

Monitoring bait uptake in badgers: a pilot study using PIT-tag system and time-lapse video surveillance

F. CAGNACCI¹ and G. MASSEI

Central Science Laboratory, Sand Hutton, York YO41 1LZ, United Kingdom

Received 19 November 2007, accepted 19 April 2008

European badgers *Meles meles* are vectors of bovine tuberculosis, and may have negative impacts on the cattle grazing industry. In order to control tuberculosis in badger populations, the use of baits containing vaccines or fertility control agents has been proposed. However, in social species such as badgers, multiple bait uptake and competition for baits at baiting stations could reduce the efficiency of baiting campaigns. We used video surveillance and Passive Integrated Transponder (PIT)-tag systems to monitor the behaviour of two social groups of badgers offered plain baits. We recorded the following data: (i) proportion of baits taken by badgers/by non-target species; (ii) potential occurrence of caching; (iii) potential occurrence of bait monopolisation and competition. Badgers removed 97.8% of baits. There was no evidence of bait uptake by non-target species. Some 85% of the baits were immediately eaten at the baiting station; caching was not observed although it cannot be excluded. In 1/3 of visits, badgers consumed two or more baits. In 30% of all visits, the contemporary presence of two or more badgers searching for baits was recorded. In three instances badgers were observed to compete for baits. This study shows evidence of aggressive behaviour and direct competition for food by free-living badgers. Bait monopolisation and intra-specific competition at feeding stations could influence bait uptake and should be evaluated in other wildlife species when bait-delivered vaccines or contraceptives are used.

KEY WORDS: aggressive behaviour, badger, caching, foraging behaviour, food competition, *Meles meles*, vaccine bait.

¹ Correspondence: Francesca Cagnacci (E-mail: cagnacci@cealp.it). Present address: Fondazione Edmund Mach, Centro di Ecologia Alpina, Viote del Monte Bondone, 38040 Trento, Italy (Tel: +39 0461939568, Fax: +39 0461948190).

INTRODUCTION

Vaccination, in combination with fertility control has been suggested as a valid and publicly acceptable option for controlling wildlife diseases and reducing overabundant populations (SMITH & CHEESEMAN 2002, MASSEI et al. in press). Baits are increasingly employed in wildlife management to deliver vaccines, toxicants and contraceptives (SOUTHEY et al. 2001, GLEN & DICKMAN 2003a). The cost-effectiveness of baiting campaigns depends on bait uptake by a high proportion of animals in the target species, which in turn is affected by non-target species uptake (SAUNDERS et al. 1999, DELAHAY et al. 2003, GLEN & DICKMAN 2003a). In an ideal baiting campaign, multiple bait uptake by individuals should be minimised to increase the proportion of animals treated with vaccines or contraceptives (WANDELER et al. 1988). However, the availability of attractive resources such as baits may result in competition for food or sites (QUY et al. 2003) and bait caching (TREWHELLA et al. 1991). In social species, access to localised food resources may be monopolised by dominant individuals (TREWHELLA et al. 1991), resulting in the consumption of baits by relatively few animals.

Badgers, *Meles meles* L., are believed to be the main wildlife reservoirs of *Mycobacterium bovis*, the causative agent of bovine tuberculosis, and are suspected of transmitting this disease to cattle in the UK (KREBS 1997). Vaccination has been considered as a potentially valid option for the control of tuberculosis in badger populations (SMITH & CHEESEMAN 2002, DONNELLY et al. 2003). Also, as a social species and food generalist, badgers represent an ideal model to study the behaviour at bait stations.

Studies on bait uptake by badgers have relied on indirect methods such as the use of bait-markers (SOUTHEY et al. 2001, 2002; CAGNACCI et al. 2006, 2007; DE LEEUW et al. 2006). However, competition and multiple uptake, leading to bait monopolisation, can only be adequately investigated by direct observations or by using remote photography or video surveillance (GLEN & DICKMAN 2003b). We used video surveillance and the PIT-tag system in a pilot study investigating the behavioural aspects of bait uptake in badgers which could potentially affect the cost-effectiveness of baiting campaigns. The aims of the study were (i) to assess the proportion of baits taken by non-target species; (ii) to determine the proportion of baits consumed on site by badgers; and (iii) to monitor potential bait monopolisation and/or competition between badgers.

