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Observer error in counts of macropod scats

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Abstract. The accuracy of faecal pellet, or scat, count data can be reduced by observer error. Two experiments were carried out to determine what proportion of Bennett's wallaby (*Macropus rufogriseus*) and Tasmanian pademelon (*Thylogale billardierii*) scats were misidentified by observers and what proportion of scats were overlooked during counts. Observers did not always correctly identify the species from which scats originated. For each species, this affected estimates of the proportion of scats that were present. Observers still made errors even when they did not attempt to make identifications for any scats that they felt were not distinct in form. On average, there was no significant difference in the proportion of scats that were misidentified by inexperienced and experienced observers. Between 3% and 12% of scats were overlooked during standard counts. The probability of overlooking a scat was positively related to vegetation height and negatively related to vegetation cover.

Introduction

Faecal pellet count techniques have been used to study trends in the abundance of a wide range of vertebrate species including deer (e.g. Bennett *et al.* 1940; Rogers *et al.* 1958; Batchelor 1975), elk (e.g. Collins and Urness 1978), rabbits (e.g. Taylor and Williams 1956; Cochran and Staines 1961) and macropods (e.g. Floyd 1980; Arnold and Maller 1987; Johnson and Jarman 1987; Bulinski *et al.* 1997). One frequently used technique involves the establishment of fixed plots of known dimension that are initially cleared of pellets and then searched for pellets at regular intervals. The number of scats deposited per metre per day can be calculated by dividing the number of scats found by the area searched and the number of days over which pellets were deposited. These data can then be used directly as a measure of relative abundance or, if reliable defecation rates are available, a further calculation can be performed to obtain measures of absolute density (Southwell 1989).

The value of scat count data can be reduced by observer error. One error that observers may make during counts is incorrect identification of the species of origin. If scats from one species are misidentified as scats from a second, sympatric species, then the abundance of the former will be underestimated and the abundance of the latter will be overestimated. A second type of observer error occurs when scats are overlooked during counts. This error may not be a concern provided that the probability of overlooking scats is uniform through space and time. However, the likelihood of overlooking scats may be influenced by the nature of the substrate onto which they are deposited. For example, scats deposited in areas of extremely thick, high vegetation may be overlooked more often than those deposited on areas of bare ground. If site characteristics vary spatially or temporally, scat count data may be biased so that it is related to both the magnitude of observer error and the abundance of animals.

Despite the widespread use of scat count techniques, few authors have quantified the extent to which data may be influenced by these types of observer error. In Tasmania, Australia, scat count techniques have been used in a number of studies (Johnson 1977; Statham 1983; Gregory 1988) to assess the abundance of Bennett's wallaby (*Macropus rufogriseus*) and Tasmanian pademelon (*Thylogale billardierii*), two macropod species that occur sympatrically across a range of habitat types. However, no author has addressed the possibility that scats from these species may be misidentified in the field, even though our personal observations suggest that they are sometimes remarkably similar in form. Furthermore, despite studies being carried out in various habitat types, there has been no work to determine what proportion of scats are overlooked during counts.

As part of a larger study examining relationships between herbivore abundance and browsing damage in Tasmanian eucalypt plantations (Bulinski 1999) we carried out two experiments to quantify the extent to which these observer errors can affect scat count data for the Bennett's wallaby and Tasmanian pademelon. The objective of the first experiment was to determine whether scats from the two macropod species could be misidentified. We hypothesised that this error could be minimised by using experienced observers and

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by not attempting to identify scats that were not distinctive in form. The objective of the second experiment was to quantify the proportion of scats that were overlooked during standard counts in the field. We hypothesised that the magnitude of this error would be related to the vegetation characteristics of a site.

Methods

Identifying scats

Two tests were employed to determine whether people could distinguish between scats from the two macropod species.

Test 1

Fifty scats were placed in each of 6 containers. Each container held a different mix of scats:

Container	1	2	3	4	5	6
No. of pademelon scats	50	40	30	20	10	0
No. of Bennett's wallaby scats	0	10	20	30	40	50

All scats were obtained from captive animals; they were collected as they were voided and then stored in a drying oven at 60°C until they were used. Scats were collected randomly with respect to the age, size and sex of individuals. As a means of identification, a small pin was inserted into each scat. The pins were identical except that small marks, made with a pair of pliers, were placed near the end of pins inserted into pademelon scats. By removing a pin and examining it, we were able to identify the species from which the scat had originated.

