Wildl. Res., 1991, **18**, 315-25

Effects on Non-target Animal Populations of a Rabbit Trail-baiting Campaign with 1080 Poison

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Abstract

Populations of non-target birds and mammals on a semi-cleared grazing property near Braidwood, New South Wales, did not appear to be affected by a trail-baiting campaign against rabbits, *Oryctolagus cuniculus*, using pellet bait and 1080 poison. Rabbit numbers were reduced by about 90% and those of the fox, *Vulpes vulpes*, another exotic pest, by about 75%. Populations of both pest species began recovering soon after the campaign, indicating the need for continued control measures.

Introduction

Rabbits, *Oryctolagus cuniculus*, are a major pest in many areas of Australia. One method used to control them is poisoning with compound 1080 (sodium monofluoroacetate). In poisoning campaigns, pieces of carrot, oat grains or pellets manufactured from bran or pollard are used as bait, which is either laid along furrows made in the earth or broadcast across the area from the air or ground.

Some concern has been expressed by the public that rabbit poisoning campaigns with 1080 might be deleterious to non-target animals, particularly native species. Studies of the sensitivity to 1080 of 110 species of animals in Australia indicate that rabbit poisoning campaigns could affect individuals of 50-62 species, particularly small macropodoids (Macropodoidea) and wombats (Vombatidae) (McIlroy 1986). There is also evidence that, on occasions, various numbers of introduced and native birds in New Zealand were poisoned by 1080 during control campaigns against rabbits and the common brushtail possum, *Trichosurus vulpecula* (Harrison 1978; Spurr 1981). This paper reports on a field study carried out during 1974-75, which sought to assess the impact on non-target animal populations of a trail-baiting campaign against rabbits using pellet baits. Unfortunately, because of errors in experimental design (Hurlbert 1984), the data collected were inadequate for inferential statistical analysis. However, they do form a basis for appraising whether there was a treatment effect and, if so, how great a one.

Methods

Study Area

The study was carried out on 'Little Bombay', a 118 ha grazing property 11 km west of Braidwood (35°27'S.,149°48'E.) in south-eastern New South Wales. The topography consisted mainly of alluvial flats and terraces along Little Bombay and Bombay Cks, with rocky hillsides along part of the northern border. Most of the area was covered with introduced or native pasture, with scattered remnant patches of native shrubs and trees, particularly along creeks, and tall eucalypt forest along parts of the northern boundary.

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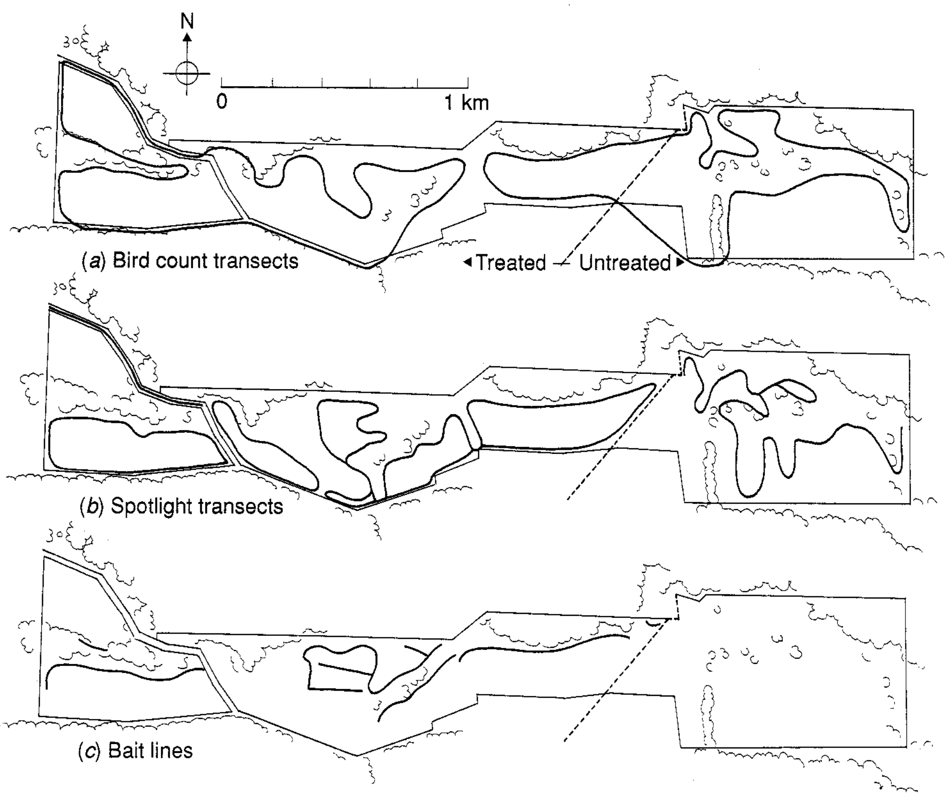

Fig. 1. Treated and untreated areas at 'Little Bombay'. (*a*) diurnal bird count transects, (*b*) spotlight count routes, and (*c*) distribution of bait trails.

