HOW EFFECTIVE ARE GRID TRAPPING, OIL CARDS AND TRACK BOARDS IN MONITORING BUSH RAT POPULATIONS?

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Monitoring populations is a key component of wildlife conservation and management. This study aimed to evaluate the effectiveness of abundance indices used for estimating populations of the bush rat *Rattus fuscipes*. The study was conducted on Fraser Island, Queensland, Australia. A trapping grid consisting of 5 x 5 trap stations, 20 m apart, was used because this configuration was typical of those used for small mammal trapping in Australia. Capture-recapture data were collected from trapping 18 grids over four consecutive nights, immediately followed by two consecutive nights of conducting oil card and track indices. On 11 grids, model M_b was selected by the CAPTURE model selection procedure, indicating increased capture probability after first capture (trap-happy). The estimated trappable population size (Ñ) on these grids was not precise with the standard error on average being 28% of Ñ. On the other seven grids, the number of animals caught was too small (<3) to estimate model parameters. The main problem of the grid trapping was that some grids caught too few animals to estimate Ñ. Our data suggest that the minimum grid area for estimating useful Ñ is one that would catch more than 8 individuals. The minimum grid area varies depending on the density of rats and should be determined by a pilot trapping study. The number of trapping occasions can be increased until a specific precision of Ñ is reached. The correlation between track index and Ñ was near the 0.05 significance level indicating tracks are potentially a reliable index for monitoring bush rat populations. The oil card index was not significantly correlated with Ñ.

Key words: capture-recapture, indices, population estimates, *Rattus fuscipes*.

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THE bush rat *Rattus fuscipes* has been extensively studied by ecology students and professionals (Taylor 1961). It is abundant and easily trappable, and it has a large range in coastal mainland Australia that is proximal to heavily populated cities and regional centres (Watts and Braithwaite 1978). The species plays an important role in many ecological communities (e.g., Lunney *et al.* 1987; Laurance 1997). Furthermore, the bush rat is an economically important pest in sugarcane (Smith *et al.* 2003) and pine plantations (McNally 1960; Warneke 1971). Accurate population monitoring is the key to evaluating the success of management programs for the abundance of bush rats in both natural and agricultural ecosystems.

Live-trapping has been the most commonly used method to monitor bush rats (e.g., Kemper 1990; Lindenmayer *et al.* 2005). The number of unique animals caught during a trapping period and number known to be alive (commonly termed as minimum number known to be alive - MNA (Krebs 1966)) have been employed as abundance indices of bush rat populations, with its first known use in the 1960's by Warneke (1971). Trap success is used as an abundance index of other rodent populations such as the house mouse, *Mus domesticus* (Brown and Singleton 1998) and vole, *Microtus oeconomus* (Boonstra *et al.* 1992). Capture-recapture data may be analysed by a number of increasingly sophisticated methods to estimate the size of the trappable population Ñ (review in Williams *et al.* 2002). Since the early use of the Petersen population estimator, a number of additional population estimators have been developed (Seber 1965, 1982; Pollock *et al.* 1990; Scharwz and Arnason 1996; Pollock 2000; Buckland *et al.* 2000; Efford 2004). The use of population models is gaining popularity because their calculations have been made easier with computer software such as CAPTURE (White *et al.* 1982), MARK (White and Burnham 1999) and SURGE (Pradel and Lebreton 1993).

Oil cards and track boards are used to index rodent pests such as house mice (Ryan and Jones 1970) and

Norway rats *R. norvigicus* (Quy *et al.* 1993) because they are easier to use and less costly than trapping methods, and do not require handling of animals, which is an important issue when considering potential zoonotic diseases. These population estimates and indices may be used for improved monitoring of bush rats. The present study is therefore aimed to evaluate the effectiveness of these methods in monitoring bush rat populations. The evaluation is based on a trapping grid of 25 traps with four trapping occasions which is typical of trapping regimes commonly used (Catling *et al.* 1997; Dickman *et al.* 1999; Penn *et al.* 2003; Lindenmayer *et al.* 2005).