Twelve people served as the 'subjects' for this test. They ranged in their experience of scat identification from completely inexperienced individuals who had never attempted to identify a scat, to highly experienced individuals who identified scats in the field on a weekly basis. We broadly grouped these individuals into two categories: (1) inexperienced – six people who had absolutely no prior exposure to scat identification; and (2) experienced – six people who had previously made numerous identifications of scats from the two species. Each person was told at the start of the test to treat each container as if it were the contents of a field plot that could contain any mix of scats from the two macropod species. Each person examined each of the 50 scats and identified them as from Bennett's wallaby or pademelon. Participants were forced to make an identification, even if they were uncertain. To assist in making identifications, a random selection of 20 reference scats from each species was provided in separate labelled containers. Throughout the test the participants were free to study both the test and reference scats for as long as they felt necessary. After completion of the test, individuals were provided with no information relating to their performance.

Test 2

This test was carried out by the same set of 12 individuals several months after Test 1. The procedure was the same as for Test 1, except that participants were allowed to place scats into an 'unidentified' category. In other words, if an individual did not feel confident that they could identity a particular scat correctly, they were not forced to choose between the two species.

Overlooking scats

This experiment was conducted at 10 first-year forestry plantations provided for use by three forestry companies. Before the study began, forestry company employees had logged most of the standing timber in each of these areas. Waste timber had been stacked into windrows and burnt, the ground had been ripped with a bulldozer to prepare planting lines, and the cover of competing vegetation had been reduced with herbicides. Eucalypt (*Eucalyptus* spp.) seedlings were planted from October to November of 1994. This study commenced in September 1995, approximately 11 months after planting. A visual inspection of these sites suggested that there was wide between-site variation in vegetation characteristics.

Ten scat plots (25 m long and 1 m wide) were established at each study site. As part of a larger study (Bulinski 1999) each of these plots was cleared of macropod (Bennett's wallaby and pademelon) scats 240 days after establishment. Plots were again searched for macropod scats 80 days later. Any that were found were identified, counted and removed. Immediately after this, the vegetation cover on each plot was assessed using six 1-m^2 quadrats placed at 5-m intervals along the plot (includes 0- and 25-m points). In each quadrat, a visual estimate of vegetation cover was made to the nearest 10% using the method of Hays *et al.* (1981). The average of these values was used as an overall estimate of the vegetation cover on each plot. Vegetation height was measured to the nearest centimetre at 0.5, 2.5, 5, 7.5 … 22.5 and 24.5 m along each plot using a 1-m ruler. The mean of these values was used as an overall estimate of the average vegetation height in each plot. Immediately after this the vegetation along the entire length of the plot was slashed using a brush-cutter. Two observers then moved on hands and knees along the plot, sifting through the vegetation and recording any additional scats that were found.

Step-wise logistic regression was used to model the probability of finding a macropod scat in relation to vegetation data. The procedure is well suited to binary response data (Cox and Snell 1989), in this case whether a scat was found or not found before slashing. The model takes the form:

$$\text{logit}(p) = \log\left(\frac{p}{1-p}\right) = \alpha + \beta x$$

where p is the response probability to be modelled, x is a vector of explanatory variables, β is the vector of slope parameters and α is the intercept parameter. Thus, an estimation of the parameters α and β allows calculation of logit (p), which in turn can be used to calculate the probability of an event occurring (p), in this case finding a macropod scat, from :

$$p = \frac{e^{(\text{logit(p)})}}{(1 + e^{(\text{logit(p)})})}$$

Data from individual scat plots were used for the analysis. Plots were excluded if no scats were found in them. The binary response variable was equal to the number of scats counted in each plot before slashing divided by the total number of scats counted in the plot (includes scats found before and after slashing). The explanatory variables were vegetation height and vegetation cover. The analysis was performed using the SAS statistics package (Sas Institute 1989). SAS provides estimates for the joint significance of explanatory variables (–2 log likelihood) and estimates for α and β. SAS also provides a measure of the level of discrimination associated with any derived model, referred to as the confidence interval displacement value or c (Sas Institute 1989). Values for c range from 0.0 to 1.0, with $c > 0.7$ being considered an acceptable level of discrimination (Lemeshow and Le Gall 1994).

