THE EFFECT OF TRANSLOCATION ON A SOCIAL GROUP OF BADGERS (*MELES MELES*)

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Final acceptance: 27 March 1996

Abstract *Animal Welfare 1996, 5:* 289-309

*A social group of six badgers (*Meles meles*) (four adults and two cubs) was translocated from urban Bexhill, East Sussex, in August 1993 to a 1216m² electrified enclosure in a part of Suffolk largely unoccupied by badgers. Three adult badgers (SY2, SY5 and SY6) escaped from the release site prior to the removal of the perimeter fence on 10 December and established a sett near a village, 2.9km from the release site. In January 1994, the remaining adult (SY4) left the release site and moved 1.8km to the grounds of a youth detention centre. The cubs did not desert the site as readily as the adults.*

Home-range sizes for two adult females, SY4 and SY6, remained relatively constant, while that of adult male SY2 increased from 50ha in February to nearly 400ha in April. The range of SY2 overlapped parts of the ranges of the two females, although SY4 and SY6's ranges never overlapped.

The percentage volume of scavenged food in the diet increased monthly between February and April which corresponded to increased garden activity over this period. Earthworms were the most important item in the diet. The establishment of both main setts near housing and the preference for foraging in gardens suggests that badgers released into novel environments may search for familiar habitats.

It is concluded that translocation can successfully establish badgers at new locations. However, translocation as a solution to problems caused by badgers must only be viewed as a last resort, not least due to the potential for disease spread.

Keywords: *animal welfare, badger, diet, home-range size, release site, translocation*

Introduction

In some circumstances, where badgers (*Meles meles*) are causing serious damage, a potential solution is to translocate the animals responsible to another site. It may be possible to move the badgers to a site within their territory, although in many cases this option is not feasible. Humane destruction of badgers may be the more humane option where a social group cannot remain in their original territory, although as yet there is no sound scientific basis for recommending destruction over translocation. A small number of badger translocation exercises have been carried out in recent years, but none of these have been followed by a proper scientific investigation, involving close monitoring of the badgers, or published results which could be useful elsewhere. In fact, in relatively few mammalian translocations are the animals monitored after release (Bright & Morris 1994). Where this has been done, a large number simply address survival and do not consider behavioural traits that may affect that survival, such as movement behaviour which may be more important than individual survival in determining if reintroduction programmes establish new populations at release sites (Estes *et al* 1993). Therefore, when it was proposed to remove a social group that were undermining the foundations of a house in Bexhill, East Sussex, the opportunity was taken to perform such an investigation to provide the first steps in understanding the consequences of translocating badgers.

Social animals, such as badgers, are more likely to survive translocation if released as a cohesive group rather than as individuals, particularly if social bonds help to prevent dispersal from the release site. Evidence also suggests that it is preferable to move a whole social group of badgers rather than to integrate single animals into a population (Cresswell 1992). Since badgers are strictly territorial and their territory boundaries are strongly defended in areas of high population density (Kruuk 1978), animals released into well-developed territorial systems would be subjected to aggression from resident badgers. Moreover, within mammalian territorial systems, it is usual to find surplus individuals that live a satellite existence, being forced to move from one group to another. These individuals are non-breeding, non-territorial and generally subordinate young animals that have a high mortality rate. Releasing additional individuals into such a system is likely to add to this nomadic population and is unlikely to contribute to the breeding population.

Owing to the fact that badgers are territorial, a group can only be moved to a new location where there is a vacant territory complete with main sett and which contains all the resources required by badgers. Reason *et al* (1993) suggested that over 1500 badger social groups had been lost in Britain as a result of persecution, indicating that there may be many areas suitable as restocking sites, provided that this would not simply encourage more persecution, particularly by badger diggers. A striking example of the depletion of a badger population is seen in East Anglia. Harris (1993) estimated that during the last century about 1450 badger social groups were eliminated in Norfolk and Suffolk by gamekeepers, due to intensive keepering in these two counties (Tapper 1992). The current population of about 150 known social groups of badgers is therefore well below the carrying capacity for this part of England. Harris (1993) suggested that reintroductions into Norfolk and Suffolk are a potentially valuable means of helping the badger population to recover to former levels. Thus, translocation of social groups may not only benefit badgers from the conservation aspect, as an alternative to humane destruction, but if successful could also act to fill gaps in certain parts of the country that are devoid of badgers. Translocating badgers into unoccupied habitat is probably more successful with a large nucleus population or when groups are added to the edges of expanding wild and introduced populations, as has been the procedure for the reintroduction of the Eurasian otter (*Lutra lutra*) in England (Jefferies *et al* 1986). Emigration is more likely in areas where there are no pressures from adjoining badgers for space (Cheeseman *et al* 1993), therefore small populations released into vacant habitat may be destined for extinction, because they are incapable of reproducing at a rate that is greater than the combined rates of mortality and emigration.

This paper describes the translocation of a group of six badgers from urban Bexhill to a rural forested area in Suffolk. This has been the first translocation of a group of badgers to be followed up with detailed scientific monitoring. The information gathered was primarily aimed at recording the response of the animals subsequent to translocation.

Materials and methods

Study animals

Six badgers were trapped over two nights in July 1993, in the garden of a property in Bexhill, East Sussex, where the house foundations were at risk of being undermined by a badger sett. The animals were transported to the RSPCA's Norfolk Wildlife Hospital, Kings Lynn, immediately after capture. Three days later each animal was sedated by an intra-muscular injection of between 25–30mg kg^{-1} (Cheeseman & Mallinson 1980) of ketamine hydrochloride (Vetalar®, Parke, Davis & Co, Pontypool, Gwent, UK), injected into the thigh. Cheeseman and Mallinson (1980) demonstrated on a sample of 194 badgers, that a mean dose of 30.8mg kg^{-1} produced a mean time to full relaxation of 1min 45s, with a mean time to recovery of 44min. This was sufficient time to carry out all the necessary procedures. These included the collection of samples of urine, faeces and tracheal aspirate for culturing, to isolate *Mycobacterium bovis* if present (Pritchard *et al* 1987). Blood samples were also taken for ELISA (enzyme linked immunosorbent assay) testing. This test detects the presence of *M. bovis* antibodies, but has a sensitivity of only 41 per cent (Goodger *et al* 1994). In addition, the weight and rectal temperature of each badger was recorded. Whilst under sedation, animals were aged, sexed and marked with a combination of ear tags and tattoo (Cheeseman & Harris 1982). Badgers were aged by examining the pattern of tooth wear. Although it was not possible to put individuals into different year classes, three different age categories were recognized: young of the year (cubs); yearlings; and animals ≥ 3 years (adults). Ear tags were applied to both ears and the tattoo placed on the ventral abdomen in the inguinal region. The six badgers included three adult females (SY4, SY5 and SY6), an adult male (SY2), and two cubs: a male (SY3) and a female (SY7). The condition of the six badgers ranged from good to very good with SY6 having previously bred. All adult badgers were fitted with radio-collars (H S Electronics, Norwich, Norfolk, UK) carried around their necks as well as beta-lights (Saunders-Roe Ltd, Hayes, Middlesex, UK), in order to facilitate observations at night.

