

## The use of habitat components by small mammals in eastern Australia

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### Abstract

*The effect of habitat components (vegetation density at two levels, litter, logs and roads) on the distribution of small mammals was assessed in adjacent areas of native forest and Pinus taeda plantation in north-eastern New South Wales. Rattus fuscipes was associated with structural complexity in native forest but not in pine plantation where it was found on downslope areas. R. rattus was associated with windrows in the pine plantation, R. lutreolus with areas devoid of a shrub layer in the pine plantation, Antechinus stuartii with logs and Melomys cervinipes with habitat components associated with rainforest areas. Road crossing by small mammals was inversely related to road width; roads severely restricted or stopped the movement of small mammals even when the road consisted of a long-unused and partly overgrown track.*

### Introduction

The association between small mammals and vegetation is often examined by reference to sharply defined or distinct vegetational zones such as coniferous/deciduous borders (Kirkland & Griffin 1974) and grassland/woodland borders (Golley 1962; Whitaker 1963) and the

association of small mammals within these broad habitat categories. Exceptions include Myton (1974) who examined the effect of ground cover on small mammal distributions and Prakash (1975) who indicated a relationship between basal cover of vegetation, root structure and rodent distribution. M'Closkey (1976) showed that spatial and temporal habitat separation were identifiable by shrub structure and substrate patchiness in seven sympatric rodents in California. Attempts have been made to relate rodent distribution to the detailed floristics of areas and to vegetation density (Robinson 1975) and to experimentally manipulate habitats to examine species diversity (Rosenzweig & Winakur 1969).

Several Australian small mammals have wide geographic distribution and inhabit widely differing vegetation types. For example, the brown marsupial mouse, *Antechinus stuartii* Macleay, inhabits temperate forest, subtropical and tropical rainforest and heath communities over a wide climatic range in south-eastern and eastern Australia (Wakefield & Warneke 1967; Wood 1970). The bush rat, *Rattus fuscipes* Waterhouse, also has a wide distribution extending from south-western Australia across southern Australia to northern Queensland (Warneke 1971). Intuitively then, a floristic analysis of habitats will have little predictive power as to habitat preferences for these wide ranging small mammals. Other components of habitat should be of greater import, particularly habitat structure. In this context a knowledge of plant species diversity did not improve prediction of bird species diversity (MacArthur & MacArthur 1961) which suggests that they recognize structure rather than the type of vegetation (Pianka 1974).

This study examined various structural components of habitats used by small mammals in north-eastern New South Wales.

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These components included vegetation density at different levels, the presence of logs and fallen trees and the effect of habitat discontinuities, in the form of roads, on the distribution of small mammals.

## Study area

A general description of the study area at Clouds Creek in north-eastern New South Wales has been given elsewhere (Barnett, How & Humphreys 1976). The study was conducted using a grid of trap locations extending through the interface between a pine plantation and native forest.

The plantation of loblolly pines, *Pinus taeda* L., was established on an area cleared of native forest, windrowed and burnt. The plantation, 7 years old, had an understorey consisting of some dense stands of *Helichrysum* sp., *Cassinia* sp. and *Acacia floribunda* (Vent.) Wild. with blady grass (*Imperata cylindrica* L.), forest wire grass (*Tetrarrhena juncea* R. Br.) and tussock grass (*Poa* sp.) covering the ground layer. The peripheral 20 m had been cleared of *Helichrysum* and *Cassinia* and was dominated by tussock and blady grasses.

The native forest varied from wet sclerophyll forest adjacent to the plantation to subtropical rainforest towards the creeks. In addition to naturally fallen trees, twelve had recently been felled and left in place. The ground cover at the edge of the native forest was dominated by blady grass and small patches of tussock grass in the area which had been burnt annually. Open areas within 50 m of the periphery and especially along the edge of the fire trail (track C below) were dominated by native blackberries (*Rubus hillii* F. Muell. and *R. moorei* F. Muell.) and bracken, *Pteridium esculentum* (Forst. f.). Ground vegetation within the wet sclerophyll forest and rainforest was principally the fern *Blechnum cartilagineum* Swartz and several types of lianas.