Results

Identifying scats

Test 1

In Fig. 1 the actual proportion of Bennett's wallaby (A) and pademelon (B) scats present in each container is compared with the mean of the estimates that were made by the 12

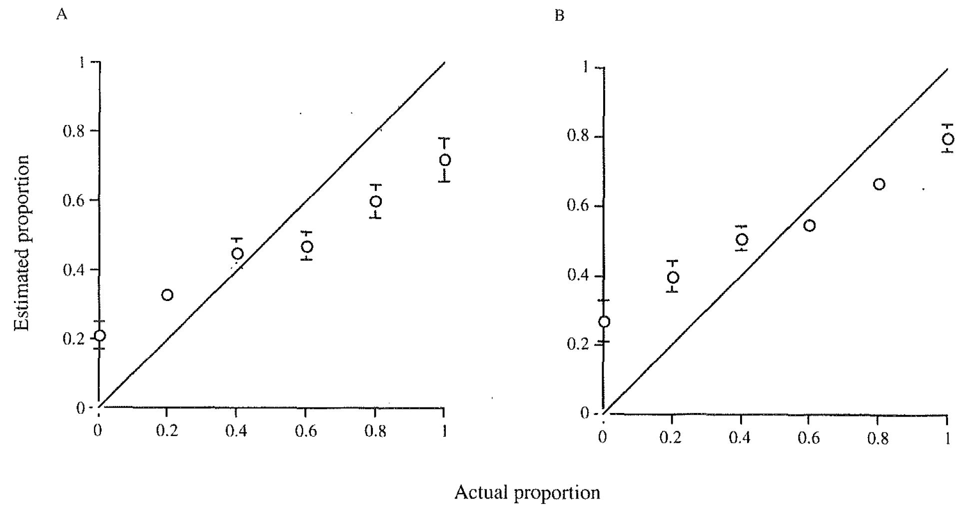

Fig. 1. Mean (±s.e.) values for the estimates made during Test 1 of the proportion of Bennett's wallaby (*A*) and pademelon (*B*) scats in each container in relation to the actual proportion that was present. A line of equivalence ($y = x$) has been included for comparison.

participants. For both species the trends are similar. Observers tended to underestimate the number of scats that were present from a species when they represented a high proportion of the total. Conversely, when scats from a particular species represented only a low proportion of the total, their numbers tended to be overestimated. Results of a Mann–Whitney test indicate that there was no significant difference between the proportion of scats misidentified by inexperienced observers and the proportion misidentified by experienced observers for either species (Bennett's wallaby: $U_{6,6} = 13.0$, $P > 0.05$; pademelon: $U_{6,6} = 12.0$, $P > 0.05$).

Test 2

The trends for Test 2 are the same as those observed in Test 1. For both the Bennett's wallaby (Fig. 2*A*) and pademelon (Fig. 2*B*), observers tended to underestimate the number of scats that were present when they represented a high proportion of the total. Conversely, when scats from a particular species represented only a small proportion of the total, their numbers tended to be overestimated. Results of a Mann–Whitney test indicate that there was no significant difference between the proportion of scats misidentified by inexperienced observers and the proportion misidentified by experienced observers for either species (Bennett's wallaby: $U_{6,6} = 15.0$, $P > 0.05$; pademelon: $U_{6,6} = 18.0$, $P > 0.05$). A Wilcoxon signed-rank test indicated that the overall difference in the mean proportion of scats misidentified was not significantly different between Test 1 and Test 2 (Bennett's wallaby: $T = 17$, $n = 12$, $P > 0.05$; pademelon: $T = 24$, $n = 12$, $P > 0.05$).