Release site

Once the badgers had been proven negative for the presence of *M. bovis* they were released into an enclosure of 1216m² of birch and alder woodland in a Suffolk forest, on 3 August 1993. The animals were released directly into an artificial sett, consisting of three entrances, each leading into a separate chamber. The chambers and tunnels of the sett were constructed from rounds of timber, with the back wall of each chamber left free of timber to enable the badgers to extend the sett. The enclosure also contained a two-hole disused fox earth. The enclosure was formed by an electrified double fence: an inner electrified polytape barrier (0.3m high) and outer electric netting (0.7m high). The inner barrier measured over 160m in length with supporting posts every 3m on average. The fence was checked daily to ensure that current levels were maintained between 5-7kV around the length of the double fence. This involved regular replacement of the battery operating the fence and the removal of any vegetation that could cause electrical shorting. This degree of care was important as the loss of shock levels would reduce the effectiveness of the fence. Between the release date and the beginning of the project (20 September 1993) the captive group was fed daily with 2440g of tinned dog food and several handfuls of peanuts. To assist with monitoring of consumption, six regular feeding sites were used, combined with six variable locations to encourage the animals to search out and forage for their food. After the project commenced, dead rabbits (*Oryctolagus cuniculus*) were also periodically supplied to familiarize the animals with carrion. The electric fence was removed on 10 December 1993 and the badgers continued to be fed at the release site with diminishing quantities of food until the end of February 1994. An artificial water supply was provided, although they appeared to prefer obtaining water from natural sources within the enclosure.

Field techniques

Animals were tracked on a rota basis and each was followed on foot from its point of first emergence until it finally returned to a sett in the morning. Since close contact was maintained with the animal being studied, it was possible to assign a very precise location to each radio fix. The animal's position was recorded every 5min throughout the night and a note made of whether the animal was active or inactive and above or below ground. From a map (scale 1:5000) each fix was transcribed into a 25m square, and for that square the habitat was assigned to one of 12 broad categories (wooded banks, woodland, heathland, arable, pasture, bramble scrub, gardens, allotments, playing fields and amenity grassland, buildings and tarmac, disused land and churchyards). Records were kept of sett occupation by individual badgers, behavioural encounters and aggression within the group, and between the group and any resident badgers around the release site.

At the start of the project, cage traps were set within the enclosure, as described by Cheeseman and Mallinson (1980), to capture the two cubs which were to be radio-collared before the electric fence was removed. Trapping was also performed periodically throughout the study, at the release site and at other sites used by the translocated badgers, to replace failed transmitters and provide information on the breeding condition of adult females. When trapping at sites from which faeces were being collected, fresh rabbit meat rather than peanuts was used to bait the traps. This bait showed no detectable remains in faeces and therefore did not interfere with the results of the dietary analysis.

Faecal analysis

As the group of badgers translocated to the forest were fed daily, these animals were not suitable subjects for a dietary analysis. Instead, faeces were collected from an established group of badgers, 3.6km from the release site, that had been successfully translocated to the forest in 1992. From this group, that still occupied its forest release site, faeces were collected between November 1993 and February 1994. Unfortunately during February a proportion of this group dispersed, probably due to local disturbance, and faeces could not be collected in sufficient numbers after this month. However, once the Bexhill badgers had left the release site and moved to new areas, faeces were collected from these sites. Intensive searches of the location were carried out each month and the position of each latrine or single faeces was marked on a map (scale 1:5000). Details of latrine size, number of pits and faeces and the distance to the nearest sett were recorded. Searches were only conducted in the second half of each month and only fresh faeces collected to ensure that the faeces resulted from food eaten by the badgers in that month. Because of the relatively small number of animals in this study and in the group released in 1992, several searches were conducted each month to ensure a sufficient sample size. Faeces were stored in labelled polythene bags and deep-frozen, for subsequent analysis. The analysis technique was based on that developed by Kruuk and Parish (1981) and subsequently used by Harris (1984). Identified food items were assigned to nine different prey categories, separately for the two groups of badgers. The percentage of badger faeces in which particular prey categories occurred was calculated, together with the percentage volume of these categories in the diet.

Analytical techniques

Home-range areas were calculated by the minimum convex polygon (MCP) method (Mohr 1947; Southwood 1966) for each animal in each month using Ranges IV (Kenward 1990), a computer software package for analysing animal location data. The availability for each study animal of the habitat categories listed above was based on each animal's MCP range area. The relatively unstable nature of the home-ranges meant that the MCP and available habitats were calculated for each month separately. The area of each habitat within a badger home-range was measured using a bit pad (Summagraphics® Bit Pad® Plus). Land occupied by buildings and water was not included in the analyses. The category 'buildings and tarmac' therefore included roads, drives and car-parks in the vicinity of pubs, shops and other commercial centres.

The analysis of habitat preference or avoidance was based on the chi-square distribution (White & Garrott 1990). The hypothesis tested was that the animal utilized each habitat category in proportion to its occurrence within the home-range, considering all habitats simultaneously. Habitat usage was quantified by the number of radio-locations recorded within each habitat type and only habitats containing more than five fixes were included in the analyses (Hayes & Winkler 1970). One night's data for SY2 were not included in the analysis as movements on this night consisted entirely of a long-distance exploratory foray. When the chi-square test rejected the null hypothesis for all habitat types considered together, 90 per cent confidence intervals for each habitat were constructed based on the Bonferroni z-statistic (Neu *et al* 1974). If the confidence interval included the availability proportion, then the hypothesis of no preference or no avoidance of the habitat category, had to be accepted. However, if the lower bound of the interval exceeded the availability proportion, the animal had shown a preference for that habitat type. Likewise, if the availability proportion exceeded the upper bound of the interval, the animal had avoided that habitat type.