Three tracks ran through the study area (labelled A, B and C in Fig. 2a). Track C was a 4.5 m wide unsealed plantation arterial road with traffic ranging from zero to about twenty vehicles a day. Track B was a feeder road 3.25 m wide in an area roaded for future plantation; it had weed growth in

parts and had a traffic use of less than one vehicle a day. Track A was an old fire trail 3 m wide which had long been closed by fallen trees, covered with low ground vegetation and had a slight litter cover.

## Methods

The study area was a grid of 286 trap locations situated 25 m apart (Fig. 1(a)). Small mammal live traps (Elliott Scientific Equipment, Upwey, Victoria) were set in the afternoon and baited with peanut butter and rolled oats; in cold wet weather the traps were placed in polythene bags. They were checked the following morning and animals caught were identified; species, sex, breeding condition and weight were recorded. New animals were marked by toe clipping and individuals were bled by puncture of the optic sinus on the first day of capture of each trapping period for physiological studies. Animals were released at the point of capture. Within each trapping period additional traps were placed at each successful trap locality to maintain a number of traps in excess of the number of animals normally captured on any night at that site. The study area was trapped seven times on alternate days during February, May, August and October 1975 and February 1976. The pine section of the grid was not trapped in August. Extensions to the original 10 × 10 (100) grid sections were made in May 1975 and trapped during subsequent sampling periods. The study involved 7372 trap nights.

At each of the 100 original trap localities in the native forest (the main 10 × 10 grid) assessment was made of components of the habitat. Each of four components (vegetation < 1 m, vegetation 1–2 m, logs and litter) was assessed visually and subjectively scored 0–3 according to the density or amount of the component (Fig. 1). Similarly 100 trap locations in the pine plantation were assessed according to the proximity of the windrows, amount of tall grass (*Imperata cylindrica*), short grass (*Poa* sp. and *Tetrarrhena juncea*) and *Helichrysum* sp. and *Cassinia* sp. (the main shrub layer). In addition all scores for each location were summed to give an index of structural complexity. The data were analysed by pairing the habitat score with the number of individual mammals of each