METHODS

Study Area

The study sites were located on Fraser Island, south east Queensland, Australia. Eighteen trapping grids were established in the key habitats found in the southern, central and northern parts of the island: heath (n = 7 grids); rainforest (5); wet sclerophyll (2); open woodland (2) and brush box habitats (2). Two additional grids (grids 1 and 14) were also established but were not trapped because of logistic difficulties. The study was conducted with the approval of the University Queensland Animal Ethics Committee (Approval number- SAS/571/03/UQ) and the Queensland Parks and Wildlife Service.

Trapping

To maintain sampling independence, the grids were at least 200 m apart to prevent individual rats from being caught by more than one grid and this did not occur during the study. The grids were located at least 20 m from the edge of a lightly used, four-wheel drive dirt track to minimise potential edge effects. Each grid consisted of 5 x 5 trap stations, 20 m apart and was sampled with one live-capture trap (Elliott, Type A; 30 x 10 x 10 cm in dimension) at each station for four consecutive nights.

The grids were trapped between 12 January and 15 February, 2004. Traps were baited with a mixture of peanut butter, honey, flour, water and vanilla essence and were checked and, when necessary, cleared, re-baited and reset as soon as possible after sunrise. Trapped animals were individually identified, and released at the point of capture. Newly captured animals were ear tagged (Hauptner) with a unique number, weighed, sexed and identified to species.

Track Index

The track boards were made of medium density fibre board "Corriboard", 1.5 m long, 100 mm wide and 2 mm thick. One surface of the board was coated with a smooth, white, plastic foil. This surface was painted with carbon powder (lampblack) suspended in methylated spirits (2g/100ml) for tracking the footprints of rats (Shepard and Greaves 1984). This method was used because the tracking surface is known to be resistant to light rain. Immediately following the trapping period, five track boards were set on the grid along a row of five stations (one board per station) for two consecutive nights. The track boards were only left in the field for two consecutive nights because this was the minimum requirement to overcome any potential variation between days. Each board was assessed for percentage covered by rat footprints each morning and, if necessary, recoated for the following night. One set of rat tracks was scored as 1%, two sets 2% and so on until 5%, after which it was difficult to discern separate sets of tracks. It was then scored by the percentage of the track board covered by rat tracks at 10% increment until 100%. A score of 100% was given when almost no carbon remained on the boards. Track index was the mean percentage of track board covered with rat footprints.

The percentage data were transformed using the standard arc sin transformation to meet the assumptions of normality, before averaging the data for each grid. The average was then converted back to percentage scale using a sin function.

Oil card index

Oil cards were 10 x 10 cm pieces of white bond paper (photocopying paper) soaked with canola oil (Ryan and Jones 1970). Immediately after the trapping period, five oil cards were set for two consecutive nights. The five oil cards were placed in the grid along a row of five stations (one per station). Oil cards and track boards were sampled concurrently on a grid. This was done to minimise the duration of the study given the populations were assumed to be closed for a short period of time. The linear placement of oil cards and track index was used in this study because these indices were typically sampled along transects. The row of oil cards and the row of track boards were 80 m apart at the opposite end of the grid to minimise any potential interference between the two methods. The spatial separation of cards and boards was smaller than the known home range span of the bush rat (Lunney *et al.* 1987) and is therefore unlikely to cause bias in the response of rats to the indices on the grid. The card was secured to the ground with a wire peg and left overnight. One hundred (10 x 10) grid cells each 10 x 10 mm were marked on the card. Consumption of the card (percentage) was assessed by counting the number of grids remained in the following morning. The cards were checked each morning, and replaced on the first day if it was gnawed by rats. The oil card index was the mean percentage area of oil card consumed each night for two nights. The percentage data were averaged as described for the track index.