For the purpose of this study, the property was subdivided into a 'treated' area of 71 ha, in which the poisoning campaign was carried out, and an 'untreated' area of 47 ha (Fig. 1).

Monitoring Methods

The populations of birds and mammals were monitored in both treated and untreated areas during the six months before, and six months after, the campaign, to determine: (1) what seasonal changes occurred in the relative abundance of animals; (2) what changes occurred in relative abundances in both areas during the poisoning campaign; and (3) how long it took any apparently affected populations to recover following the poisoning campaign.

All counts (except those of common combats, *Vombatus ursinus*) were made along fixed transects through, or close to, the main feeding areas or habitats used by the animals in the area.

Diurnal Bird Counts

Standardised counts of birds were made on foot, along one fixed transect through each area (Fig. 1*a*) during five days of suitable weather in each of July, September and November 1974, and January 1975 (pre-poisoning) and February, May and July 1975 (post-poisoning). The same observer followed the same route at the same time each day, beginning 30 min after sunrise. The length of each route and the average time it took to walk them were:

Treated area: 6·4 km, 2·7 h (range 2·2–3·6 h)
Untreated area: 3·3 km, 1·7 h (range 1·3–2·0 h).

Counts were made of all birds that were observed (sometimes with the aid of binoculars) and heard within a 50 m wide strip on either side of the observer. Bird calls that could not be definitely ascribed to the transect strip were not recorded.

Spotlight Counts of Mammals and Nocturnal Birds

Spotlight counts of mammals and nocturnal birds were made each night after the diurnal bird counts along a different fixed transect through each area to those transects used for the diurnal bird counts (Fig. 1*b*). The same observer always covered the same route. During July and September 1974, the counts were obtained on foot with a spotlight (6 V, 30 W), beginning 45 min after sunset. One preliminary count was also obtained in the same way in the treated area during February 1974. However, after November 1974, when the ground became less boggy, all spotlighting was carried out with a spotlight (12 V, 55 W) from the bonnet of a 4WD vehicle, in an endeavour to more easily observe rabbits among the pasture grasses. These counts began in the treated area 45 min after sunset and in the untreated area about 1·5 h later. The length of each route and the average time it took to cover them were:

Treated area:	8·7 km,	2·5 h (range 2·3–2·9 h) on foot
		1·3 h (range 1·0–1·8 h) by vehicle
Untreated area:	3·8 km,	1·4 h (range 1·2–1·7 h) on foot
		0·8 h (range 0·7–1·5 h) by vehicle.

Estimates of Wombat Numbers

Because spotlight counts do not provide accurate estimates of the population numbers of common wombats (McIlroy 1977), two other methods were used in the treated area during December 1973, July, September and November 1974, and February and May 1975. Indirect estimates (McIlroy 1977) were obtained by inspecting the 121 burrows in the area on five consecutive days and determining the mean number of burrows used per 24 h. Traps were then set at every used burrow for a further five days for direct mark-recapture estimates. An indirect estimate of numbers was also obtained in January 1975, but there was insufficient time to obtain a direct estimate before the poisoning campaign began. It was not possible to obtain either type of estimate in the untreated area during the study because of the limited number of traps and time available after other fieldwork each day.

Estimates of Small-mammal Numbers

Small-mammal trapping was abandoned in both areas after 800 trap nights during July 1974 using Elliott traps baited with rolled oats and peanut butter resulted in the capture of only one *Antechinus stuartii* and two *Rattus fuscipes*.

Bait Acceptance Trials

Two preliminary field trials were carried out prior to the poisoning campaign to determine whether wombats and birds might eat carrot or pellet baits. In the first trial, during October 1974, three shallow furrows, 250 m in length and 30 m apart, were dug across part of a pasture adjacent to eucalypt forest in the Brindabella Valley, 85 km west of Braidwood. This area was chosen after observations indicated that it contained a similar range of birds and mammals to those present at 'Little Bombay'. Pellets, identical to those later used at 'Little Bombay', were laid along one furrow at a density of 6·8 kg km^{-1} and 5 g cubes of carrot were laid along a second furrow at a density of 14 kg km^{-1}. Both densities were about double those suggested for free-feeding along trials where medium infestations of rabbits occur (i.e. 2–3 kg km^{-1} for pellets and 5–8 kg km^{-1} for carrots), but were comparable to densities suggested for heavy infestations of rabbits (Anon. 1988). The middle furrow was left as an unbaited control. Neither type of bait contained poison and, contrary to custom, they were not dyed green to deter birds from removing them. For six days after the baits were laid, an observer in a hide 100 m from the furrows kept records of all animals feeding on the bait or present on the pasture between sunrise (*c.* 0522 hours) and sunset (*c.* 1817 hours). The pellets were replaced by fresh ones at the end of the first day following light showers of rain, and the bait lines were replenished at the end of the fourth day of observations.

