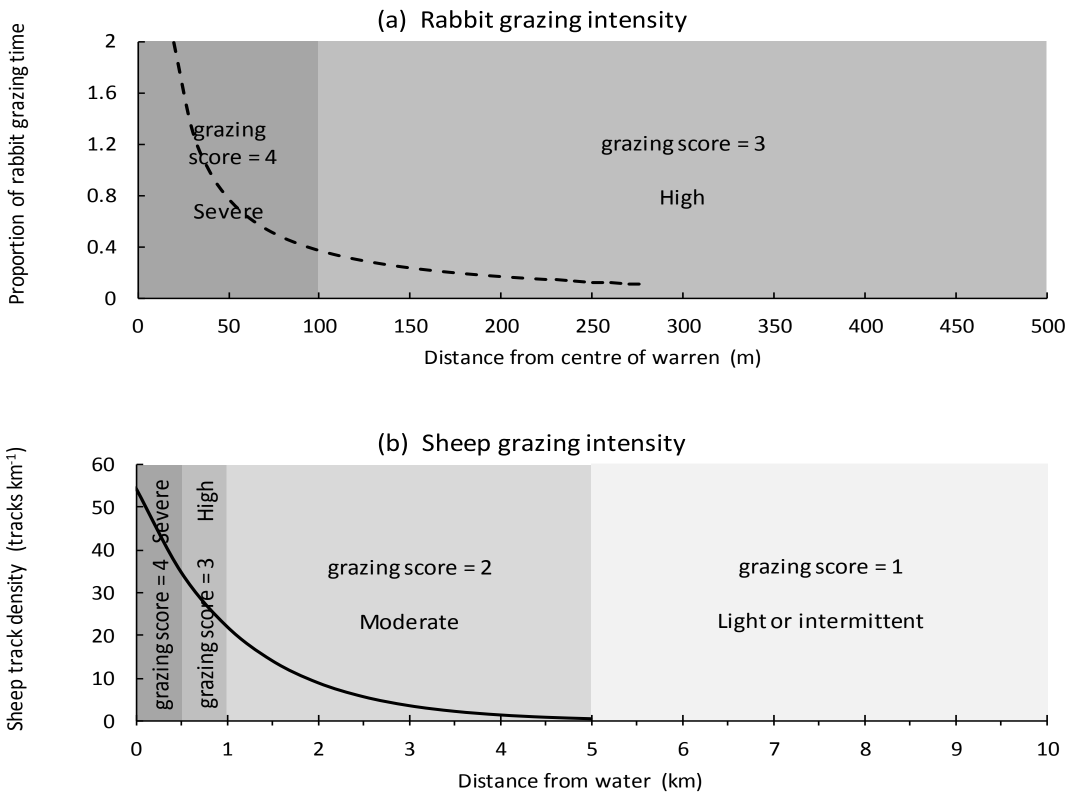
Simulated multiple regression analysis of relationships between vegetation condition and relative abundance of sheep and rabbits

Background

Tiver and Andrew (1997) estimated the relative influence of herbivores on native vegetation in north-eastern South Australia by comparing vegetation condition at numerous sites to a grazing impact score for each major herbivore on a scale of 0-4, where 3 represented heavy grazing influence.

Rabbit grazing was scored as 3 at all sites between 100-500 m from rabbit warrens. Although rabbits occasionally venture >400 m from warrens in extreme circumstances (Cooke 1982), they rarely graze beyond 200 m from a warren (Armstrong 1988; Leigh *et al.* 1989), with 95% home ranges in arid areas of 82-191 m radius (Fullagar 1979; Moseby *et al.* 2005). The score 3 was therefore applied to a distance more than double their normal grazing range, and > 85% of the area scored that way was outside of their usual grazing range.

Fig. 1 Relationship between changes in grazing intensity of (a) rabbits and (b) sheep in arid areas, and grazing intensity scores used by Tiver and Andrew (1997), measured for each species in relation to increasing distance from their respective centres of activity. Fitted curve for rabbit grazing from Armstrong (1988, p 126) based on observation data of P Fullagar and C Davey at Calindary Station, New South Wales. The fitted curve over-estimated recorded grazing beyond 200 m (Armstrong 1988, Figs 3.1.3 and 3.1.4). Armstrong noted 'negligible' grazing beyond 240 m and recorded no grazing beyond 280 m from the warren. Fitted curve for sheep from Pringle and Landsberg (2004), Equation 3.