Overlooking scats

In total, 2831 macropod scats were found before slashing. A further 246 scats were found after slashing, bringing the total to 3077. The number of scats found at a plantation prior to slashing ranged from 0 to 526 (Table 1). The total number of

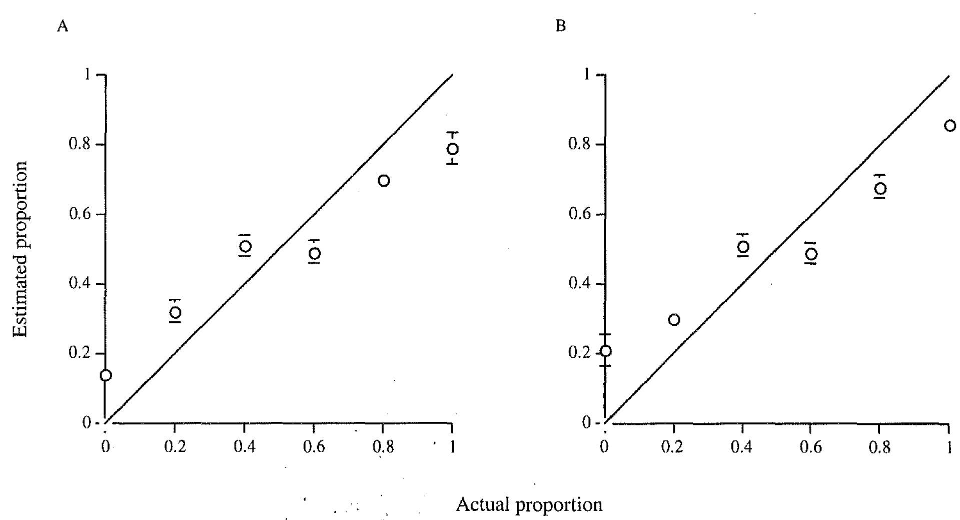

Fig. 2. Mean (±s.e.) values for the estimates made during Test 2 of the proportion of Bennett's wallaby (*A*) and pademelon (*B*) scats in each container in relation to the actual proportion that was present. A line of equivalence ($y = x$) has been included for comparison.

Table 1. Totals for the number of scats found before and after slashing
The percentage of scats overlooked is shown together with mean vegetation height and cover for each site (standard deviations are shown in parentheses)

Plantation	No. of scats found		Percentage overlooked	Vegetation height (cm)	Vegetation cover (%)
	Before slashing	After slashing			
1	255	270	5.6	6.3 (15.1)	16.0 (29.4)
2	142	160	11.3	13.0 (24.1)	30.4 (36.2)
3	526	574	8.4	10.2 (16.0)	25.5 (18.3)
4	350	388	9.8	11.8 (18.3)	8.0 (8.5)
5	470	496	5.2	8.9 (17.3)	38.5 (34.0)
6	309	317	2.5	6.8 (13.0)	59.2 (31.0)
7	321	350	8.3	15.2 (19.2)	23.8 (23.7)
8	79	90	12.2	27.7 (24.5)	33.0 (27.9)
9	379	432	12.3	10.8 (18.8)	13.0 (15.6)
10	0	0	–	6.3 (10.4)	74.8 (34.0)

scats found at a plantation (i.e. those found before and after slashing) ranged from 0 to 574. The percentage of scats that were overlooked (i.e. those found after slashing) was 2.5–12.3%. A paired *t*-test, comparing the total number of scats found at plantations before and after slashing, indicated a significant difference between the two groups ($t = 4.445$, d.f. = 9, $P < 0.01$).

A Chi-squared analysis comparing the observed number of scats missed to that which would have been expected if scats were missed randomly with respect to site indicated that there is a highly significant difference between the two ($\chi^2 = 35.2$, d.f. = 8, $P < 0.01$). The probability of overlooking scats was therefore not constant across sites. The data from Plantation 10 were excluded from the analysis because no scats were found at this plantation.

Between-site differences in the proportion of scats that were overlooked may have resulted from differences in the vegetation characteristics at plantations. Mean vegetation height was 6.3–27.7 cm while mean vegetation cover was 8–75%. A stepwise logistic regression indicated that the probability of finding a scat was significantly related to vegetation height and vegetation cover (–2 log likelihood = 28.7, $P = 0.0001$). The probability of counting a scat can be described by:

$$\text{logit}(p) = 2.431 + [(-0.028 \times \text{height}) + (0.010 \times \text{cover})]$$

where p = probability of counting a scat. However, the confidence interval displacement value ($c = 0.593$) associated with this model suggests that its predictive powers are poor.