The second trial was carried out in the treated area at 'Little Bombay' during November 1974. Two small piles, each containing 39 pieces of undyed carrot or pellets, were placed alongside each other in the middle of a 2 m^2 plot of raked earth in front of nine burrows being used by wombats, and the amount of bait eaten by the wombats each night was recorded for the next three days. Any bait taken was replenished late each afternoon. Dual piles of each bait were also placed on raked plots at five more-distant sites within the wombats' known home ranges, and the amount of bait eaten per night was recorded for three days.

Poisoning Campaign

On 18 January 1975, the Rabbit Inspector from the Braidwood Pastures Protection Board inspected the property and indicated where bait trails should be laid. The main sites were around warrens and between refuge areas (e.g. creekside vegetation) and feeding areas (e.g. open pasture). Livestock management requirements, and the height and density of the ground cover, subsequently influenced the layout of the bait lines, but on 19 January 4·2 km of trail was constructed in the treated area (Fig. 1*c*) using a single furrow plough. Because of the property owner's wish and a lack of available time, no furrow was constructed in the non-treated area. Commercially manufactured pellets, commonly used for rabbit control in the district, were then laid by hand along the shallow furrow at a density of 2·2 kg km^{-1} for the first 'pre-feed'. A second 'pre-feed' was laid on 24 January, with extra pellets (i.e. 2·8 kg km^{-1}, or one pellet every 30 cm instead of every 45 cm) placed at those sections of the trail where rabbits had fed on the bait previously. Finally, on 28 January, toxic pellets were laid along the trail at a density of 2·2 kg km^{-1}. All baits used during the campaign were dyed green. The toxic pellets were prepared by the Rabbit Inspector by sprinkling a known amount of 1080 solution over the pellets in a revolving concrete mixer, giving a nominal 1080 concentration of 0·05% w/w or 0·5 mg 1080 per bait.

The bait lines were inspected daily for 12 days after the toxic pellets were laid and all animals found dead along or near the trail, or during searches of the property, were recorded. Post-poisoning counts of animals, in both treated and untreated areas, began on 2 February after all remaining pellets had been removed.

Results

Bait Acceptance Trials

Only four species of birds (galahs, pied and grey currawongs and magpies) were observed feeding on the baits in the Brindabella Valley trial, and then only infrequently (Table 1).

Table 1. Numbers of observations of animals feeding on baits in the Brindabella Valley, October 1974

–, not observed

Species	Animals in area	Animals feeding in area	Animals feeding on pellets	Animals feeding on carrots	Animals feeding on the control line
		Birds			
White-faced heron	9	6	–	–	–
Maned duck	19	19	–	–	–
Masked lapwing	2	2	–	–	–
Galah	813	720	22	4	5
Sulphur-crested cockatoo	12	12	–	–	–
Crimson rosella	379	255	–	–	–
White-cheeked rosella	45	30	–	–	–
Kookaburra	2	1	–	–	–
Willie wagtail	14	1	–	–	–
Common starling	30	23	–	–	–
Australian magpie-lark	1	1	–	–	–
Australian magpie	609	557	1	10	10
Pied currawong	221	195	2	1	2
Grey currawong	110	83	1	–	–
Little raven	26	24	–	–	–
		Mammals			
Fox	3	–	–	–	–
Rabbit	979	57	–	–	–

Table 2. Mean numbers of birds and mammals recorded per kilometre in treated and untreated areas before and after a rabbit-poisoning campaign at 'Little Bombay', 1975