METHODS

The study was conducted between the 4th and the 20th of August 2003 in two of the 36 well established badger social groups (ROGERS et al. 1998) in an 11 km² study area (Woodchester Park, UK, 51°43'N 2°16'E): Parkmill and Hedge. In this area, the territorial boundaries of social groups and active setts are routinely determined in the spring of each year by bait marking (DELAHAY et al. 2000). Both social groups occupied territories of approximately 0.4 km² each, around a main sett of 30 m ca, were non-contiguous and approximately 4 km apart. During 2003 the population density of Woodchester Park was 24 adult badgers/km². Estimated group size was 17 badgers (nine

males and eight females) in Parkmill and 12 badgers (five males and seven females) in Hedge. At capture, all animals were given a unique fur clip pattern for individual identification and, in Parkmill only, 4 males and 5 females were fitted with Passive Integrated Transponder (PIT) tag collars.

Baits were distributed at dusk for 6 nights between the 4th and the 12th of August 2003 in Parkmill and between the 14th and the 20th of August 2003 in Hedge. In both areas, nine baits were placed daily around the main active sett (minimum distance of 2 m between adjacent baits). Each bait was placed in a depression of the ground and then covered by a large stone (> 2 kg) to protect it from the rain and to deter non-target species (DELAHAY et al. 2000). Each bait was made up of 40 g minced beef, mixed with 15 ml of 3% (w/w) porcine skin gelatine (Sigma-Aldrich Co., Poole, UK).

At each sett, all baits were filmed simultaneously using three video surveillance sets, thus obtaining three "visual fields" of three baits each, per social group per night. Each video surveillance equipment set consisted of two 12 v dryfit batteries (Sonnenschein A500, CMP Batteries Ltd., Stevenage, UK) placed in a metal ammunition box, linked to a watertight plastic box containing a time-lapse video recorder (Sanyo TLS-9168P, Sanyo Electric Co. Ltd., Basel, Switzerland), to a camera (Sanyo CCT-533 "Vista") and to two infra red lights (Tracksys Ltd., Nottingham, UK). The camera was mounted on a tripod and placed 2-6 m from the baits. Therefore, each visual field was on average 9 m². In Parkmill only, two baits per visual field were mounted on a PIT-tag ID logging system each (Single channel logger, Francis Scientific Instruments, Cambridge, UK), consisting of an aerial linked to a time logger. The aerial was buried so that the top was at the same level as the surface of the ground. A magnet was tethered to the aerial and placed on the bait. When the magnet was removed, the specific code of any PIT-tagged badger and the time of removal were recorded by the logger. If a PIT-tag collared badger approached the aerial, the PIT-tag code and time were recorded by the logger, thus allowing us to time the presence of individual badgers at the baiting stations. PIT-tag and video data were collected from sunset to dawn. A "visit" was defined as an animal entering and then leaving the visual field. On each filming session, all the visits by any species (and by tagged badgers) within the visual fields were recorded until all baits were removed. When a visit involved the removal of a bait, the following variables were recorded: 1. species; 2. time of removal; 3. location where the bait was consumed (directly at the baiting station, within the visual field or removed from the visual field); 4. multiple uptake, defined as consumption of two or more baits during a visit; 5. number of badger visits to the visual field before each bait was removed, as an indication of the latency to consume baits. The proportion of baits consumed and the number of visits were compared between social groups with the 2-sample test for equality of proportions with Yates' continuity correction performed by R 2.4.0 (2006).

The simultaneous presence of two or more badgers in all visual fields of the same area, as shown by the time logger, was also recorded, together with instances of aggression or competition for a bait. Badgers were considered to be searching for baits if they were actively sniffing the ground while moving between baiting stations. "Competition" was defined as two or more badgers trying simultaneously to gain access to a single bait. "Aggression" was defined as an attack on another individual.