Kruskal-Wallis one-way analyses of variance were followed by *a posteriori* Tukey-type test of means (Dunn 1964). Non-parametric Tukey-type comparisons of means were also conducted following chi-square comparisons of proportions (Zar 1984).

Results

Behaviour and activity at release site

The badgers emerged from the artificial sett on their first night (3 August) and spent some time investigating the enclosure area. They paid particular attention to the disused fox earth within the site and after the second night the badgers had excavated small quantities of soil from each of the two holes of the earth. By the 11 August, bedding had been drawn into the entrances of the fox earth, suggesting that the badgers were occupying it, while the artificial sett remained apparently unused. Within the enclosure only low levels of dunging were observed above ground, with a single latrine located beside the fox earth which occasionally contained fresh faeces.

Observations and trapping revealed that three badgers (SY2, SY5 and SY6) had escaped from the enclosure prior to the commencement of field work in September. Since the fence line remained undisturbed, the date of escape was unknown. It was also not known if the animals had left the release site together or singly.

By 12 October the two cubs had been collared and SY4 re-collared after transmitter failure. Day positions of the three animals confirmed that the artificial sett had effectively been vacated. Of 91 days information on day locations between 12 October and 20 February, only SY7 was located in the artificial sett on a single occasion. Although the fox earth had soon become the preferred daytime harbourage, night observations revealed that all three badgers frequently entered the artificial sett, especially the two cubs.

Due to initial problems with transmitters, the early part of the project was spent trapping to replace failed transmitters and to collar the two cubs. The intensive trapping and the disturbance it caused, resulted in only limited information on badger emergence and feeding behaviour during the captive phase. Following the removal of the fence, activity at the release site was low with badgers above ground for only short periods of time. This low activity continued throughout the period of monitoring at the release site. During December the mean length of time active above ground for each animal was 18.5min (Table 1), falling to as little as 2.8min in January. This figure rose to approximately 5min per badger per night for the two cubs during February. Both SY3 (Kruskal-Wallis, $H = 12.63$, $df = 2$, $P < 0.005$) and SY7 ($H = 21.12$, $df = 2$, $P < 0.0001$) spent significantly longer above ground per night during December than during January and February. SY3 also spent a significantly greater amount of time above ground in December than in the following month ($H = 9.93$, $df = 1$, $P < 0.005$).

Table 1 Monthly levels of activity at the release site, after removal of the electric fence; figures are the mean length of time (min) above ground per badger per night ± standard error.

Month	Badger no.	Time active (min)	No. of nights
December	SY3	15.8±2.9	12
	SY4	17.5±4.1	12
	SY7	22.1±3.6	12
January	SY3	3.7±1.5	19
	SY4	1.9±1.4	13
	SY7	2.9±1.5	19
February	SY3	3.8±2.8	8
	SY7	6.3±3.3	8

Within each month no significant differences were detected between badgers in the mean length of time above ground each night. These analyses included nights when the animals remained below ground. This behaviour reached a peak in January with no recorded emergence of SY3 on 13 nights (68.4%), 11 nights for SY4 (84.6%) and 15 nights for SY7

(78.9%). Corresponding to the low level of above ground activity was the limited movement away from the fox earth sett. During the period of night monitoring at the release site (10 December–20 February), with the exception of SY4, no badger was observed to leave the original fenced area.

SY4 left the release site on 22 January leaving the two cubs at the fox earth sett. On 3 March an unmarked adult male badger was trapped at the release site and shortly after this SY3 vacated the area. Also in March, the carcass of SY7 was removed from the fox earth sett after a period of about two weeks when the badger had not been recorded above ground at night. Unfortunately the carcass was too decomposed for a post-mortem examination.

Movement and ranging behaviour

In February, the three escaped animals were located at sett A (see Figure 1), 2.9km from the release site and in close proximity to a village. Two of these animals, SY2 and SY6, were captured and re-collared. The other badger (SY5) was never trapped although was observed in the village on several occasions, either alone or feeding with SY2 and SY6. During February, seventeen nights tracking data were collected for the two collared badgers. This revealed that SY2 spent considerable time in close proximity to SY6. Both animals frequently foraged together and even travelled together between feeding sites, which resulted in similar home-range sizes (Table 2). The extent of the overlap of the two ranges is revealed in Figure 2. The range size of SY2 and SY6 during this month was largely influenced by the emergence above ground of two cubs belonging to SY6. At this stage both adult badgers spent a large proportion of each night in the vicinity of sett A and only travelled short distances from the sett. During these short foraging trips one of the adults always remained with the cubs. This behaviour continued for five days.

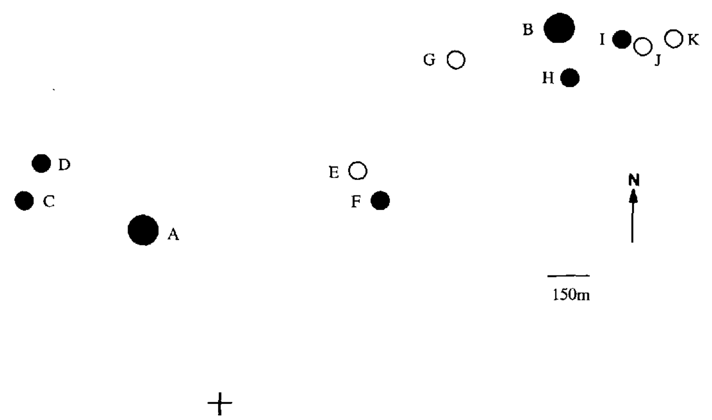

Figure 1 **Spatial distribution of setts utilized by SY2, SY4 and SY6. Setts were located between February and April 1994 in the vicinity of a village. Solid circles represent setts used as daytime refuges, open circles setts entered during the night but not used as daytime lying up sites. Main setts are indicated by large circles, other setts by smaller circles. The cross represents a particular grid reference which is included on all subsequent figures.**

Table 2 Monthly home-range sizes (minimum convex polygons).