Grid	Habitat Type	Population Estimate Ñ	s.e. of population estimate	Model	Number individuals caught	Oil card index	Track index	Trap success (adjusted)
2	Heath	2.0	0	M_b	2	21.85	1.66	13.04
3	Heath	2.0	0	M_b	2	35.07	0.86	7.41
4	Rainforest	8.14	0.23	M_b	8	13.63	0.46	16.61
5	Brushbox	7.8	1.84	M_b	7	50.62	11.44	21.01
6	Brushbox	10.5	4.72	M_b	7	15.62	3.83	16.13
7	Rainforest	6.7	2.14	M_b	6	2.63	4.27	13.82
8	Rainforest	11.1	4.6	M_b	8	39.27	2.42	18.01
9	Heath	2.0	0	M_t	2	16.16	0.00	3.71
10	Heath	1.0	0	M_t	1	8.84	0.00	2.04
11	Woodland	1.0	0	M_t	1	6.14	0.00	2.04
12	Woodland	2.0	0	M_t	2	20.52	0.00	3.05
13	Heath	1.0	0	M_t	1	17.76	0.00	2.04
15	Heath	2.0	0	M_t	2	8.23	0.00	3.05
16	Heath	2.0	0	M_t	2	12.31	0.00	7.41
17	Wet sclerophyll	4.1	0.23	M_b	4	88.69	8.14	12.78
18	Rainforest	9.8	3.62	M_b	8	73.00	1.52	22.88
19	Rainforest	5.2	1.98	M_b	5	32.34	6.13	19.72
20	Wet sclerophyll	2.0	0	M_b	2	62.69	2.62	7.57

Table 1, Population estimates (Ñ), their standard errors, model, number of individuals, track index, oil card index and trap success of bush rats (*Rattus fuscipes*) at 5 x 5 trapping grids on Fraser Island, Australia. Trap success is the number of captures per 100 trap-nights. Track index was the percentage of the track board covered by rat tracks. Oil card index was the percentage consumption.

Population estimate Ñ

Populations were assumed to be closed during the four days of trapping and were estimated based on the mark-recapture data using the Program CAPTURE (Otis *et al.* 1978) within the program MARK (White and Burnham 1999).

Number of animals caught

The minimum number known to be alive (MNA) was traditionally used to index bush rat population. Since only one trapping session was conducted, MNA was effectively the number of unique animals caught during the trapping occasion. Therefore the use of the term "MNA" would be misleading in this experiment and hence it was replaced by the more appropriate term "number of animals caught" (Slade and Blair 2000).

Trap success

Trap success was the total number of captures, including recaptures, during a trapping period, expressed as the number of captures per 100 trap nights, after correction for captures of non-target species and sprung traps (Nelson and Clark 1973; Beauvais and Buskirk 1999). All trap success indices were transformed using the frequency density transformation of Caughley (1977) to account for traps becoming unavailable once they have caught a rat.

RESULTS

A total of 71 individual rats were captured 138 times on the 18 grids over 1,729 trap-nights. There were 17 (42.5% of all captures), 32 (71.1%) and 25 (92.5%) recaptures on the second, third and fourth night of trapping. The population estimate, Ñ, population model, number of animals caught, oil card index, track index and trap success are listed in Table 1. The Model M_b was selected by the CAPTURE model selection procedure for 11 of the 18 of the grids. Model M_b allows an animal to exhibit a behavioural response to first capture and become either "trap-happy" or "trap-shy" (Otis *et al.* 1978). On these 11 grids increased capture probability after first capture (trap-happy) was confirmed by the model. As Boulanger and Krebs (1994) suggested using one model consistently for comparison, Model M_b should be used for all grids. However, on seven grids, the number of animals caught was either one or two. These sample sizes were too small for estimating the parameters of model M_b. We therefore used model M_t, the next less sophisticated model. However, the use of model M_t resulted in Ñ being the number of animals caught and the standard error of Ñ being zero.

	Population Estimate Ñ	No. individuals caught	Trap success	Oil card index
No. individuals caught	0.973			
	<0.0001			
Trap success	0.857	0.915		
	<0.0001	*<0.0001*		
Oil card index	0.274	0.3	0.471	
	0.272	*0.227*	*0.049*	
Track index	0.43	0.481	0.636	0.543
	0.075	*0.044*	*0.005*	*0.02*

Table 2. Correlation between population estimates (Ñ) and other indices. Pearson correlation coefficient and probability values (italic) are listed.