Sheep grazing was scored as 3 at all sites 500-1000 m from water (Fig 1b). Sheep graze about 5 km from water and grazing intensity declines with increasing distance from water (Pringle and Landsberg 2004). The score 3 was therefore applied in a heavily-used inner 10% of their normal grazing range and, in general, the grazing scores for sheep were consistent with published estimates of sheep grazing patterns.

Using grazing impact scores that are inappropriate (for rabbits), and unbalanced with respect to each other, is likely to have led to erroneous conclusions about the relative impact of the different herbivores. To demonstrate how this might happen, a simulation was conducted on a dataset (attached), created with similar parameters to those used by Tiver and Andrew (1997).

Method

In the simulated data, vegetation was given a condition score between 1 and 5. To aid visual representation (Figs. 2-4), decimal increments were added or subtracted where multiple data points had common values to give a final score of 0.8 to 5.1

Rabbit and sheep abundance are often positively correlated in sheep pastoral zones because stock watering points are generally in the most fertile areas and/or in alluvial valleys and run-on areas that often support the highest rabbit densities. For the purpose of this demonstration, rabbits were assigned abundance scores of 0 to 4, negatively correlated with vegetation score. That is consistent with the recorded strong negative relationships between rabbit density and vegetation condition set out in the main document to which this is supplementary material. Sheep were assigned abundance scores of 0 to 4, less closely negatively correlated with vegetation score because of the weaker recorded relationships between distance from permanent water and vegetation condition in pastoral areas.

A second rabbit score was then calculated to simulate errors that would occur if high rabbit abundance was frequently over-estimated, as could occur using the method of Tiver and Andrew (1997) (Fig. 1a).

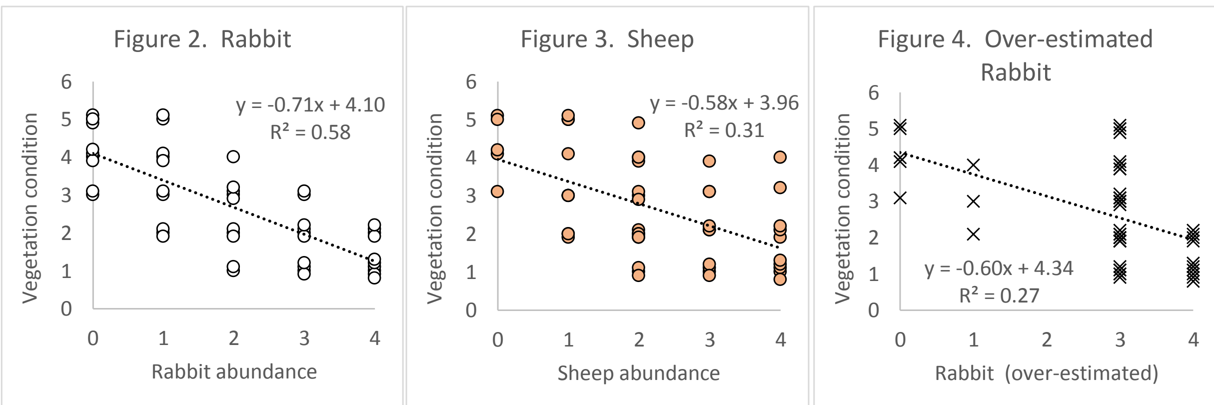
- every 2nd rabbit score of 0 was adjusted to 3,
- every 2nd and 3rd rabbit score of 1 was adjusted to 3
- all rabbit scores of 2 were adjusted to 3

Regression analyses were conducted in Statistica V9.1 and Figures were drawn in Excel

Results

Figures 2 to 4 show simple linear regressions that are all significant at the P<0.001 level. Coefficients for the two rabbit models are similar but the over-estimated rabbit scores greatly reduce the amount of variation in vegetation condition explained by variation in rabbit score (Figs. 2, 4).

Figs. 2-4 Relationships of vegetation score to rabbit, sheep and overestimated rabbit abundance from a simulated data set.