Month	Badger no.	Home-range size (ha)	No. of nights
February	SY2	50.0	7
	SY6	68.6	10
March	SY2	270.8	5
	SY4	66.2	6
	SY6	108.1	5
April	SY2	399.0	5
	SY4	87.3	4
	SY6	82.2	5

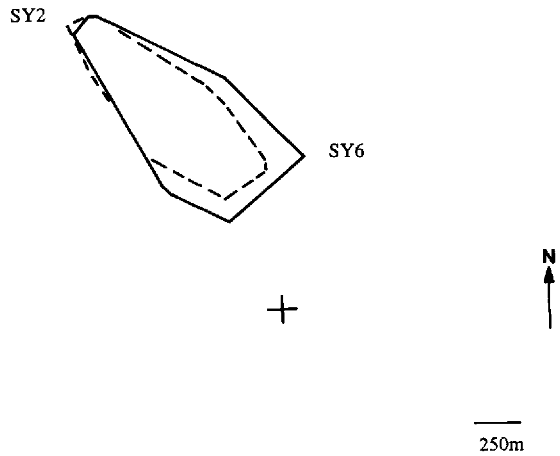

Figure 2 Home-range area (minimum convex polygon) for SY2 and SY6 during February.

In March, SY4 was located at sett B in the grounds of a youth detention centre, 1.8km from the release site and 1.7km from sett A. Both setts had been established from fox earths and were in close proximity to housing. During this month, SY2 began travelling greater distances and frequently visited SY4 at sett B and even remained during the day at this sett and other setts used by SY4. This increased movement resulted in a five-fold increase in range area to 270.8ha. The ranges of SY4 and SY6 were not observed to overlap (Figure 3), while that of SY2 encompassed parts of the ranges of both SY4 and SY6.

In April, SY2 continued to visit SY4 and made other lengthy exploratory forays. On one occasion this badger travelled a straight route of 2.2km from sett A, moving almost entirely along woodland edges and field boundaries, before returning to sett A via a circular route. This behaviour increased the home-range size to 399.0ha. The range sizes for SY4 and SY6 remained relatively unchanged from March. As with the previous month, no overlap of ranges was detected for SY4 and SY6, while the home-range of SY2 continued to overlap parts of the ranges of these two female badgers (Figure 4).

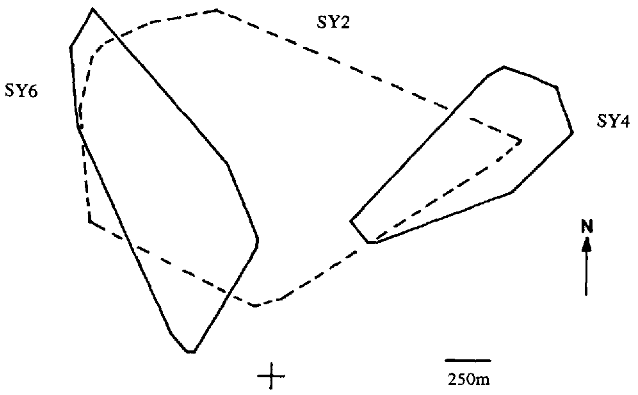

Figure 3 **Home-range area (minimum convex polygon) for SY2, SY4 and SY6 during March.**

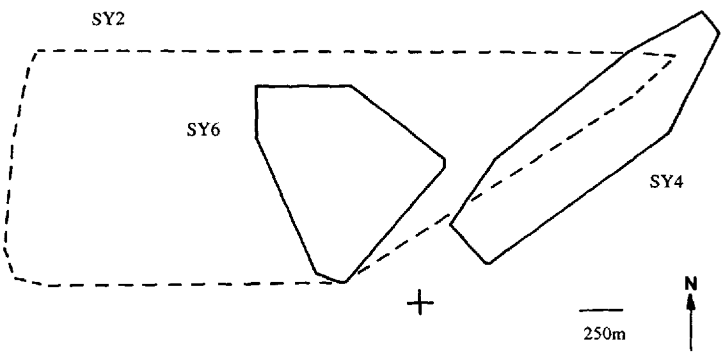

Figure 4 **Home-range area (minimum convex polygon) for SY2, SY4 and SY6 during April.**

Sett occupation

Between 5 February and 18 May, 96 days information were obtained on daytime lying up sites for SY2 and SY6. For SY4, data on day positions were obtained on 66 days between 8 March and 18 May. The relative positions of each sett are shown in Figure 1. This figure also includes setts that were entered by badgers during nightly movements, but not used as daytime refuges. Five different daytime locations were identified for the adult male (SY2), four locations recorded for SY4 and two for SY6. When considering all setts entered, these values are raised to eight, seven and three for SY2, SY4 and SY6, respectively. All the setts used by these three badgers were derived from fox earths, usually with single entrances and frequently under the roots of fallen trees. Table 3 shows the proportion of days spent in each sett. Despite extensive searches of the area, the day position of SY4 was unknown on over 34 per cent of the monitoring period. Only those setts used by SY2, SY4 and SY6 as daytime lying up sites were found to be associated with latrines. Latrines were clumped around setts and the mean distance between latrine and closest sett was 22.1m. Of the 14 latrines located, three (21%) were within 5m of a sett and nine (64%) within 10m of a sett.

Table 3 **Proportion of day locations at each sett indicated in Figure 1.**

Badger	A	B	C	D	E	F	G	H	I	J	K	Unknown	Days
SY2	70.8	4.2	13.5	1.0	0	0	0	0	6.3	0	0	4.2	96
SY4	0	42.4	0	0	0	1.5	0	1.5	19.7	0	0	34.9	66
SY6	81.3	0	18.7	0	0	0	0	0	0	0	0	0	96

Habitat utilization

Table 4 shows which of the habitats within the badgers' home-ranges were avoided, preferred or used directly in relation to their availability.