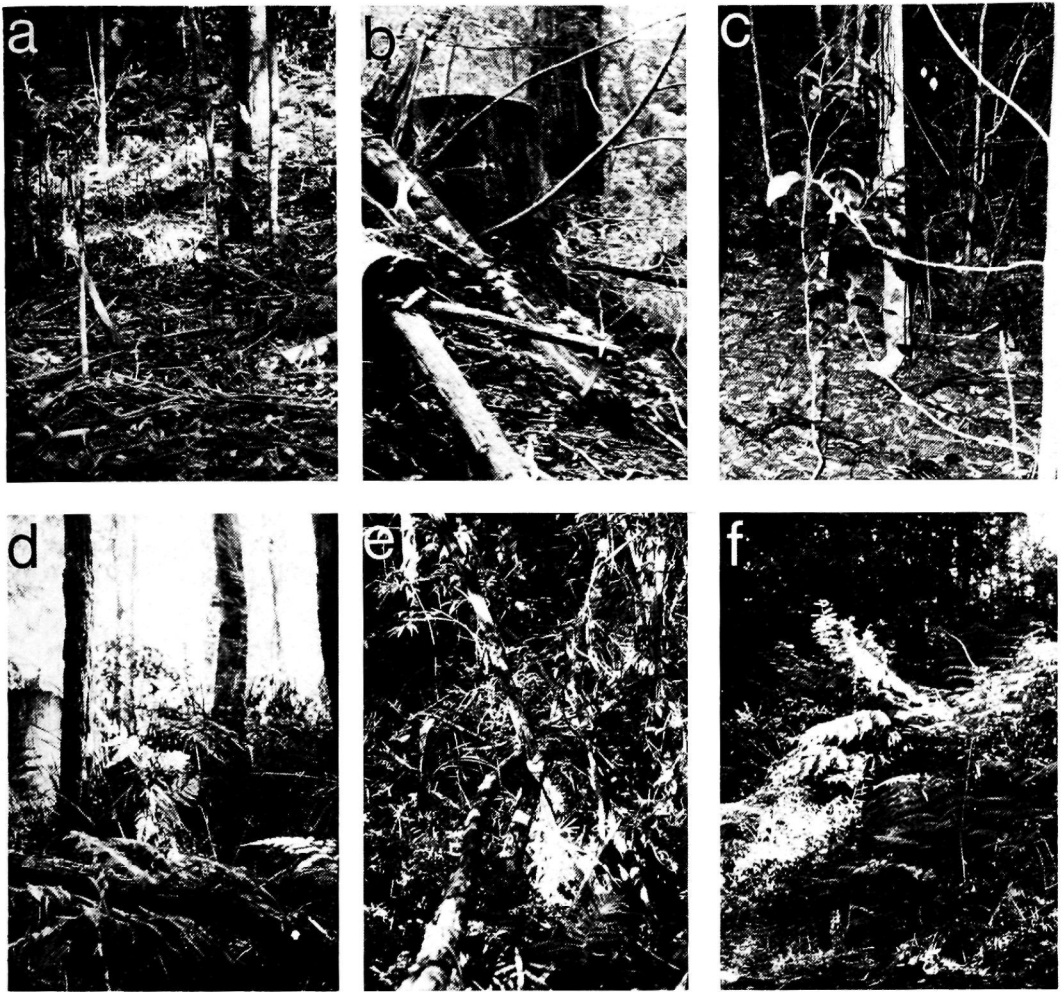


FIG. 1. Photographs showing the ratings given to various habitat components in the native forest grid.

	Photograph					
	(a)	(b)	(c)	(d)	(e)	(f)
Vegetation < 1 m	0	0	1	2	3	3
Vegetation > 1 m	0	0	1	0	2	3
Litter	3	2	2	1	2	0
Logs	0	3	0	1	1	1

species caught at that trap location and the Spearman's rank correlation coefficient calculated (Siegel 1956). Some of the mammal data were additionally analysed using Cole's (1949, 1957) indices of interspecific association.

The movement of small mammals was calculated as the average distance between successive recaptures during a trapping period

and all movements were checked to determine whether road crossing had occurred.

## Results

Six species of small mammal were trapped on the grid; these were *Rattus fuscipes* Waterhouse, *Antechinus stuartii* Macleay, *Melomys*

TABLE 1. Number of individuals (number of captures) and density  $\text{ha}^{-1}$  in four areas of the grid\*

	Pine		Native		
			Edge	Centre	Extension
<i>R. fuscipes</i>	♂	15 (33) 2.0	5 (12) 3.6	8 (20) 1.6	8 (8) 1.5
	♀	16 (47) 2.1	5 (8) 3.6	8 (28) 1.6	7 (21) 1.5
<i>A. stuartii</i>	♂	5 (7) 0.67	6 (8) 4.3	16 (46) 3.3	6 (11) 1.3
	♀	0	5 (22) 3.6	18 (71) 3.7	10 (36) 2.1
<i>M. cervinipes</i>	♂	0	0	6 (17) 1.2	1 (1) 0.2
	♀	0	0	11 (25) 2.2	1 (1) 0.2

\*Density estimated as in Barnett *et al.* (1977).

*cervinipes* Gould, *Rattus lutreolus* Gray, *Rattus rattus* L. and *Mus musculus* L. Only *R. fuscipes* had populations present in both the pine plantation and the native forest (Fig. 2(b) and Barnett *et al.* 1976). The summary data for the more common species are given in Table 1.

#### *Rattus fuscipes*

In the native forest the number of individual *R. fuscipes* captured was correlated with structural complexity ( $r_S = 0.30$ ;  $P < 0.001$ ) and the females were positively associated with the density of vegetation between 1 and 2 m above ground ( $r_S = 0.29$ ;  $P < 0.005$ ). Within the pine plantation this species was not significantly associated with any of the components considered.

#### *Antechinus stuartii*

*A. stuartii* was found in native forest (Fig. 2(c)) where males were inversely associated with the vegetation density below 1 m ( $r_S = -0.21$ ;  $0.05 > P > 0.01$ ) while females were associated with logs ( $r_S = 0.21$ ;  $0.05 > P > 0.01$ ) which they use for refuge. There was a strong negative correlation between vegetation density below 1 m and logs ( $r_S = 0.49$ ;  $P < 0.005$ ) while logs and litter were strongly associated ( $r_S = 0.39$ ;  $P < 0.005$ ).