Species	Mean numbers ± s.e. km^{-1}			
	Untreated area		Treated area	
	Before	After	Before	After
	Birds			
White-faced heron (*Ardea novaehollandiae*)	0·48±0·21	0·48±0·18	0·47±0·11	0·56±0·15
Straw-necked ibis (*Threskiornis spinicollis*)	0	1·21±0·70	0·13±0·06	0·50±0·17
Brown falcon (*Falco berigora*)	0	0·06±0·06	0·09±0·06	0·03±0·03
Australian kestrel (*F. cenchroides*)	0·12±0·07	0·12±0·12	0·03±0·03	0·13±0·06
Stubble quail (*Coturnix pectoralis*)	0·97±0·15	0·42±0·23	0·44±0·14	0·13±0·09
Masked lapwing (*Vanellus miles*)	0	0	0·19±0·08	0·06±0·06
Gang-gang cockatoo (*Calocephalon fimbriatum*)	0	0·12±0·00	0·44±0·29	0·19±0·19
Galah (*Cacatua roseicapilla*)	0·30±0·30	0·30±0·30	0·69±0·69	0·06±0·06
Sulphur-crested cockatoo (*C. galerita*)	2·60±1·60	1·03±0·42	2·94±0·97	1·41±0·42
Crimson rosella (*Platycercus elegans*)	0·24±0·15	4·49±0·71	1·13±0·33	2·81±0·37
White-cheeked rosella (*P. eximius*)	0	0·36±0·24	0·41±0·21	1·13±0·13
Fan-tailed cuckoo (*Cacomantis flabelliformis*)	0·72±0·57	0	0	0·03±0·03
Kookaburra (*Dacelo novaeguineae*)	0·73±0·15	0·67±0·22	0·41±0·15	1·00±0·19
Dollarbird (*Eurystomus orientalis*)	0	0·30±0·30	0·03±0·03	0·41±0·04
Welcome swallow (*Hirundo neoxena*) } Tree martin (*H. nigricans*)	0	2·67±0·77	5·19±2·18	0·28±0·17
Richard's pipit (*Anthus novaeseelandiae*)	0·61±0·17	1·94±0·76	0·28±0·15	0·06±0·06
Black-faced cuckoo-shrike (*Coracina novaehollandiae*)	0·18±0·07	0·12±0·07	0·41±0·16	0·31±0·05
Scarlet robin (*Petroica multicolor*)	0	0	0·03±0·03	0·22±0·14
Eastern yellow robin (*Eopsaltria australis*)	0·30±0·19	0·18±0·07	0·06±0·06	0·25±0·09
Rufous whistler (*Pachycephala rufiventris*)	1·09±0·40	0·97±0·22	1·62±0·21	0·82±0·05
Grey shrike-thrush (*Colluricincla harmonica*)	0·24±0·11	0·18±0·07	0·60±0·10	0·31±0·10
Grey fantail (*Rhipidura fuliginosa*)	4·73±0·37	3·88±0·31	1·53±0·17	1·12±0·10
Willie wagtail (*R. leucophrys*)	1·09±0·18	0·60±0·30	0·84±0·22	1·28±0·25
White-throated treecreeper (*Cormobates leucophaea*)	0	0·73±0·21	0·25±0·11	0·81±0·21
Red wattlebird (*Anthochaera carunculata*)	0	0	0·03±0·03	0·13±0·03
Noisy friarbird (*Philemon corniculatus*)	0·12±0·07	0·24±0·11	0·41±0·04	0·47±0·09
Yellow-faced honeyeater (*Lichenostomus chrysops*)	1·70±0·52	0·42±0·16	1·87±0·20	1·19±0·20
White-eared honeyeater (*L. leucotis*)	5·88±0·91	4·60±0·48	1·37±0·17	1·56±0·05
Australian magpie (*Gymnorhina tibicen*)	2·00±0·35	2·79±0·35	4·50±0·43	5·07±0·30
Pied currawong (*Strepera graculina*)	1·52±1·30	0	1·31±0·78	0·34±0·13
Grey currawong (*S. versicolor*)	0·06±0·06	0	0·06±0·04	0·69±0·33
Raven (*Corvus* sp.)	1·70±0·35	1·15±0·53	1·72±0·63	3·66±0·71
	Mammals			
Eastern grey kangaroo (*Macropus giganteus*)	1·00±0·21	2·16±0·17	2·25±0·36	3·08±0·37
Red-necked wallaby (*M. rufogriseus*)	0	0·05±0·05	0·14±0·06	0·36±0·02
Fox (*Vulpes vulpes*)	0·26±0·00	0·10±0·06	0·37±0·07	0·09±0·04
Rabbit (*Oryctolagus cuniculus*)	5·37±0·20	5·79±0·14	4·37±0·21	0·43±0·07

Of these, galahs fed most frequently on pellets, and magpies most frequently on carrot baits. None of the other 11 species of birds and two species of mammals observed in the area, which were also present at 'Little Bombay', fed on the baits.

Although no baits were taken from the sites in open pasture at 'Little Bombay', wombats ate all 30 pellets at one site near a burrow during the first night, 28–30 pellets at another burrow site during each night, 1–4 pellets at four burrow sites during 1–3 nights and 1–6 pieces of carrot at one of these four sites during each night.