Table 4a **Habitat utilization by SY2 from February to April.**

Month	Habitat type	Percentage area	Percentage use	90% confidence interval ($x10^{-2}$)
February	Wooded banks	1.20	59.26	50.97–67.63
	Woodland	26.27	14.29	8.37–20.23
	Gardens	4.39	6.87	2.60–11.20
	Arable	15.32	0	-
	Pasture	46.98	10.05	4.99–15.21
	Buildings and tarmac	1.20	0	-
	Heathland	4.04	7.41	2.96–11.84
	Disused land	0.60	2.12	-
March	Wooded banks	0.46	14.64	9.00–20.20
	Woodland	6.74	22.18	15.61–28.79
	Gardens	5.21	17.57	11.56–23.64
	Arable	30.53	3.77	0.77–6.83
	Pasture	23.25	28.03	20.88–35.12
	Buildings and tarmac	5.16	0.84	-
	Heathland	22.09	5.86	2.17–9.63
	Disused land	3.33	5.86	2.17–9.63
	Bramble scrub	0.15	0	-
	Allotments	1.04	0.84	-
	Churchyards	0.07	0.41	-
	Playing fields and amenity grassland	1.97	0	-
April	Wooded banks	1.85	42.57	32.84–52.36
	Woodland	5.93	6.76	1.83–11.77
	Gardens	10.63	43.24	33.43–52.97
	Arable	53.17	2.70	0–5.90
	Pasture	3.17	0	-
	Buildings and tarmac	7.86	0.68	-
	Heathland	4.07	0	-
	Disused land	9.96	4.05	0.13–7.87
	Playing fields and amenity grassland	3.21	0	-

The most consistent trend was the preference for wooded banks by all three badgers each month and the avoidance of arable land. Gardens were preferentially selected by SY6 each month and in some months by SY2 and SY4. SY6 also preferred foraging on disused land, although avoided pasture during February and March. This habitat was sometimes avoided by the other two animals. The utilization of the remaining habitats was more variable. Woodland was generally avoided by SY6, although was preferred by SY4 each month. Bramble scrub was preferred by SY4 each month and both SY2 and SY6 avoided heathland at some stage during the three months of radio-tracking.

Table 4b **Habitat utilization by SY4 during March and April.**

Month	Habitat type	Percentage area	Percentage use	90% confidence interval ($x10^{-2}$)
March	Wooded banks	1.66	38.17	30.53–45.87
	Woodland	6.66	32.37	25.01–39.79
	Gardens	5.92	8.30	3.95–12.65
	Arable	56.05	2.90	0.25–5.55
	Pasture	13.39	2.90	0.25–5.55
	Buildings and tarmac	8.05	4.56	1.23–7.77
	Disused land	0.76	0	-
	Bramble scrub	1.59	9.96	5.27–14.73
	Playing fields and amenity grassland	5.92	0.84	-
April	Wooded banks	1.21	21.95	14.77–29.23
	Woodland	4.29	21.95	14.77–29.23
	Gardens	2.53	10.24	4.92–15.48
	Arable	46.33	3.41	0.24–6.56
	Pasture	13.60	13.66	7.70–19.70
	Buildings and tarmac	8.10	11.22	5.69–16.71
	Disused land	5.04	0	-
	Bramble scrub	1.33	6.83	2.40–11.20
	Playing fields and amenity grassland	17.57	10.74	5.30–16.10

Analysing the monthly pattern of habitat utilization for those habitats that were preferred revealed that for SY2 (χ^2 = 69.24, *df* = 2, $P<0.001$) and SY6 (χ^2 = 20.16, *df* = 2, $P<0.001$) the proportion of radio-fixes in gardens increased significantly each month between February and April. No significant difference was detected in the proportion of garden radio-fixes for SY4 (χ^2 = 0.50, *df* = 1, $P>0.05$). The reverse situation was detected for the pattern of use of wooded banks. For SY2 the proportion of radio-fixes on wooded banks during February was significantly greater than in March and April and also higher in April than March (χ^2 = 93.84, *df* = 2, $P<0.001$). In February the proportion of fixes on wooded banks for SY6 was also significantly greater than in the following months (χ^2 = 34.17, *df* = 2, $P<0.05$). Wooded banks were used significantly more in March than April by SY4 (χ^2 = 13.70, *df* = 1, $P<0.001$) as was woodland (χ^2 = 6.01, *df* = 1, $P<0.05$). The proportion of locations recorded for SY6 on disused land was significantly higher in

March than during February and April (χ^2 = 6.12, df = 2, $P<0.05$), while no significant difference was detected for SY4 in the pattern of utilization of bramble scrub (χ^2 = 1.40, df = 1, $P>0.05$).

Table 4c **Habitat utilization by SY6 from February to April.**

Month	Habitat type	Percentage area	Percentage use	90% confidence interval (x10^{-2})
February	Wooded banks	0.57	41.61	34.46–48.74
	Woodland	23.29	17.11	11.65–22.55
	Gardens	7.79	14.77	9.66–19.94
	Arable	12.57	1.68	0.17–3.57
	Pasture	40.83	10.40	5.98–14.82
	Buildings and tarmac	5.38	1.68	0.17–3.57
	Heathland	6.03	8.39	4.38–12.42
	Disused land	1.09	4.36	1.36–7.24
	Playing fields and amenity grassland	2.45	0	-
March	Wooded banks	0.37	20.16	14.08–26.32
	Woodland	20.85	16.53	10.84–22.16
	Gardens	3.45	18.95	13.02–24.98
	Arable	16.86	0.81	-
	Pasture	50.11	29.84	22.83–36.77
	Buildings and tarmac	1.52	0	-
	Heathland	5.77	3.23	0.52–5.88
	Disused land	0.14	9.67	5.19–14.21
	Bramble scrub	0.65	0.81	-
	Playing fields and amenity grassland	0.28	0	-
April	Wooded banks	0.48	24.34	17.45–31.15
	Woodland	18.51	10.62	5.77–15.63
	Gardens	10.08	30.53	23.15–37.85
	Arable	29.05	0.88	-
	Pasture	25.67	23.89	17.09–30.71
	Building and tarmac	6.08	0.44	-
	Heathland	6.44	2.65	0.11–5.29
	Disused land	1.14	6.65	2.64–10.56
	Bramble scrub	1.17	0	-
	Playing fields and amenity grassland	1.38	0	-

Feeding behaviour

Faecal analyses for the Bexhill group (SY2, SY4, SY5 and SY6) revealed that earthworms were by far the most important food item (64.6% of volume in April or 72.0% if leaves are ignored) (Table 5). In each month, earthworms occurred in almost all faeces. The volume of leaves (mainly grass) ingested in February and March was significantly greater than in April (Kruskal-Wallis, H = 42.81, df = 2, $P<0.0001$). With the exception of leaves and moss which were accidentally ingested while feeding on earthworms, the other food categories formed only a minor part of the diet. The volume of insects in the diet increased from 0.9 per cent in February to 5.1 per cent in April, although this rise was not significant (H = 1.08, df = 2, $P > 0.05$). Insects included ground beetles, noctuid moth caterpillars and in April tipulid larvae were also consumed.