#### *Melomys cervinipes*

The mosaic-tailed rat *M. cervinipes* was trapped only in the native forest and almost exclusively in areas of rain forest (Fig. 2(d)). Females were negatively associated with

vegetation density below 1 m ( $r_S = -0.26$ ;  $0.01 > P > 0.005$ ) and both males and females were associated with litter ( $r_S = 0.25$ ;  $0.05 > P > 0.01$ ). Vegetation < 1 m and litter were negatively associated ( $r_S = -0.27$ ;  $0.01 > P > 0.005$ ).

#### *Rattus lutreolus*

The swamp rat *R. lutreolus* was trapped only in the pine plantation (Fig. 2(d)) where it was negatively associated with *Helichrysum* and *Cassinia* scrub ( $r_S = -0.37$ ;  $P < 0.005$ ). Scrub was not found on the periphery of the plantation since it had been cut out of that area before the study started.

#### *Rattus rattus* and *Mus musculus*

The black rat, *R. rattus* and the house mouse *M. musculus*, both exotic species, were trapped only in the pine plantation. *R. rattus* was associated with the windrows ( $r_S = 0.31$ ;  $P < 0.005$ ).

#### Interspecific associations

Although *Rattus fuscipes* and *Antechinus stuartii* were both widespread in the native forest they were not significantly associated ( $\chi^2 = 3.44$ , N.S.; Cole's (1949) index of inter-specific association). There was a tendency for *Melomys cervinipes* to be associated with *A. stuartii* ( $r_S = 0.149$ ) and negatively associated with *R. fuscipes* ( $r_S = -0.115$ ) but neither was significant ( $P > 0.05$ ). When all three species were considered together, *R. fuscipes* and *A. stuartii* were less closely associated when *M. cervinipes* was present