RESULTS

Out of 108 baits, the fate of 19 was not known because of video equipment failure (Table 1). Of the 89 baits filmed in 31 visual fields, 87 were removed by badgers whilst 2 were not removed. Bait consumption started in

the first part of the night in both social groups (Parkmill: average time = 10:00 ± 00:15 pm ranging between 8:56 pm and 0:19 am; Hedge: average time 9:02 ± 00:04 pm ranging between 8:39 pm and 9:28 pm).

At least three different individuals from each social group were recognizable in the visual fields throughout the experiment and in a single night. Most individuals were recorded as “unmarked”, either because they were never captured or because the fur clip pattern was not clearly visible. Two dogs and three rabbits were also filmed in the visual fields, but no baits were taken by these non-target species. A greater proportion of baits were eaten *in situ* in Parkmill than in Hedge (93.5% vs 75.6%). In 1/3 of the visits badgers removed two or three baits at a time (equivalent to 59.8% of all the baits), and in half of all visits badgers removed a single bait (37.9% of the baits). Visits by badgers that did not result in bait uptake were recorded throughout the experiment (16.7% of all visits) and did not differ between the two social groups (Table 1). On average, 0.61 badger visits occurred before a bait was removed (i.e. baits were not always immediately consumed by visiting badgers). In nine instances, the contemporary presence of two or more badgers searching for baits was recorded (i.e. 30.3% of all visits). In three cases, badgers simultaneously tried to gain access to a single bait, which in two cases, one per social group, led to aggressive behaviour. In both cases, one individual pushed the other one away from the baiting station: the “attacker” consumed the bait and the “attacked” moved away.

DISCUSSION

This study suggested that the foraging behaviour of badgers might, to some extent, limit the efficiency of large scale baiting campaigns due to intra-specific bait monopolisation and competition. On the other hand, the lack of bait uptake by non-target species indicated that, if baits are placed around the main setts, badgers are likely to be the main target of baiting campaigns.

Bait uptake by non-target species is usually a major problem for the cost-effectiveness of vaccination/fertility control campaigns (THOMSON & KOK 2002, GLEN & DICKMAN 2003a). Although the method used to deliver the baits in this study resulted in no uptake by non-target species, the density of badgers in the study area was very high. It is possible that more bait uptake by non-target species would be observed in areas with lower densities of badgers. The presence of dogs indicated that pets should also be considered as non-target species.

Caching behaviour reduces the potential number of individuals which may have access to the baits. For instance, foxes can cache 1/3 or more of the baits taken (TREWHELLA *et al.* 1991, SAUNDERS *et al.* 1999). In this study, most of the baits taken by the badgers were consumed as soon as they were discovered; however, as some baits were removed from the visual fields, caching cannot be excluded. In future studies, beads of different colours (DELAHAY *et al.* 2000) together with PIT-tags could be included into the baits, in order to monitor them after removal, whether eaten or not.

The observation that the baits available in a single visual field were not always discovered at the first visit, suggested that the method used allowed, in

Table 1.

Bait uptake by two social groups of badgers offered 9 baits per day for 6 days. In each social group, bait uptake was recorded in 3 visual fields containing 3 baits each.

	Parkmill	Hedge	Total	Percentage of baits removed/ visits filmed	Group comparison
Baits delivered	54	54	108		
Visual fields filmed (excludes equipment failures)	17	14	31		
Baits filmed	47	42	89		
Badger visits filmed	28	38	66		
Baits removed	46	41	87		
Baits removed by badgers	46	41	87	100.00	
Baits eaten at the feeding station (not removed at all)	28	9	37	42.5	$\chi^2 = 11.9$, $df = 1$, $P < 0.001$
Baits eaten within the visual field	43	31	74	85.1	$\chi^2 = 4.1$, $df = 1$, $P < 0.05$
Visits with no bait eaten	2	9	11	16.7	$\chi^2 = 2.1$, $df = 1$, $P > 0.05$
Visits with one bait eaten	12	21	33	50.0	$\chi^2 = 0.6$, $df = 1$, $P > 0.05$
Visits with two baits eaten	8	4	12	18.2	$\chi^2 = 2.4$, $df = 1$, $P > 0.05$
Visits with three baits eaten	6	4	10	15.1	$\chi^2 = 0.8$, $df = 1$, $P > 0.05$
Two or three baits eaten in the same visit	32	20	52	59.8	$\chi^2 = 3.1$, $df = 1$, $P > 0.05$
Average number of badger visits prior to bait consumption	0.48	0.76	0.61		
Events of simultaneous presence of badgers in search of baits within the filmed area (all three visual fields)	4	5	9		
Max number of badgers simultaneously searching baits within the filmed area (all three visual fields)	3	3	6		
Observations of competition for a single bait	2	1	3		
Observations of aggressive behaviour	1	1	2		