Foraging in gardens accounted for the scavenged food items observed in the diet of these badgers. This particular food category included items such as bread, cake, peanuts, cooked meat bones, raisins and bird seed. The increased garden activity between February and April resulted in the rise in the volume of scavenged food from 2.7 per cent in February to 16.6 per cent in April (H = 5.43, df = 2, $P > 0.05$). Dustbins were almost certainly the source of the non-food items (aluminium foil, paper, tissue, glass, rubber and polythene food wrappers) in their diets.

Table 5 **Diet of badgers translocated from Bexhill; figures are the percentage volume of food categories in the diet and in parentheses the percentage occurrence in the diet. Sample sizes for February, March and April were 26, 42 and 27 respectively.**

Food category	February	March	April
Earthworms	52.7 (100.0)	55.4 (97.6)	64.6 (96.3)
Insects	0.9 (3.8)	1.2 (4.8)	5.1 (11.1)
Slugs	3.1 (11.5)	2.4 (9.5)	0 (0)
Birds	1.3 (3.8)	2.1 (4.8)	1.1 (3.7)
Mammals	2.7 (11.5)	1.2 (2.4)	0 (0)
Leaves	27.2 (92.3)	24.5 (90.5)	10.3 (33.3)
Moss	7.1 (30.8)	3.6 (14.3)	0 (0)
Scavenged	2.7 (7.7)	8.4 (16.7)	16.6 (33.3)
Non-food items	2.2 (7.7)	1.2 (4.8)	2.3 (7.4)

Earthworms were less important in the diet of the badgers released into the forest in 1992 (Table 6), compared to the Bexhill badgers, although they still formed the bulk of the diet of these badgers rising significantly in volume from 29.8 per cent in November to 39.0 per cent in February (H = 8.07, df = 3, $P < 0.05$). The volume of sugar beet in the diet increased from 12.4 per cent in November to a peak of 26.2 per cent in January (H = 8.84, df = 3, $P < 0.05$). Although there was an overall significant difference, the conservative nature of the Tukey-type multiple comparison of means meant that no single month could be isolated as being significantly distinct from any other. Fruit was of major importance in the diet and reached a peak in November, when it formed 33.3 per cent of the diet, significantly higher than in December (H = 8.87, df = 3, $P < 0.05$). The fruit consumed between November and February was predominantly wind-fall apples, although during November ornamental plums were also consumed (48% of fruit in diet) and to a lesser extent in December (5% of fruit in diet). With the exception of insects, mainly ground beetles, which formed up to 19.8 per cent of the diet in December, the other food categories comprised only a minor part of the diet during these months.

Table 6 **Diet of badgers translocated in 1992; figures are the percentage volume of food categories in the diet and in parentheses the percentage occurrence of the various food categories in the diet. Sample sizes for November, December, January and February were 47, 28, 19 and 15 respectively.**

Food category	November	December	January	February
Earthworms	29.8 (74.5)	30.4 (75.0)	30.9 (89.5)	39.0 (93.3)
Insects	8.7 (27.7)	19.8 (42.9)	9.4 (31.6)	18.4 (60.0)
Slugs	2.0 (6.4)	0 (0)	2.0 (5.3)	2.2 (6.7)
Birds	0.6 (2.1)	2.8 (10.7)	2.7 (10.5)	5.9 (20.0)
Mammals	3.1 (8.5)	3.7 (7.1)	6.0 (15.8)	0 (0)
Leaves	8.4 (31.9)	8.3 (32.1)	4.0 (15.8)	7.4 (33.3)
Moss	1.7 (6.4)	0.9 (3.6)	0 (0)	1.5 (6.7)
Sugar beet	12.4 (21.3)	20.7 (39.3)	26.2 (47.4)	3.7 (6.7)
Fruit	33.3 (57.4)	13.4 (25.0)	18.8 (42.1)	21.9 (46.7)

Breeding

SY6 was found to be lactating in February and subsequently a 3.7kg female cub was trapped at sett A on 5 March. Adult behaviour indicated that the cub started above-ground movements by mid-February and was therefore born around mid-December; an exceptionally early birth date. On 26 February SY6 was observed with two cubs foraging in a garden. Since that date, two badger cubs were seen feeding independently of SY6 on numerous occasions up to the end of the study in May. Unfortunately the second cub was never trapped and its sex remains unknown.

Public attitude

The success of the present study owed much to local cooperation. In particular, the fate of the three escaped badgers would probably have gone unknown without the information supplied by a local landowner. The badgers utilizing the village were noted to have caused a number of minor nuisances. These included digging in a compost heap, digging holes in lawns and riffling through dustbins and dustbin bags. There was no evidence that these activities reduced the enthusiasm of local residents, who continued to encourage the badgers into their gardens with food. Another householder provided the badgers access to his garden by placing badger gates in the rabbit netting around the perimeter of his property. Prison officials at the detention centre also made plans to erect badger gates on land surrounding the detention centre.

Discussion

In Norfolk and Suffolk, the loss of an estimated 1450 badger social groups to gamekeepers occurred about a century ago, so it initially seems strange that during the interim period the population has not recovered to its former level. However, a study of a high density badger population in Gloucestershire has shown that badgers are poor colonists, even when living at high density (Cheeseman *et al* 1993). This may explain why large areas of these two counties remain uncolonized, especially since the few populations that did remain were largely fragmented. In Suffolk, at present, approximately 270 setts have been recorded, of which 88 are thought to be main setts (Harris 1993). The distribution of setts is patchy and almost entirely restricted to the south of the county, stretching from Ipswich across to Sudbury (M Grimwade personal communication 1993). Successful badger reintroductions have already been achieved in west Norfolk and it has been suggested that these reintroductions have prevented the badgers in this part of the county from becoming extinct (Harris 1993). The forest used as the release site in the present study was situated in an area of Suffolk largely unoccupied by badgers. This particular forest had been used for a previous translocation in 1992 and so landowners were fairly familiar with the procedures involved. Indeed, the enthusiasm and cooperation shown by the landowners and the local farmers was a major factor in selecting this particular site.