Effect of the Poisoning Campaign on Bird Populations

A total of 103 species of birds was observed in both areas during the study but many were either vagrants, seasonal residents (present only during winter or spring–early summer), or were observed infrequently, and in low numbers, during the counts.

Mean numbers of 32 species recorded per km in the treated and untreated areas before (i.e. January 1975) and after (i.e. February 1975) the poisoning campaign are shown in Table 2. Australian magpies, white-eared honeyeaters and grey fantails were the most common species throughout the campaign.

It is clear from Table 2 that the numbers of some species recorded along the transect in the treated area decreased after the campaign, whereas the numbers of other species increased. In some cases, similar changes in numbers occurred along the transect in the untreated area, but in other cases opposite changes occurred. To more clearly show the nett trend of the changes in the treated area over the poisoning period, rates of increase were calculated for each species. The rates were based on differences between ln-transformed counts (expressed as mean numbers recorded per km) before and after the campaign in the treatment (r_t) and control (r_c) areas. The rate r_c was then subtracted from r_t to obtain the nett trend.

Fifteen, or almost half, of the species recorded in the treated area showed a negative nett trend in numbers during the poisoning period (Table 3). Welcome swallows and tree martins (grouped together because it was difficult to count them separately while they were flying) and crimson rosellas showed the greatest negative nett trend. Mean numbers (and standard errors) of 'swallows' counted per day along the transects during the five-day sampling periods decreased in the treated area from $5 \cdot 2 \pm 2 \cdot 0$ km^{-1} immediately before the campaign to $0 \cdot 3 \pm 0 \cdot 2$ km^{-1} after the campaign (i.e. $r_t = -1 \cdot 42$), but increased from 0 to $2 \cdot 7 \pm 0 \cdot 7$ km^{-1} (i.e. $r_c = 1 \cdot 16$) in the non-poisoned area (Tables 2 and 3). Mean numbers of crimson rosellas counted per day increased from $1 \cdot 1 \pm 0 \cdot 3$ to $2 \cdot 8 \pm 0 \cdot 3$ km^{-1} (i.e. $r_t = 0 \cdot 63$) in the treated area after the campaign, but in the non-poisoned area they increased from $0 \cdot 2 \pm 0 \cdot 1$ to $4 \cdot 5 \pm 0 \cdot 6$ km^{-1} (i.e. $r_c = 1 \cdot 47$). Only one bird, a fan-tailed cuckoo, was found dead in the treated area immediately after the campaign. An autopsy revealed no signs of bait in its gizzard or of why it had died, although its organs were not analysed for the presence of 1080.

Effect of the Poisoning Campaign on Mammal Populations

The mean numbers of four species of mammals recorded per kilometre in both areas directly before and after the campaign are shown in Table 2. Three of the species (rabbit, eastern grey kangaroos, *Macropus giganteus*, and foxes, *Vulpes vulpes*) showed negative nett trends in numbers in the treated area during the poisoning campaign (Table 3).

Rabbits

The mean number of rabbits (±s.e.) observed in the treated area peaked at $47 \cdot 0 \pm 5 \cdot 5$ in September 1974, but decreased sharply after the baiting to only $3 \cdot 8 \pm 0 \cdot 6$ in February 1975 (Fig. 2*a*). Sixteen dead rabbits, all with stomachs containing pellets, were found along or near the bait trail during early February 1975, and the smell of dead animals was noted at seven abandoned wombat burrows that were known to be used by rabbits, and at three

Table 3. Observed rates of increase of birds and mammals in treated area (r_t) and control area (r_c) during January–February 1975

Species	Rate of increase r_t	r_c	Nett trend r_{t-c}
Welcome swallow/Tree martin	−1·42	1·16	−2·58
Rabbit	−1·32	0·07	−1·39
Crimson rosella	0·63	1·47	−0·84
Richard's pipit	−0·17	0·45	−0·62
Rufous whistler	−0·36	0	−0·36
Straw-necked ibis	0·27	0·58	−0·31
Gang-gang cockatoo	−0·16	0·10	−0·26
Galah	−0·24	0	−0·24
Eastern grey kangaroo	0·24	0·47	−0·23
Grey shrike-thrush	−0·20	−0·04	−0·16
Sulphur-crested cockatoo	−0·44	−0·28	−0·16
White-throated treecreeper	0·36	0·51	−0·15
Australian magpie	0·11	0·25	−0·14
Masked lapwing	−0·11	0	−0·11
Brown falcon	−0·05	0·05	−0·10
Fox	−0·23	−0·14	−0·09
Noisy friarbird	0·04	0·10	−0·06
Grey fantail	−0·17	−0·16	−0·01
Black-faced cuckoo-shrike	−0·04	−0·05	0·01
Red wattlebird	0·01	0	0·01
White-faced heron	0·06	0·01	0·05
Australian kestrel	0·08	−0·01	0·09
Stubble quail	−0·24	−0·36	0·12
Dollarbird	0·31	0·18	0·13
Red-necked wallaby	0·18	0·04	0·14
Pied currawong	−0·40	−0·54	0·14
White-cheeked rosella	0·44	0·25	0·19
Fan-tailed cuckoo	0·03	−0·16	0·19
Scarlet robin	0·20	0	0·20
Eastern yellow robin	0·16	−0·07	0·23
White-eared honeyeater	0·09	−0·18	0·27
Yellow-faced honeyeater	−0·28	−0·58	0·30
Kookaburra	0·36	−0·05	0·41
Grey currawong	0·40	−0·05	0·45
Willie wagtail	0·22	−0·31	0·53
Raven	0·60	−0·32	0·92