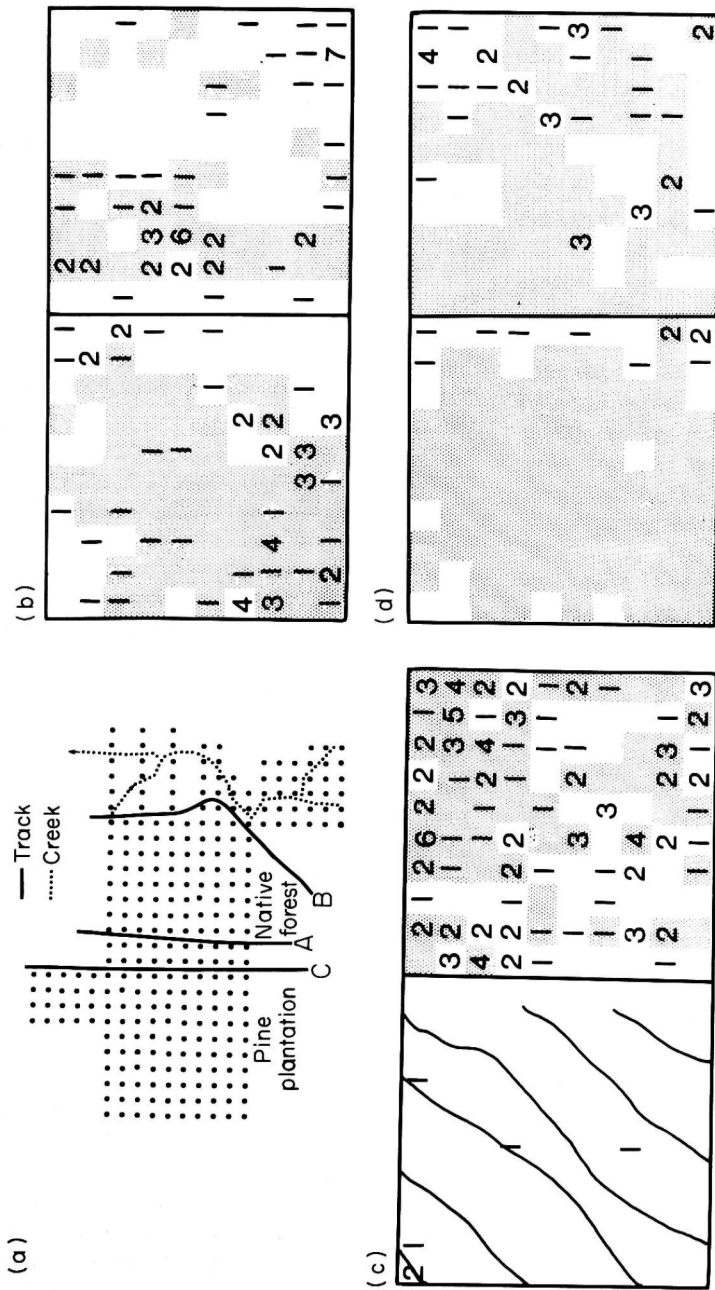


FIG. 2(a) Stylized plan of the study area showing the location of traps (dots), roads (A, B and C; see text) and creeks. The associations of the various species with habitat structure were derived from the two main blocks ( $10 \times 10 = 100$ ) of trap positions while the movement data were obtained from the entire grid. In Fig. 2(b), (c) and (d) the left side represents the 100 trap locations in the pine plantation and the right side those in the native forest; they are separated by road C. (b) The number of individual *Rattus fuscipes* captured at each trap location on the main grid. Positions where no individuals were trapped are left blank. Shading on the pine grid denotes areas of *Helichrysum* and *Cassinia* sp. rated  $\leq 2$  (range of rating used = 0 to 3); on the native forest grid shading denotes vegetation between 1 and 2 m rated  $\geq 2$ . (c) The number of individuals of *Antechinus stuartii* captured at each trap location on the native forest grid and *Rattus rattus* on the pine grid. The lines on the latter represent windrows and shading on the native forest grid denotes logs rated  $\geq 2$ . (d) The number of individuals of *Rattus lutreolus* captured at each trap location on the pine grid and of *Melomys cervinipes* on the native forest grid. Shading on the latter represents vegetation  $< 1$  m rated  $\geq 2$  and on the pine grid denotes *Helichrysum* and *Cassinia* sp. rated  $> 0$ .

TABLE 2. Movements (m) between successive recaptures; mean  $\pm$  S.E. (n)

	<i>A. stuartii</i>	<i>R. fuscipes</i>	<i>M. cervinipes</i>
Male	70 $\pm$ 8 (37)	95 $\pm$ 14 (45)	69 $\pm$ 14 (9)
Female	54 $\pm$ 4 (68)	42 $\pm$ 4 (65)	70 $\pm$ 11 (12)

than when it was absent ( $t = 6.072$ ;  $P < 0.001$ ; Cole's (1957) index of partial interspecific association). This suggests that there was some interaction between the two rodent species but more data on *M. cervinipes* are required.

### Movement

Male *R. fuscipes* and *A. stuartii* moved further between successive captures than did females (Table 2); this is a common occurrence in small mammals (Stickel 1946; Eriksen 1949; Miller 1958; Allred & Beck 1963). There were differences in average seasonal movements both within and between sexes (Barnett *et al.* 1977) particularly in male *A. stuartii* during the mating period. The minimum average distance between successive captures (42 m) for any species studied was recorded for *R. lutreolus*. The maximum

width of the roads considered was about 8 m and usually considerably less (see 'study area'). Despite this no *M. cervinipes* and few *A. stuartii* and *R. fuscipes* were trapped on both sides of any track or road. In the case of the latter two species the numbers crossing the roads were inversely related to the width of the road (Fig. 3). Even the small, overgrown and disused track influenced the movement of small mammals. This is indicated by the control data (road width 0) derived from the number of crossings between trap lines in five areas of the native forest grid not associated with roads. Four of the five recorded road crossings by *A. stuartii* occurred during May, the fifth occurred in August, a period of increased male movement (Barnett *et al.* 1977). *R. fuscipes* crossed roads throughout the year both within and between sampling periods; eight of the nine 'within sample period' crossings occurred during February and May.

### Discussion

In the temperate forests of Victoria *R. fuscipes* was thought to be associated with cover (Warneke 1971) but Robinson (1975), also in Victoria, could find no combination of ground and shrub layer densities clearly favoured at all times; mainland populations (Sherbrooke Forest) favoured a more open shrub layer than an island population (Glennie Island). In tropical rainforest in Queensland *R. fuscipes* was associated with the increased density of shrub layer caused by tree fall and subsequent regeneration (Freeland 1972). In native forest at Clouds Creek it was associated with structural complexity and shrub layer density but not in the adjacent pine plantation. Vegetation density *per se* may not have been a limiting factor in the plantation (it was very dense throughout) and other factors, perhaps soil moisture (Warneke 1971) may have influenced the distribution; in the pines *R. fuscipes* was found mainly on the lower south-west slopes of the grid.