principle, several badgers to gain access to the baits. In many cases, baits were consumed in groups of two or three in the same visit, indicating multiple uptake, potentially leading to bait monopolisation by individual badgers. This is consist-

ent with the results obtained by bait markers in the same study area which indicated multiple bait uptake by some badgers (CAGNACCI et al. 2007). Furthermore, badgers were observed competing for the baits and in some instances showing aggressive behaviour. The preliminary results of this study thus indicate that bait monopolisation and competition could affect bait uptake by badgers.

At medium and high population densities, badgers live in social groups and maintain territories (KRUUK 1989, ROGERS et al. 1998). In such populations, the main sett, where much group activity is concentrated, represents a target area for vaccination which is ecologically meaningful (DELAHAY et al. 2003). To improve bait consumption by a high proportion of the badger population the following approaches could be tested: 1. widening the area of distribution of baits around each main sett so as to decrease the simultaneous presence of individuals at any one stations; 2. regularly changing the location of the feeding stations, to limit progressive spatial learning by badgers (MELLEGREN & ROPER 1986); 3. using conditioned taste aversion to decrease bait monopolisation (GENTLE et al. 2004, CAGNACCI et al. 2005).

Oral contraceptives and vaccines are increasingly used worldwide to prevent economic losses resulting from zoonotic diseases and to mitigate the impact of over-abundant wildlife on human interests. This study highlighted how the efficiency of these methods may be affected by the social behaviour of target species. Hence, when baits are used to deliver pharmaceuticals, the effects of potential competition, multiple bait uptake and caching should be evaluated in every wildlife species.

ACKNOWLEDGMENTS

This study was funded by the Department for Environment, Food & Rural Affairs (Defra), UK. Fieldwork in Woodchester Park was carried out with the kind permission of The National Trust. Thanks to Richard Delahay, John Woods, Alastair Ward, Bryony Tolhurst, Anton de Leeuw and Gavin Wilson, and to the Woodchester Park field team for technical advice. Thanks to Gavin Western, Julia Coats, Lucia Bargagli and Beatrice Bruzzi for assistance with the fieldwork. We are grateful to Tim Roper for reading and commenting on the first draft.

REFERENCES

- CAGNACCI F., MASSEI G., COATS J., DE LEEUW A. & COWAN D. 2006. Long-lasting systemic bait markers for Eurasian Badgers. *Journal of Wildlife Diseases* 42: 892-896.
- CAGNACCI F., MASSEI G., COWAN D. & DELAHAY R. 2005. Can learned aversion be used to control bait uptake by Eurasian Badgers? *Applied Animal Behaviour Science* 92: 159-168.
- CAGNACCI F., MASSEI G., COWAN D., WALKER N. & DELAHAY R. 2007. Effects of bait type and deployment strategy on uptake by free-living badgers. *Wildlife Research* 34: 454-460.
- DELAHAY R.J., BROWN J.A., MALLISON P.J., SPYVEE P.D., HANDOLL D., ROGERS L.M. & CHEESEMAN C.L. 2000. The use of marked bait in studies of the territorial organization of the European Badger (*Meles meles*). *Mammal Review* 30: 73-87.