areas of dense scrub near the bait trail. After the baiting, mean numbers of rabbits increased in the treated area, and by May 1975 had reached 14·2 ± 1·2. In the untreated area, rabbit numbers increased throughout the study except for a minor decline during November 1974, which also occurred in the treated area, when the spring flush of growth made observation of rabbits more difficult than during other sample months. Young rabbit kittens were observed in both areas only from September 1974 to February 1975.

Foxes

The number of foxes observed in the treated area decreased abruptly immediately after the baiting (Fig. 2*b*). During the campaign, foxes were observed on several occasions eating poisoned rabbits, and fox scats containing remains of rabbits were found frequently along

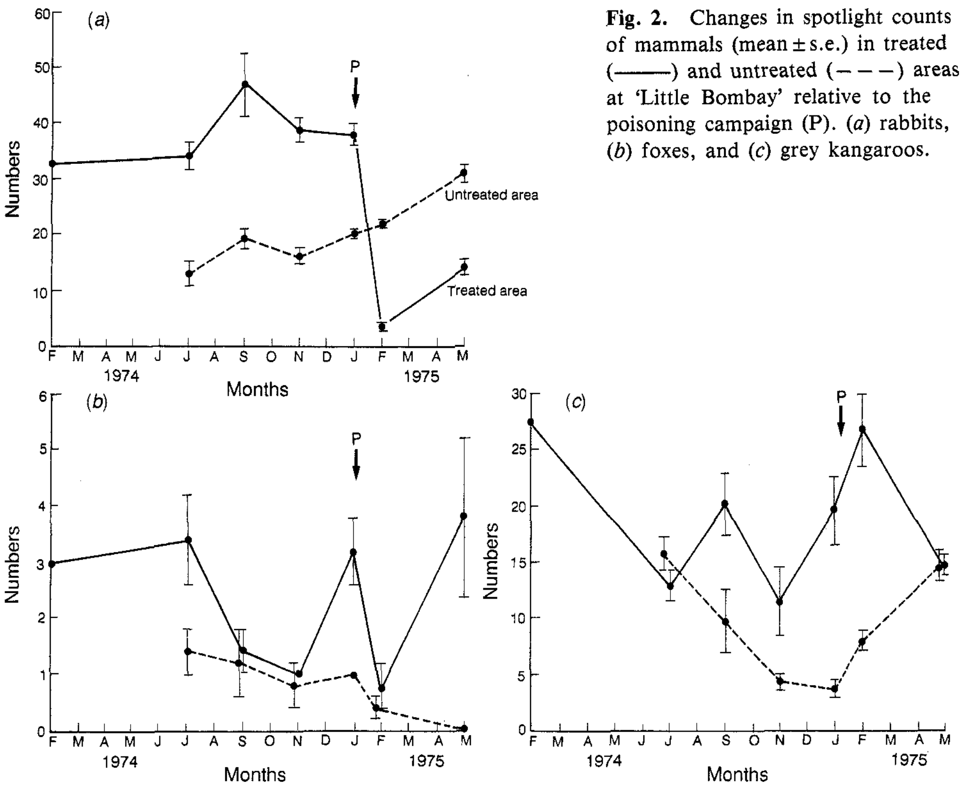

Fig. 2. Changes in spotlight counts of mammals (mean ± s.e.) in treated (——) and untreated (– – –) areas at 'Little Bombay' relative to the poisoning campaign (P). (*a*) rabbits, (*b*) foxes, and (*c*) grey kangaroos.

the poison trail. By May 1975, fox numbers had increased to their highest during the study period. In the untreated area, fox numbers generally declined throughout the study period (Fig. 2*b*).