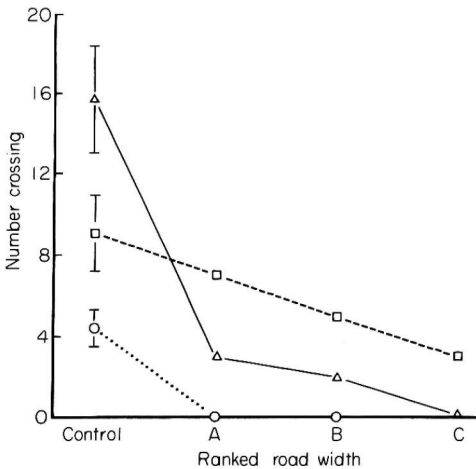


FIG. 3. The relationship between road width and the number of *Antechinus stuartii* (Δ), *Rattus fuscipes* (□) and *Melomys cervinipes* (○) recorded crossing the roads from February 1975 to February 1976.

The roads are ranked according to width as the effective width is compounded due to the variation in vegetation cover and logs on the roads. Control is the number of crossings ( $\bar{x} \pm$  S.E.), between trap lines not separated by roads. Only roads B and C were available to *M. cervinipes*.



Robinson (1975) tried unsuccessfully to associate the distribution of *R. fuscipes* with detailed floristics. Since this species is wide-ranging in its habitat associations the predictive power of this approach is suspect.

The varied response to habitat alteration in different parts of Australia may reflect differences in niche breadth. The food niche of *Rattus fuscipes* may vary both seasonally and regionally. In southern Australian forests *R. fuscipes* is omnivorous but feeds on increasing amounts of plant material in winter both in Victoria (Warneke 1971; Robinson 1975) and in South Australia (Wheeler 1970). In Queensland tropical rainforests this species is predominantly phytophagous throughout the year (Freeland 1972).

*Melomys cervinipes* is arboreal (Wood 1971) and vegetarian; its distribution was not associated with vegetation density in Queensland tropical rainforest (Freeland 1972). At Clouds Creek where the study stretched through various forest types, *M. cervinipes* captures were negatively associated with the density of the herb layer and positively associated with litter; these characteristics (little herb layer and much litter) serve only to distinguish rainforest areas where *M. cervinipes* lives and are in themselves probably not important attributes of its habitat. *M. cervinipes* is not a widespread species and it is found only in tropical and subtropical rainforest (Ride 1970).

*Rattus lutreolus* had the most circumscribed distribution of the species captured, being present only on the periphery of the plantation where there was no shrub layer, and only during the first two trapping periods. This species is known to have populations which move locally, possibly to find the appropriate soil moisture conditions (R.W. Braithwaite, personal communication).

If the approach used here to relate habitat structure to the distribution of small mammals is valid then it should be demonstrable experimentally. Habitat structure is more readily manipulated in the field (e.g. provision of artificial reefs in marine studies or nesting boxes to simulate tree hollows for birds and arboreal mammals) than is species composition. Such manipulation could provide empirical verification of correlative evidence.

Oxley, Fenton & Carmody (1974) found

that small mammals crossed roads only if the clearance between the forest margins was less than 30 m and that traffic volume and type of road surface were probably unimportant. The smallest road they considered had a clearance of 9 m which was larger than the largest road in our study; even the latter was sufficient to eliminate crossings by *Antechinus stuartii* and restrict the movement of *Rattus fuscipes*. *Melomys cervinipes* crossed none of the roads, but only A and B were accessible to this species. Our study was not limited to the summer and autumn periods as in Oxley *et al.* (1974) and all *Antechinus stuartii* and 58% of *Rattus fuscipes* crossings were recorded during winter (May–August). In the case of *R. fuscipes*, the restricted movement between the pine plantation and the native forest is supported by the significant weight differences between females in the forest and plantation, indicating a probability of two separate populations. The nipple number may also differ between the populations (Barnett *et al.* 1977).