Ñ was highly significantly correlated with the number of individuals and trap success, both of which were in turn highly significantly correlated with each other (Table 2). The oil card index was significantly correlated with the track index and with trap success, but not with Ñ (Table 2). The track index was significantly correlated with the number of animals caught and with trap success, but not with Ñ (Table 2).

DISCUSSION

The potential bias of using Ñ as the basis for evaluating the indices is because the spatial extent of the trappable population is unknown and is implicitly assumed to be constant. Ñ is often treated as a vague and evasive synonym for population density but it is not. The spatial extent was inevitably larger than the area covered by the grid (edge effect). The size of this edge effect varies with the trap layout, and with home range size, which is in turn likely to vary with rat density and with habitat. This problem may be overcome by using radio tracking to estimate the spatial extent of the trappable population or by using simulation and inverse prediction to estimate unbiased population density (Efford 2004).

However, unbiased estimation of population density is a major and unsolved problem in animal trapping studies. Population density is what wildlife managers ultimately want to know about in most monitoring programs (Krebs 1985). For example, an economic threshold of bush rat density is required to make sound management decisions to implement rodent control measures in sugarcane farms (review in Hone 1994). Furthermore, known or unbiased estimates of densities of bush rats should be used to critically evaluate the performance of Ñ and the indices. It is, however, not feasible to obtain estimated densities in the field. Until such data are available, the most practical approach is to use a large sample of Ñ as the basis to evaluate critically the performance of the indices. This approach is supported by Davis *et al.* (2003) and Manning *et al.* (1995) who demonstrate that Ñs are significantly correlated with the known density of populations of house mice and voles confined in enclosures.

The correlations of Ñ with number of animals caught and with trap success were not unexpected because Ñ cannot be less than the number of animals caught (e.g., Hilborn *et al.* 1976; Boonstra 1985; Efford 1992), and because Ñ is seldom much larger than numbers of animals caught with Models M_b and M_t. Nevertheless, the strong correlations (>0.80) suggest that the index and the model are proportional (Slade and Blair 2000), and that both indices are reliable. Number of animals caught is a more reliable index than trap success because it was more strongly correlated with Ñ than trap success (Table 2). Wood (1971) reported a similar finding that that there were no marked differences between the monthly MNA (number of animals caught) and Lincoln-Petersen population estimates (Ñ with Model M_0) of a single population of bush rats for 40 months. Slade and Blair (2000) also reported a strong correlation (>0.9) between the Lincoln Petersen estimate and MNA for five species of rodents, trapped monthly at a single site from 1973 to 1993. The number of animals caught by kill trapping has been used to monitor pest rodent populations (e.g., Tobin and Sugihara 1992) and may be used for monitoring pest population of bush rats. Using simulations and statistical theory, McKelvey and Pearson (2001) demonstrate that the number of animals caught is a good index of population size, because it generally exhibits lower variance and less sensitivity to the sources of variation in capture probabilities than the models in circumstances where the performance of the models as an index is compromised by small sample sizes.

The oil card index was not significantly correlated with Ñ, indicating this index should not be used for monitoring bush rat populations. Mutze (1998) reported a similar finding that oil card consumption was not a reliable index of the abundance of mice when alternative food was available. Whisson *et al*. (2005) also reported a lack of correlation between a chew card index and known densities of six population of voles confined in pens.

The significant correlations between trap success, number of animals caught, oil card and track indices might simply reflect that the responses of rats to these indices were associated. The associations of rats entering a trap, gnawing an oil card and walking across a track board were possibly due to rats being actively foraging on the grid.

Observed index is a product of the density of rats and the mean probability that a rat will respond to the index method. Clearly, differences in these indices may be due to differences in the probability of rats responding to the index rather than differences in rat density. If the probability of rats responding to the index varies little over time or between sites, then the index can be used reliably to track temporal or spatial changes in density (review in Engemann 2005).