Grey kangaroos

The poisoning campaign had no observed effect on the population of grey kangaroos in the study area. In the treated area, the fluctuations in numbers were probably correlated with flushes observed in their food supplies. The highest mean number per night was recorded in February 1975 immediately after the poisoning campaign (Fig. 2*c*). In the untreated area, numbers declined from July 1974 to January 1975 and then increased again. No empirical information was obtained on their movement to and from adjacent areas, or on the food supplies in these areas.

Wombats

The number of wombats present, based on burrow use and trapping results, declined by one or two animals in the treated area after the poisoning campaign. Maximum numbers (12) were recorded in July 1974. No dead wombats were found but two marked animals were never retrapped after the campaign. There was no statistical difference between pre- and post-poisoning numbers. Indirect and direct estimates of numbers were $9 \cdot 9 \pm 1 \cdot 7$ and 10 wombats, respectively, during January 1975, and $8 \cdot 7 \pm 1 \cdot 2$ and 10 wombats, respectively, during February 1975.

Wallabies

Mean numbers (± s.e.) of red-necked wallabies, *Macropus rufogriseus*, ranged from $0 \cdot 2 \pm 0 \cdot 2$ to $3 \cdot 2 \pm 0 \cdot 2$ per night in the treated area and from 0 to $0 \cdot 8 \pm 0 \cdot 2$ per night in the untreated area. Numbers in the treated area were highest immediately after the poisoning campaign.

Other mammals

Data obtained by spotlight counts of other animals in both areas were too fragmentary to allow comparison. Numbers of feral cats, *Felis catus*, ranged from zero on many nights to four in the treated area during one night immediately after the baiting. One common brushtail possum was observed in the untreated area.

Discussion

Effect of the Poisoning Campaign on Bird Populations

Because of errors in experimental design, particularly the lack of appropriate replication and independence, the data obtained in this study are inadequate for statistical assessment of treatment effects. The nett trends in the numbers of different species in the treated area can be used to provide a subjective assessment, but their generality cannot be evaluated because they may also have been a function of other differences between the treated and untreated areas.

Although welcome swallows and tree martins showed the largest, negative nett trend in numbers in the treated area during the campaign, it is highly unlikely that some birds were poisoned. Both species feed on aerial insects rather than on bait or poisoned animals. The changes in their numbers are more likely to reflect the movements of young birds and post-breeding adults into and out of the areas prior to migration. Crimson rosellas, the most susceptible to pellet bait of 12 of the species for which sensitivity data are available (McIlroy 1984), also showed a large, negative nett trend in numbers, even though their numbers increased in both areas after the poisoning campaign. Caution is necessary, however, in interpreting this as evidence of poisoning mortality. No rosellas were observed feeding on pellets during both the campaign and Brindabella Valley trial, and none were found dead after the campaign, despite extensive searches. It is more likely that the trend reflects the sudden influx of rosellas into the untreated area during February 1975, when they began feeding on various ripe fruits in the house orchard on the property. Mean numbers of crimson rosellas observed per day fluctuated in both treatment and non-treatment areas during the seven sampling months, but varied more in the untreated area. Numbers in the untreated area were lowest during January 1975, just before the campaign, when only two birds were observed, on two occasions, and highest during autumn and winter, when up to 82 rosellas were observed feeding on acorns near the house. Nevertheless, some crimson rosellas have been found dead after a rabbit-poisoning campaign with carrot bait (J. McIlroy, unpublished data), so further monitoring of the effect of rabbit-poisoning campaigns on their numbers may be warranted.

Eastern yellow robins and fan-tailed cuckoos, ranked second and third, respectively in susceptibility, also increased in numbers in the treated area after the campaign but declined in numbers in the non-treated area. None of the four species observed eating pellet baits at Brindabella appeared adversely affected by the campaign, even though they were all regarded as susceptible to being poisoned by pellet bait (McIlroy 1984). In fact, numbers of ravens and grey currawongs increased in the treated area and declined in the untreated area during January–February 1975 (Table 2). Both species may have been attracted to the treated area during February by the dead rabbits or by grasshoppers that became abundant suddenly in that area during that month. Other species also showed positive nett trends in the treated area during the same period (Table 3). These changes in numbers, as with the variations in numbers that occurred during other months, appeared to be due to seasonal changes in their behaviour, such as the establishment or abandonment of breeding territories, formation and movements of post-breeding flocks, and migration.

Effect of the Poisoning Campaign on Mammal Populations

Rabbits were the only species definitely known to have been poisoned during the campaign. Overall, their numbers in the treated area decreased by about 90% (i.e. from $38 \cdot 0 \pm 2 \cdot 1$ to $3 \cdot 8 \pm 0 \cdot 6$ per night). However, the population soon began to recover. During February 1975, nine different rabbits were seen in the area, all within 40–220 m of where baits had been laid. Four of the rabbits ran back to adjacent roadsides and untreated land, but the rest were observed feeding in areas adjacent to their refuges that had not been bisected by the bait trail. By May 1975, mean numbers had increased to $14 \cdot 2 \pm 1 \cdot 2$ per night, indicating the need for strategic placing of bait trails and sustained control measures, including the use of other methods such as the removal of harbour, destruction of warrens and exclusion fencing.