Discussion

Identifying scats

Estimates of animal abundance obtained from scat counts can be skewed if significant error is made in the identification of scats from sympatric species (Neff 1968). Johnson and Jarman (1987), for example, carried out a survey of eastern grey kangaroos (*Macropus giganteus*) and red-neck wallabies (*M. rufogriseus*) using scat counts. They found that kangaroo numbers tended to be underestimated while wallaby numbers were overestimated. The authors attributed this result to mistakenly identifying wallaby pellets as kangaroo pellets.

Authors who have carried out population studies of the Bennett's wallaby and Tasmanian pademelon have generally implied that the scats from these two species are readily distinguishable. Johnson (1977: 76–77) states that: 'Bennett's wallaby, pademelon and brush possum each deposit pellets of characteristic and identifiable form'. He describes 'typical' scats from the two macropod species as: 'Bennett's wallaby – discrete, ovoid pellets which are dorso-ventrally flattened, and about 2.5 cm long. Pademelon pellets – cylinders of about 2.5 × 1.1 cm. These are deposited in groups of two to about ten which are adhered end to end or partially overlapped. Gregory (1988: 27) does not describe the criteria by which he distinguished between the two species, stating simply 'faeces were identified'. Statham (1983: 39) states that scats from pademelons are 'distinguished from *M. rufogriseus* pellets by being cylindrical rather than flattened'. None of the authors make reference to any difficulty in identifying scats although Johnson (1977: 76–77) does concede that 'forms vary between individuals, and within individuals over time'.

The results of this study indicate that scats from the two macropod species are not as distinct from each other as these authors purport. All of the people involved in this experiment, including some who were frequently making scat identifications in the field, made incorrect identifications. This error affected the accuracy of estimates for the proportion of scats present for each species. If the proportion of scats from one species was low, or absent, the estimated proportion of scats present tended to be overestimated and *vice versa*. This trend may have been partly an artefact of experimental design. For example, the results may partially reflect the subconscious expectation of observers that scats from the two species were present in a 1 : 1 ratio. However, similar bias may also operate in the field so that observers' prejudices about what animals 'should be there' may influence scat count data.

We do not consider that these results totally invalidate scat counts as a useful means of measuring the relative abundance of macropods. While errors were made by observers, changes in the actual proportions of scats present in a container were still mirrored by changes in the estimated proportions. Thus, large changes in animal abundance could still be expected to be reflected by changes in scat count data. It should also be pointed out that observers may have actually performed better in 'field conditions'. It is possible that the process of collecting scats and drying them may have removed some of the cues that observers are able to use in the field to distinguish between scats from different species. For example, the colour and texture of scats may have changed because of the drying process. In effect, it may be that the results presented here overestimate the potential for misidentification of scats.

The major concern to arise from these results, though, is that the accuracy of scat count data for two (or more) macropod species may be influenced by the magnitude of the difference between the number of scats present for each species. Consider, for example, two identical sites 'A' and 'B'. At site A, 50 Bennett's wallaby scats and 50 pademelon scats are deposited. At site B, 450 Bennett's wallaby scats and 50 pademelon scats are deposited. The results shown in Fig. 1 suggest that if scat counts were carried out at both sites, the relative abundance of pademelons at site B would appear to be at least two times greater than at site A. Clearly, however, this is not the case.

The results also suggest that it is inappropriate to use scat counts as a means of determining the presence or absence of two (or more) macropod species in any area where they are known to occur sympatrically because observers over-estimate when scats from a particular species occur in low numbers or when they are absent. The results from any presence/absence survey using scat counts are, therefore, likely to indicate that wherever one species occurs, the other occurs also.

It appears that, without a large expenditure of effort, there is not much scope for improving the ability of observers to correctly distinguish between the scats of the two macropod species. We reasoned that it might be possible to reduce this type of error by not attempting to identify those scats that are not distinctive in form and by using experienced observers for counts. However, this reasoning was not supported by the results: for both species there was no significant difference in the proportion of scats misidentified in Test 1, where observers identified all scats, and the proportion misidentified in Test 2, where observers identified only those scats about which they felt confident. Furthermore, the 'experienced' observers used in these tests performed no better, on average, than the inexperienced observers. This suggests that identification skills might be improved only by very extensive training. Even then, a proportion of scats may never be confidently identified because they are not distinctive enough.