Multiple regression analysis of vegetation condition against rabbit and sheep scores

Multiple regression of vegetation condition against (original) rabbit and sheep abundance scores indicated that the variation in vegetation condition was best explained by rabbit abundance (Table 1). Inclusion of sheep abundance score did not explain a significant proportion of the model variance. The sheep term therefore should not be retained, leaving a single rabbit term explaining 58% of the variance in vegetation score (Fig. 2).

Table 1 Parameter estimates for multiple regression of vegetation scores against sheep and rabbit scores

parameter	coefficient	s.e.	P
intercept	4.232	0.253	0.000
sheep	-0.121	0.127	0.347
rabbit	-0.645	0.112	0.000

This model indicated that variation in vegetation condition could be adequately explained by rabbit abundance alone and that sheep abundance was an insignificant influence.

When the analysis was repeated using the over-estimated rabbit abundance scores instead of the original rabbit abundance scores, sheep abundance was the only significant term to be retained in the model, leaving a single sheep term explaining 31% of the variance in vegetation score (Table 2, Fig. 3). This model indicated that variation in vegetation condition could be adequately explained by sheep abundance and that rabbit abundance was an insignificant influence.

Table 2 Parameter estimates for multiple regression of vegetation scores against sheep and over-estimated rabbit scores.

parameter	coefficient	s.e.	P
intercept	4.394	0.413	0.000
sheep	-0.396	0.170	0.024
over-estimated rabbit	-0.305	0.187	0.109

Conclusion

This simulation shows how over-estimation of one parameter (rabbit score) can lead to underestimation of its explanatory influence. Of equal importance, it can also lead to over-estimation of the explanatory power of other factors (in this instance, sheep score).

The data were chosen to demonstrate an extreme change. They are not data used by Tiver and Andrew (1997). Less extreme over-estimation of one parameter is likely to cause less extreme errors in its relative explanatory power rather than complete reversal of the parameters that are significant, as occurred in this example. The linear model is used to demonstrate a principle in a simple manner but it remains possible that other non-linear models that may have provided a slightly better fit to the simulated data.

Although the simulated changes were extreme it is within the bounds of possibility, as shown in Fig. 1a, that in a sample of sites chosen from pastoral areas that are more than 300 m from the nearest rabbit warren and ungrazed by rabbits, half of the sites might be 300-500 m from a warren and therefore classed by Tiver and Andrew's system as "heavily grazed, score = 3" (as presented in the simulated data for sites with original rabbit grazing score = 0).

To put this in context, if rabbit warrens occurred at 700 m intervals across the landscape in a square grid pattern, every point within that area would be within 500 m from the nearest warren and classed by Tiver and Andrew's system as "heavily grazed, score = 3". Only 60% of that area would be within 300 m of a warren, and likely to be grazed by rabbits to a significant extent.

Conclusions about rabbit grazing impact based on a classification system that may have classified large areas that are ungrazed by rabbits to be heavily grazed by them are, therefore, unreliable (i.e. they may or may not be correct), as are conclusions about other herbivore impacts based on multivariate analyses which include those rabbit grazing parameters.

References

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Simulated Data

Vegetation score	Rabbit grazing score	Sheep grazing score	Over-estimated rabbit grazing score
5	0	1	3
5.1	0	0	0
4.9	0	2	3
5	0	0	0
4	0	4	3
4.1	0	0	0
3.9	0	3	3
4.2	0	0	0
3	0	2	3
3.1	0	0	0
5	1	1	3
5.1	1	1	3
4	1	2	1
4.1	1	1	3
3.9	1	2	3
3	1	1	1
3.1	1	3	3
2	1	1	3
2.1	1	2	1
1.9	1	1	3
4	2	2	3
3	2	1	3
3.1	2	2	3
2.9	2	2	3
3.2	2	4	3
2	2	2	3
2.1	2	3	3
1.9	2	2	3
1	2	2	3
1.1	2	2	3
3	3	1	3
3.1	3	3	3
2	3	2	3
2.1	3	3	3
1.9	3	4	3
2.2	3	3	3
1	3	3	3
1.1	3	3	3
0.9	3	2	3
1.2	3	3	3
2	4	1	4
2.1	4	4	4
1.9	4	2	4
2.2	4	4	4
1	4	4	4
1.1	4	4	4
0.9	4	3	4
1.2	4	4	4
0.8	4	4	4
1.3	4	4	4

shaded data increased to value=3 to simulate over-estimation of high rabbit abundance