Fox numbers in the treated area decreased by about 75% during the poisoning campaign (i.e. from $3 \cdot 2 \pm 0 \cdot 6$ to $0 \cdot 8 \pm 0 \cdot 4$ per night), but also fell in the untreated area by about 60% (i.e. from $1 \cdot 0 \pm 0$ to $0 \cdot 4 \pm 0 \cdot 2$ per night). This may indicate that foxes from all over the property were attracted to the treated area by the number of dead rabbits lying about and that many were then poisoned. Foxes are highly sensitive to 1080 poison, readily eat pellet baits (Brunner 1983; J. McIlroy, unpublished data) and were known to have eaten some of the dead rabbits. Their numbers in both areas, however, also fluctuated at other times of the year. Their decline in numbers during late winter and spring was probably due to mortality, especially from shooting by farmers (five known deaths) and skin collectors, and their more cryptic behaviour during the breeding season. The increase in numbers in the treated area just before the campaign, and in May after the campaign, probably arose from dispersal of juveniles, indicating that their populations, like those of the rabbit, can recover quickly from the effect of a poisoning campaign.

Two wombats, an adult male and an immature female, either left the treated area, died naturally or were poisoned between November 1974 and February 1975. If either wombat had eaten 30 toxic pellets during a night (as two wombats did during the earlier bait acceptance trial) then it would have ingested $12 \cdot 5$ mg of 1080. This is well above the LD_{50} of $3 \cdot 0$–$8 \cdot 6$ mg of 1080 per wombat (McIlroy 1982). Evidence suggests that the adult male was killed by the campaign, and possibly died inside a burrow, as other poisoned wombats have done (McIlroy *et al.* 1981). From recapture data, he appeared to be a permanent resident and thus was unlikely to disperse from the area as immature wombats generally do (McIlroy 1973). Also, he was in prime condition when last trapped in November and was unlikely to have died from natural causes. Finally, toxic bait was taken by an unidentified animal from the trial only a few metres from the main burrow that this wombat had used before the campaign. In contrast, the immature female was more likely to have survived by dispersing to another area before the campaign began.

Conclusion

This study indicates that populations of rabbits can be reduced greatly by trail-baiting campaigns, using pellet bait and 1080 poison, without any apparent, major effect on non-target animal populations. It also raises the question of whether evaluations of risk faced by non-target animals from rabbit-poisoning campaigns based on their sensitivity to 1080 and susceptibility to baits (McIlroy 1986) are realistic. It must be stressed, however, that this query is based on the results from only a single, inadquately designed study, involving pellet baits in one small area in south-eastern New South Wales during summer, and better, replicated studies are required. There is evidence from other studies that native animals have been killed by rabbit-poisoning campaigns at other times of the year. For example, individuals of 16 species of birds and mammals were found dead in forest areas in New South Wales after pellets or carrots containing 1080 were applied in trails or broadcast from the air (McIlroy 1982). It is not clear from the information available which type of bait and method of application killed the animals, but the results from the present study suggest that trail-baiting with pellets was probably less likely to be responsible. In New Zealand, aerial broadcasting of pellet baits for the control of brushtail possums was found to kill fewer birds and affect fewer species than did screened carrot bait (Harrison 1978). In contrast, aerial broadcasting of carrot bait in another forest area in New South Wales killed individuals of three species of birds and six species of mammals (J. McIlroy, unpublished data).

In conclusion, a qualification is added to the statement by McIlroy (1986), that what counts ultimately in a poisoning campaign is not the death of individual non-target animals but the overall effect on their populations. If rabbit poisoning campaigns are considered necessary, then they should be conducted in a way that achieves their aim but minimises the risk to all non-target animals. Rabbit control should not consist of intermittent poisoning campaigns when rabbit numbers have been allowed to build up, but should be an ongoing task involving a suite of methods, including farming practices, which make the environment unsuitable for rabbits.

Acknowledgments

We thank Drs G. Caughley and J. Wood for statistical advice, Dr J. Loveday and Mr J. Vaughan for permission to carry out the study at 'Little Bombay' and provision of facilities, and Mr J. Webb, formerly Rabbit Inspector, Braidwood Pastures Protection Board, for assistance with the poisoning campaign.

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Manuscript received 17 July 1989; revised 5 October 1989, 9 April 1990, 22 August 1990 and 25 February 1991; accepted 5 March 1991