Overlooking scats

If scat counts are used as a relative measure of animal abundance, then the degree of error involved with counts does not matter as long as it remains constant in space and time. Where this is not the case, counts may be biased. It has long been recognised that the error associated with direct counts of animals during aerial surveys, perhaps the census method most analogous to scat counting, can be influenced by a range of factors (Caughley *et al.* 1976). However, there has been very little examination of the possible biases associated with scat counts, despite the wide range of species and habitat types for which the method has been used. Presumably this reflects the confidence of observers that either all the scats present are counted, or that the chance of overlooking scats is equal for all sites.

In this study, not all scats were found during standard counts on forestry plantations. From a total pool of 3077 scats, 92% were found prior to slashing vegetation. Overall then, the error associated with overlooking scats was low. However, the magnitude of this error varied between sites. The implication of this finding is that between-site differences in scat count data may partially reflect observer bias and differences in site characteristics. It may be possible to negate such site-specific bias by applying correction factors to raw count data so that between-site differences in scat 'sightability' are taken into account (e.g. Bayliss and Giles 1985).

In this study, we used logistic regression to model the probability of finding a scat as a function of vegetation measures. Increases in vegetation height were found to reduce the chances of finding a scat while increases in vegetation cover improved the chances. The latter result seems counter-intuitive and we are unable to offer any strong arguments as to why this trend was observed. It may be that a low, dense covering of vegetation improves scat visibility by holding scats up off the ground and by providing a strongly contrasting background.

Unfortunately, a great deal of the residual variation was not explained by the derived model, indicating that other, unmeasured, variables exert a significant influence on the probability of finding a scat. These variables will need to be isolated before any correction factors can be developed that will substantially improve the accuracy of scat count data. There are a range of factors that may warrant further investigation including lighting (Low *et al.* 1981; Bayliss and Giles 1985; Short and Bayliss 1985) and observer ability (Van Etten and Bennett 1965; Caughley *et al.* 1976; Packard *et al.* 1985; Short and Bayliss 1985). Alternatively, the accuracy of counts might be improved by using a different method of counting to that employed here. For example, if narrower plots were used observers may miss fewer scats because they have a smaller 'search edge' to scan as they move along the plot.

Conclusion

Many studies have used scat counts as a means of measuring relative animal abundance. Of these studies, there are few that have acknowledged the potential for observer error to have influenced their data. However, this study has shown that at least two types of observer error can influence scat count data. The most serious of these errors occurred when observers incorrectly identified scats. We recommend that observers should test their identification abilities wherever scat counts are used to measure the abundance of sympatric species that deposit scats of similar form. If scats are frequently misidentified then another means of census should be considered.

Observers should also not dismiss the possibility that the number of scats found in a plot may be partially related to the vegetation characteristics within the plot. In this study we found that the probability of 'missing' scats was related to vegetation height and cover, even though our tests were performed in areas where vegetation was generally short and between-plot variation was relatively low. We suggest that people should be particularly wary of this type of error where they intend to collect data from very different habitat types (e.g. grazed grassland and dense forest), or if the vegetation characteristics at a study site undergo significant change during the data-collection period.

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References

Arnold, G. W., and Maller, R. A. (1987). Monitoring population densities of western grey kangaroos in remnants of native vegetation. In 'Nature Conservation: the Role of Remnants of Native Vegetation'. (Eds D. A. Saunders, G. W. Arnold, A. A. Burbidge and A. J. Hopkins.) pp. 219–225. (Surrey Beatty and Sons: Sydney.)

Batchelor, C. L. (1975). Development of a distance method for deer census from pellet groups. *Journal of Wildlife Management* **37**, 641–652.

Bayliss, P., and Giles, J. (1985). Factors affecting the visibility of kangaroos counted during aerial surveys. *Journal of Wildlife Management* **49**, 686–692.

Bennett, L. J., English, P. F., and McCain, R. (1940). A study of deer populations by use of pellet-group counts. *Journal of Wildlife Management* **4**, 398–403.