Harrison (1958) noted that the Malaysian wood rat, *Rattus jalorensis* Bonhote, homed less across areas with roads than across areas without roads, indicating that roads formed a substantial barrier to movement. The most striking example of the separation of adjacent small mammal populations by roads is for *Rattus rattus diardi* Harrison in Singapore. A population of these rats infested with the vector mites for scrub typhus was contained within an area of 100 acres (40 ha) surrounded by roads; the adjacent populations across roads in all directions never carried the vector (Lawley 1957). Roads have also been shown to impede bird dispersal (Diamond 1973) and Joule & Cameron (1975) used minor paved, ploughed or mowed paths to reduce substantially the movement of rodents between adjacent grassland plots.

The importance of roads in separating small mammal populations, at least in the short term, is well established but the marked effect of the minor, unused and overgrown tracks considered here has not previously been reported; here the road width is small compared with the average distance between successive recaptures. Failure to record crossings may be due to, first, the road acting as a physical barrier to crossing (e.g. the

animal may be inhibited from crossing open ground or moving beneath a disrupted canopy). Secondly, the animals may establish territories or home ranges along readily identifiable physical boundaries. There is no obvious association between habitat boundaries and home ranges in Brant's (1962) data for the harvest mouse *Reithrodontomys megalotis longicauda* or in enclosures of *Mus musculus* (Lidicker 1976) where home ranges were centered on feeding areas. Thirdly, the road may act indirectly through normal social interactions that become associated with the road. In general, any part of an individual's home range in which it spends relatively less time than in other more favourable parts will form part of a potential boundary. Consider the simplest case of a homogeneously favourable habitat through which runs a band of less favourable habitat (a track for example); an individual crossing the unfavourable band will be further from the closest possible home range centre than any individual on the other side of the unfavourable band. As a consequence it will more likely lose an agonistic encounter (Anderson & Hill 1965). Home range or territorial boundaries thus have a greater probability of following the margins of even small unfavourable areas. The failure to record road crossings need not be the result of roads acting as a physical barrier but a consequence of social interactions which are themselves associated with roads.

We have no evidence to refute these hypotheses but the nature and size of the roads considered in this study makes the barrier hypothesis suspect, and there is no evidence from the detailed studies cited above to support the second hypothesis.

Oxley *et al.* (1974) considered that the effective size of conservation areas may be reduced by roads due to their restricting gene flow within the area. The evidence presented here, in which minor tracks impede movement, has serious implications for this expression of management policy as most roads in conservation areas constitute access tracks for management and fire trails; the larger public roads considered by Oxley *et al.* (1974) are few. Should our third hypothesis apply, at least to minor roads, then the implications for conservation areas are of less

import as roads merely mimic habitat discontinuities and normal social interactions restrict the movement of individuals. In this case emigrant type (cf. Anderson 1970) or dispersing individuals, usually juveniles, should not be prevented from crossing roads; our data are too few to test this. However, Schreiber & Graves (1977) found that the homing ability of two species of small mammals was not affected by powerline clearings 49 m and 104 m wide which is consistent with our third hypothesis.

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### References

- Allred D. & Beck D.E. (1963) Range of movement and dispersal of some rodents at the Nevada atomic test site. *J. Mammal.* **44**, 190–200.
- Anderson P.K. (1970) Ecological structure and gene flow in small mammals. *Symp. zool. Soc. Lond.* **26**, 299–325.
- Anderson P.K. & Hill J.L. (1965) *Mus musculus*: experimental induction of territory formation. *Science, N.Y.* **148**, 1753–5.
- Barnett J.L., How R.A. & Humphreys W.F. (1976) The mammals of Clouds Creek, north-eastern New South Wales. *Aust. Zoologist*, **19**, 23–34.
- Barnett J.L., How R.A. & Humphreys W.F. (1977) Small mammal populations in pine and native forests in north-eastern New South Wales. *Aust. Wildl. Res.* **4**, 233–40.
- Brant D.H. (1962) Measures of the movements and population densities of small rodents. *Univ. Calif. Publ. Zool.* **62**, 105–84.
- Cole L.C. (1949) The measurement of interspecific association. *Ecology*, **30**, 411–24.
- Cole L.C. (1957) The measurement of partial interspecific association. *Ecology*, **38**, 226–33.
- Diamond J.M. (1973) Distributional ecology of New Guinea birds. *Science, N.Y.* **179**, 759–69.
- Eriksen A.B. (1949) Summer populations and movements of the cotton rat and other rodents of the Savannah River Refuge. *J. Mammal.* **30**, 133–40.