The artificial sett within the enclosure was a relatively non-elaborate construction which may have resulted in its early abandonment. However, it was important that at least during the first few nights the animals had a secure refuge. It is probable that the artificial sett was used for defecating as this behaviour was rarely recorded above ground within the enclosure. Large underground latrines have been found in a number of excavated setts (Roper 1992). As with the 1992 release, this group of badgers favoured a disused fox earth which they started to modify as early as the second night at the release site. Due to the variable success of artificial setts and the preference of badgers for natural structures, release sites are frequently selected in Suffolk that contain natural refuges such as disused fox earths. This allows cheaper and less permanent artificial setts to be constructed within release sites, to act only as temporary shelters. Recently in Suffolk an artificial sett was constructed from straw bales, which were removed once the badgers had opened up the natural holes within the enclosure.

Although voltage levels were maintained between 5–7kV in the double fence surrounding the enclosure, three badgers still managed to escape. Despite the large voltage, an animal that touched a wire with a less sensitive area of its body such as neck, back or chest may not have felt a shock and may have been able to cross the fence. An experiment to examine the effectiveness of different types of electric fence to control badger movement (Hahesy *et al* 1992) revealed that on one occasion (25%) a five strand electric fence was breached, despite the badger contacting the fence on its way through. The same experiment found that electrified flexinet was also breached when an animal pushed underneath, between the bottom strand and the ground. Given these observations, perhaps too much reliance was placed on the voltage through the electric fence, rather than the impenetrable nature of the barrier. Instead, perhaps a more effective option would have been to use some type of badger fencing (Harris *et al* 1994), at least 125cm high and dug 50cm into the ground. Small sections of the fence could then be opened once the animals had become acclimatized. In this way it would be possible to leave the fence standing, thereby reducing disturbance, during the critical period when badgers are exploring the land surrounding their release site. The fence could then be removed at a later date when the badgers had become established at the new site.

The only sign of disturbance at the fence line occurred at the beginning of September, when scratching was noted on the outside of the enclosure. This may have originated from a failed attempt by the escaped badgers to return to the enclosure. This highlights one of the potential problems with electric fencing in that unless the badgers have escaped by digging under the fence they will not easily be able to return to the enclosure.

By the 22 January only the two cubs remained at the release site, supporting previous observations from badger releases that cubs are less inclined to desert the release site than adults. The RSPCA have released several badger groups into Suffolk consisting entirely of orphaned cubs. Although these groups were not intensively monitored, in over 80 per cent of these releases, some, if not all the badgers within each group either occupied the release site or lived in close proximity (C Seddon personal communication 1994). One individual was recorded to have survived over four years after release. In other releases in Suffolk, adults were found to travel long distances and their likelihood of dispersal was high. For example, one particular badger travelled 9km from the release site during the first 24 hours following release and was eventually discovered a month later, 23km from the release site (M Grimwade personal communication 1994). Adult badgers also commonly disrupted the release process by digging their way out of the enclosure. It is possible that the behavioural inflexibility of adults reduces their ability to adapt to the changes experienced on release (Sempéré *et al* 1986).

It was originally intended to hold the group of badgers in the enclosure for a period of 4–6 weeks, although due to a problem with transmitters and the difficulty of trapping the captive badgers, SY3, SY4 and SY7 were held at the release site for over 18 weeks. Although badgers are less active during the winter (Harris 1982) the restricted behaviour recorded from December–February was likely to have been induced by the length of time these animals had been confined within the enclosure. Following removal of the fence, the badgers were never observed to cross the original fence line, nor approach it. This suggested they had become conditioned to avoid this area by repeated electric shocks. Although some authors stress the merits of a long acclimatization period (eg Moore & Smith 1990), there is probably an optimum length of time to hold badgers before releasing them. The 18-week captivity period in the present study probably exceeded this optimum period. The role of the electric fencing in conditioning the animals to avoid the perimeter of the enclosure, after the fencing was removed, may have encouraged SY3 and SY4 to disperse, rather than gradually extending their range around the release site. At the end of March, SY3 was sighted in a park in a town over 9km from the release site. Unfortunately this individual was never relocated.

The extent to which badgers will disperse, depends largely on the density of the population. In areas of high badger density, where social structure is well organized, dispersal between social groups is very limited (Kruuk 1978; Cheeseman *et al* 1988). As density decreases, social structure is thought to become less stable and badgers probably move more freely. The distances travelled by SY2, SY4, SY5 and SY6, away from the release site were relatively small compared to those recorded by adult badgers in other translocations in Suffolk. In areas completely devoid of badgers, dispersal distances will be influenced largely by the availability of suitable habitat. Unfortunately, in the present study, no information was obtained on the dispersal behaviour of the badgers as they left the forest release site.

The home-range areas of SY2, SY4 and SY6 were considerably larger than normal for even a low to medium density badger population. Observations on badger behaviour in a high density area in Gloucestershire, following the removal of several social groups, revealed that badgers moving into cleared areas moved erratically over relatively long distances and used more setts than usual compared with badgers in undisturbed areas (Cheeseman *et al*

1993). This behaviour closely matches that recorded for SY2 and SY4. Areas of low badger density have been found to have a high incidence of abandoned main setts (Cresswell *et al* 1990). These authors suggested that the transient behaviour of badgers at low density, regularly changing setts, would account for this phenomenon. The large range size of SY2 was mainly due to several exploratory excursions. On these occasions, SY2 would travel relatively quickly and move entirely along field boundaries. Work in the Netherlands has demonstrated the importance of hedgerows in providing corridors for dispersing animals, thereby promoting movement between isolated groups of badgers (Lankester *et al* 1991).