Bulinski, J. (1999). Quantifying and predicting mammalian herbivore damage in Tasmanian eucalypt plantations. Ph.D. Thesis, University of Tasmania, Hobart.

Bulinski, J., Goldney, D., and Bauer, J. (1997). The habitat utilisation and social behaviour of captive rock-wallabies: implications for management. *Australian Mammalogy* **19**, 191–198.

Caughley, G., Sinclair, R., and Scott-Kemis, D. (1976). Experiments in aerial survey. *Journal of Wildlife Management* **40**, 290–300.

Cochran, G. A., and Staines, W. J. (1961). Deposition and decomposition of faecal pellets by cottontails. *Journal of Wildlife Management* **25**, 432–435.

Collins, W. B., and Urness, P. (1978). Elk pellet group distribution and rates of deposition in aspen and lodgepole pine habitats. In 'North American Elk: Ecology, Behaviour and Management'. (Eds M. Boyce and I. Hayden-Wing.) pp. 140–144. (University of Wyoming: Laramie.)

Cox, D. R., and Snell, E. J. (1989). 'The Analysis of Binary Data.' 2nd Edn. (Chapman and Hall: London.)

Floyd, R. B. (1980). Density of *Wallabia bicolor* (Desmarest) (Marsupialia : Macropodidae) in eucalypt plantations of different ages. *Australian Wildlife Research* **7**, 33–37.

Gregory, G. (1988). The control of pest wallaby populations. M.Sc. Thesis, University of Tasmania, Hobart.

Hays, R. L., Summers, C., and Seitz, W. (1981). Estimating wildlife habitat variables. United States Department of the Interior, Fish and Wildlife Service Technical Report 81/47.

Johnson, C. N., and Jarman, P. J. (1987). Macropod studies at Wallaby Creek. VI. A validation of the use of dung-pellet counts for measuring absolute densities of populations of macropodids. *Australian Wildlife Research* **14**, 139–145.

Johnson, K. (1977). Methods for the census of wallaby and possum in Tasmania. Tasmanian National Parks and Wildlife Service Technical Report 77/2.

Lemeshow, S., and Le Gall, J. R. (1994). Modelling the severity of illness of ICU patients. *Journal of the American Medical Association* **272**, 1049–1055.

Low, W. A., Müller, W. J., Dudzinski, M. L., and Low, B. S. (1981). Population fluctuations and range community preference of red kangaroos in central Australia. *Journal of Applied Ecology* **18**, 27–36.

Neff, D. J. (1968). The pellet-group count technique for big game trend, census and distribution: a review. *Journal of Wildlife Management* **32**, 597–614.

Packard, J. M., Summers, R. C., and Barnes, L. B. (1985). Variation of visibility bias during aerial surveys of manatees. *Journal of Wildlife Management* **49**, 347–351.

Rogers, G., Julander, O., and Robinette, W. L. (1958). Pellet group counts for deer census and range use index. *Journal of Wildlife Management* **22**, 193–199.

SAS Institute. (1989). 'SAS/STAT Users Guide, Version 6.' 4th Edn. (SAS Institute: Cory.)

Short, J., and Bayliss, P. (1985). Bias in aerial survey estimates of kangaroo density. *Journal of Applied Ecology* **22**, 415–422.

Southwell, C. (1989). Techniques for monitoring the abundance of kangaroo and wallaby populations. In 'Kangaroos, Wallabies and Rat-kangaroos'. (Eds G. Grigg, P. Jarman and I. Hume.) pp. 659–693. (Surrey Beatty and Sons: Sydney.)

Statham, H. (1983). Browsing damage in Tasmanian forest areas and effects of 1080 poisoning. Forestry Commission of Tasmania Bulletin No. 7.

Taylor, R. H., and Williams, R. M. (1956). The use of pellet counts for estimating the density of populations of the wild rabbit, *Oryctolagus cuniculus*. *New Zealand Journal of Science and Technology* **38**(B), 236–256.

Van Etten, R. C., and Bennett, C. L. (1965). Some sources of error in using pellet-group counts for censusing deer. *Journal of Wildlife Management* **29**, 723–729.

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