- DELAHAY R.J., WILSON G.J., SMITH G.C. & CHEESEMAN C.L. 2003. Vaccinating badgers (*Meles meles*) against *Mycobacterium bovis*: the ecological considerations. *Veterinary Journal* 166: 43-51.
- DE LEEUW A.N.S., SMITH G.C. & WOODS J.A. 2006. Use of iophenoxic acid to assess bait uptake by European badgers, pp. 243-254. In: Cowan P.D. & Feare C.J., Edits. Vertebrate pest management. *Fürth, Germany: Filander Verlag*.
- DONNELLY C.A., WOODROFFE R., COX D.R., BOURNE J., GETTINBY G., LE FEVRE A.M., MCINERNEY J.P. & MORRISON W.I. 2003. Impact of localised badger culling on tuberculosis incidence in British cattle. *Nature* 426: 834-837.
- GENTLE M., MASSEI G. & SAUNDERS G. 2004. Levamisole can reduce bait uptake in wild foxes. *Mammal Review* 34: 325-330.
- GLEN A.S. & DICKMAN C.R. 2003a. Effects of bait-station design on the uptake of baits by non-target animals during control programmes for foxes and wild dogs. *Wildlife Research* 30: 147-149.
- GLEN A.S. & DICKMAN C.R. 2003b. Monitoring bait removal in vertebrate pest control: a comparison using track identification and remote photography. *Wildlife Research* 30: 29-33.
- KREBS J.R. 1997. Bovine tuberculosis in cattle and badgers. Report to the Rt Hon Dr Jack Cunningham MP. *London, UK: MAFF Publications*.
- KRUUK H. 1989. The social Badger. *Oxford, UK: Oxford University Press*.
- MASSEI G., COWAN D.P., COATS J., GLADWELL F., LANE J. & MILLER L.A. (in press). Effect of the GnRH vaccine GonaCon™ on the fertility, physiology and behaviour of wild boar. *Wildlife Research*.
- MELLGREN R.L. & ROPER T.J. 1986. Spatial learning and discrimination of food patches in the European badger (*Meles meles* L.). *Animal Behaviour* 34: 1120-1134.
- QUY R.J., COWAN D.P. & LAMBERT M.S. 2003. Adapting baiting tactics to match the foraging behaviour of Norway rats: a balance between efficacy and safety, pp. 451-456. In: Singleton G.R. et al., Edits. Rats, mice and people: rodent biology and management. *Canberra: ACIAR*.
- ROGERS L.M., DELAHAY R.J., CHEESEMAN C.L., LANGTON S., SMITH G.C. & CLIFTON-HADLEY R.S. 1998. Movement of badgers (*Meles meles*) in a high-density population: individual, population and disease effects. *Proceedings of the Royal Society, London* 265: 1269-1276.
- R DEVELOPMENT CORE TEAM 2006. Version 2.4.0. R: A language and Environment for Statistical Computing. *Vienna: R Foundation for Statistical Computing*.
- SAUNDERS G., KAY B. & MCLEOD L. 1999. Caching of baits by foxes (*Vulpes vulpes*) on agricultural lands. *Wildlife Research* 26: 335-340.
- SMITH G.C. & CHEESEMAN C.L. 2002. A mathematical model for the control of diseases in wildlife populations: culling, vaccination and fertility control. *Ecological Modelling* 150: 45-53.
- SOUTHEY A.K., SLEEMAN D.P. & GORMLEY E. 2002. Sulfadimethoxine and Rhodamine B as oral biomarkers for european badgers (*Meles meles*). *Journal of Wildlife Diseases* 38: 378-384.
- SOUTHEY A.K., SLEEMAN D.P., PRENDERGAST J., O'SULLIVAN R.F. & MULCAHY M.F. 2001. Use of biomarkers to assess the feasibility of delivering a vaccine to badgers (*Meles meles*). *Journal of Zoology* 253: 133-139.
- THOMSON P.C. & KOK N.E. 2002. The fate of dried meat baits laid for fox control: the effects of bait presentation on take by foxes and non-target species, and on caching by foxes. *Wildlife Research* 29: 371-377.
- TREWHELLA W.J., HARRIS S., SMITH G.C. & NADIAN A.K. 1991. A field trial evaluating bait uptake by an urban fox (*Vulpes vulpes*) population. *Journal of Applied Ecology* 28: 454-466.
- WANDELER A.I., CAPT S., KAPPELER A. & HAUSER R. 1988. Oral immunization of wildlife against rabies: concept and first field experiments. *Reviews of Infectious Diseases* 10: 649-653.