Earthworms were the principal item in the diet of the badgers translocated from Bexhill and a major component of the diet of the 1992 release group. The importance of earthworms in the diet of the badger has been identified by research workers in various countries in the past (Andersen 1955; Skoog 1970; Bradbury 1974; Kruuk 1978; Kruuk *et al* 1979; Kruuk & Parish 1982). Mammals and birds formed only a minor part of the diet, but may merely reflect the time of year in which the study was carried out as small rodents, birds (Andersen 1955; Skoog 1970) and lagomorphs (Kruuk & Parish 1981) have been recorded as important food items in the summer. Fruit was found to be a major component of the diet for the 1992 translocated group. Several commercial orchards provided this group with large quantities of wind-fall fruit throughout the period of data collection. The importance of fruit in the diet of badgers during autumn has been shown previously (Harris 1984; Skinner & Skinner 1988). In a study of a population of urban badgers in Bristol, Harris (1984) found that fruit was of major importance between August and November, when it formed 48-61 per cent of the diet. Scavenged food came second to earthworms in importance for the badgers translocated from Bexhill. This food category resulted from foraging in gardens, and included items from a diversity of sources since they were impossible to distinguish. The category scavenged food, includes food specifically put out for badgers by local householders, food put out for wild birds or household pets and gleanings from dustbins and compost heaps. This preference for foraging in gardens can probably be attributed to their past experience of urban Bexhill. Indeed, both main setts (A and B) were situated in close proximity to housing. In a study examining the merits of releasing rehabilitated hedgehogs, it was found that urban hedgehogs released into rural areas would travel long distances (up to 5km) in an attempt to search for the same kind of habitat from which they originated (Morris 1993). Clearly this behaviour is likely to result in increased mortality.

The repeated preference for wooded banks merely reflected the location of the two main setts in this habitat. The greater use of wooded banks by SY2 and SY6 in February can largely be attributed to the emergence above ground of the two cubs, when both adults spent a large proportion of each night on the main sett. The generally lower level of activity seen in badgers at this time of year also accounted for the increased activity around the main sett. The avoidance of pasture was unexpected since the available pasture was short grass horse paddocks. Kruuk (1978) found that almost 99 per cent of the time spent by badgers on pasture was on short grass, which covered only 45 per cent of all pasture. Another radio-tracking study in Gloucestershire revealed that throughout the year badgers of all ages and sexes spent 60 per cent of their foraging time on permanent pasture, which only comprised 25 per cent of the available habitat (C L Cheeseman unpublished data 1996). Unfortunately no quantified data were available on the types of habitat present in Bexhill within the territory of the translocated social group, so the significance of avoidance and/or preference of particular habitats in Suffolk are difficult to interpret. However, the continual preference for gardens by all three animals indicates that these animals were content to forage in a familiar habitat. This behaviour has important implications for future translocations involving urban badgers as nuisance badgers removed from urban areas, released into rural locations, may simply search for their former habitat and create similar problems. In the present study, the translocated badgers caused only minor nuisances and were accepted with great enthusiasm by all local householders and landowners with whom contact was made.

Following completion of this study, SY4 was found dead on the side of a road, 240m from sett B, having been hit by a vehicle. As SY4 was familiar with this stretch of road, her death cannot be attributed to erratic movements resulting from the translocation. This event was not unexpected considering that approximately 50,000 badgers are killed on Britain's roads each year (Harris 1989).

Conclusions and animal welfare implications

The ultimate success of a translocation exercise should be judged on how well the badgers survive and breed in the new location. Although the short-term aim of translocation may be to remove badgers from where they are causing a problem, this can only be justified if the badgers are likely to settle peacefully in the new area and provided the translocation itself causes no long-term serious suffering. The main findings and conclusions from this translocation exercise are listed below. The information obtained during this study, in particular the birth of two cubs, would indicate that this translocation was a success, despite some degree of fragmentation of the original group. In order to obtain a reliable database on the effects of translocation, it is essential to carry out a number of replicates to allow for the effects of variables such as season of the year, different age and sex composition of social groups, the habitat in the relocation area, the size of the initial holding enclosure and the degree and duration of aftercare following relocation. In addition, it would be worthwhile in any future translocation involving urban badgers, to address if badgers from an urban environment seek out familiar habitat. Although the information gathered was based on a single translocation exercise it forms an important step in providing preliminary guidelines for future translocations.

Summary of the key factors which have emerged from this translocation exercise

(1) Considerable groundwork is required prior to the translocation exercise to ensure that the badgers are released into an area that contains habitat suitable for feeding and sett construction. Also, the area preferably has other badger groups within the vicinity of the release site as emigration is more likely where there are no pressures from adjoining badgers. Ideally the release site should contain a natural refuge, such as a disused fox earth, as well as some form of artificial sett.

(2) Good public relations must be maintained at all stages during the translocation exercise.

(3) The use of electric fencing to confine the badgers at the release site needs to be reviewed. Since half the social group managed to cross the fence and those that remained were conditioned into avoiding the periphery of the enclosure even after removal of the fence, perhaps a more suitable alternative would be badger fencing,

at least 125cm high and dug 50cm into the ground. This would be opened after acclimatization of the badgers.

(4) There is clearly an optimum confinement period, particularly when electric fencing is used to hold the animals at the release site. We would recommend that this should be approximately two weeks, but will vary according to the season and the climatic conditions prevailing during the release period.

(5) Despite some fragmentation of the original group, the information obtained during this study would indicate a successful translocation.

(6) As urban badgers released into rural areas may simply search for their former habitat type, further translocations of this kind need to be monitored to determine if this is the case.

(7) Further introductions are needed in the area surrounding the initial release site to account for mortality and emigration, thereby ensuring the continued existence of a breeding population.

(8) Finally, we should draw attention to the risk of disease spread. This is particularly important if badgers are known to originate from areas where bovine tuberculosis is endemic in the badger population.

Acknowledgements

We would like to thank Forest Enterprise, farmers and landowners who have given access to their land and allowed this project to be undertaken. We gratefully acknowledge help given by colleagues in ADAS, both during the capture phase of the operation and during the subsequent release. The authors are also grateful to Margaret Grimwade for establishing the suitability of the release site and providing advice throughout the study. JAB would like to thank Richard Davis, Ewan Calcott and Steve Morris for their help and encouragement, along with Mark and Rachel Sly for their generous hospitality. Dr Warren Cresswell and Elaine King provided valuable comments on drafts of the manuscript. This project was entirely funded by MAFF.

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