- Freeland W.J. (1972) *A rainforest and its rodents*. M.Sc thesis, University of Queensland.
- Golley F.B. (1962) *Mammals of Georgia*. University of Georgia Press, Athens.
- Harrison J.L. (1958) Range of movement of some Malayan rats. *J. Mammal.* 39, 190–206.
- Joule J. & Cameron G.N. (1975) Species removal studies I. Dispersal strategies of sympatric *Sigmodon hispidus* and *Reithrodontomys fulvescens* populations. *J. Mammal.* 56, 378–96.
- Kirkland G.L. & Griffin R.J. (1974) Microdistribution of small mammals at the coniferous–deciduous forest ecotone in northern New York. *J. Mammal.* 55, 417–27.
- Lawley B.J. (1957) The discovery, investigation and control of scrub typhus in Singapore. *Trans. R. Soc. Trop. Med. Hygiene*, 51, 56–61.
- Lidicker W.Z. (1976) Social behaviour and density regulation in house mice living in large enclosures. *J. Anim. Ecol.* 45, 677–98.
- MacArthur R.H. & MacArthur J.W. (1961) On bird species diversity. *Ecology*, 42, 594–8.
- M'Closkey R.T. (1976) Community structure in sympatric rodents. *Ecology*, 57, 728–39.
- Miller R.S. (1958) A study of a wood mouse population in Wytham Woods, Berkshire. *J. Mammal.* 39, 477–93.
- Myton B. (1974) Utilization of space by *Peromyscus leucopus* and other small mammals. *Ecology*, 55, 277–90.
- Oxley D.J., Fenton M.B. & Carmody G.R. (1974) The effects of roads on populations of small mammals. *J. appl. Ecol.* 11, 51–9.
- Pianka E.R. (1974) *Evolutionary Ecology*. Harper and Row, London.
- Prakash I. (1975) The population ecology of the rodents of the Rajasthan Desert, India. In: *Rodents in Desert Environments*, pp. 75–116. (Ed. by I. Prakash and P.K. Ghosh). W. Junk, The Hague.
- Ride W.D.L. (1970) *A Guide to the Native Mammals of Australia*. Oxford University Press, Oxford.
- Robinson A.C. (1975) *Some aspects of the population ecology of the bush rat Rattus fuscipes (Waterhouse)*. Ph.D. thesis, Monash University.
- Rosenzweig M.J. & Winakur J. (1969) Population ecology of desert rodent communities – Habitats and environmental complexity. *Ecology*, 50, 558–72.
- Schreiber R.K. & Graves J.H. (1977) Powerline corridors as possible barriers to the movement of small mammals. *Am. Midl. Nat.* 97, 504–8.
- Siegel S. (1956) *Nonparametric Statistics for the Behavioural Sciences*. McGraw-Hill, New York.
- Stickel L.F. (1946) The source of animals moving into a depopulated area. *J. Mammal.* 27, 301–7.
- Wakefield N.A. & Warneke R.M. (1967) Some revision of *Antechinus* (Marsupialia) 2. *Vic. Nat.* 84, 68–99.
- Warneke R.M. (1971) Field study of the bush rat (*Rattus fuscipes*). *Wildl. Contr. Vict.* 14, 1–115.
- Wheeler S.H. (1970) *The ecology of Rattus fuscipes greyi on Kangaroo Island, South Australia*. Ph.D thesis, University of Adelaide.
- Whitaker J.O. (1963) Food, habitat and parasites of the woodland jumping mouse in central New York. *J. Mammal.* 44, 316–21.
- Wood D.H. (1970) An ecological study of *Antechinus stuartii* (Marsupialia) in south-east Queensland rainforest. *Aust. J. Zool.* 18, 185–207.
- Wood D.H. (1971) The ecology of *Rattus fuscipes* and *Melomys cervinipes* (Rodentia: Muridae) in a south-eastern Queensland rainforest. *Aust. J. Zool.* 19, 371–92.

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