Brown *et al*. (1996) reported a tight correlation (r = 0.989) between numbers of black rats (*R. rattus*) and a track index from a removal study. Whisson *et al*. (2005) were not able to demonstrate a significant correlation between a track index and density of voles using six populations of known sizes confined in enclosures. Our data showed the correlation between track index and Ñ was near the 0.05 significance level, indicating tracks are potentially a reliable index for monitoring bush rat populations, while also being a non-invasive, low effort technique. The track index may or may not work in habitats where the bush rat and other rat-sized rodent species are sympatric. Field trials are required to determine if the track index is species specific at these sites.

Management Implications

We recommend that the track index is used for monitoring bush rats because of its simplicity and correlation with Ñ. However, the index should be used with replication to provide a simple measure of precision for comparisons. If there are no replicates in the experiment, grid trapping and population modelling will provide a variance estimate of Ñ for comparison. A larger trapping grid should be used for this because the main problem with the commonly used grid trapping regime was the very small number of individuals caught per grid. The parameters of Model M_b could not be estimated on grids where the number of animals caught was less than 3. Although M_b parameters were estimated on grids where the number of animals caught ranged from 3 to 8, Ñ was not precise with the standard error on average being 28% of Ñ.

Given the benchmark output of capture-recapture analyses is Ñ, one should not use the raw number of animals caught or trap success, as all three are calculated from the same capture-recapture data (Nichols and Pollock 1983). Furthermore, only Ñ comes with a variance estimate which allows the test for significant difference in Ñ between grids. However, it is surprising that the number of animals caught and MNA have been used more frequently than Ñ. In fact, of all the numerous published population studies on bush rat populations examined in this study, only one attempted to estimate Ñ (Wood 1971). The reason for not using Ñ was not specified in these reports. A plausible reason was that the sample size was too small to estimate precise and unbiased Ñ (review in McKelvey and Pearson 2001).

Our data highlight the need to improve the grid trapping regime for studying *R. fuscipes*. Otis *et al.* (1978) suggested that a population size of 50 and a mean capture probability as high as 0.50 is required to produce precise estimates. In general, five trapping occasions and a 10 x 10 trapping grid is the minimum requirement to estimate precise Ñ (Otis *et al.* 1978). However, grids of 20 traps (10 m apart in 2 x 10 configuration) have been used for studying small mammals including *R. fuscipes* by Catling *et al.* (1997), 25 traps (10 m apart in 5 x 5) by Lindenmayer *et al.* (2005) and 24 traps (10 m apart in 12 x 2) by Penn *et al.* (2003)

The number of individuals caught per grid may be increased by enlarging the area of the grid so that more trappable animals occur in the grid. If additional traps are not available, the grid area can be enlarged by increasing the spacing between traps from 20 m to, perhaps, 30 m. Although this will reduce the density of traps and possibly the number of recaptures and the precision of Ñ, this may not be a problem given the bush rat is trap-happy.

Because estimator precision is a function of the number of model parameters, one should eliminate nuisance parameters (Williams *et al.* 2002). Our capture history data indicate that pre-baiting by placing bait in traps or at trap stations over four days before the traps are actually set would reduce the trap-happy response of bush rats. As a result, model M_b would be replaced by model M_0 (constant capture probability among animals). There are less parameters in model M_0 (2 parameters) than M_b (3) and hence the model precision would be improved. Furthermore, pre-baiting would also increase the overall capture probability of bush rats that would further improve the model precision.

The number of trapping occasions may be increased to improve the precision of Ñ. The standard errors can be calculated at the end of each trapping occasion and additional trapping occasions are conducted until the required precision is reached. The number of trapping occasions should be no more than 10 or the assumption that the population is closed to loss and gain may be violated (Otis *et al.* 1978). Alternatively, a pilot study may be used to obtain a rough population estimate and capture probability, which are then used to determine the grid size based on computations provided by Otis *et al.* (1978) and White *et al.* (1982). Our data suggest that the minimum grid size for *R. fuscipes* is one that would catch more than 8 individuals.

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